CONTINUING STUDIES TO IMPROVE AND EVALUATE THE FINGERLING COLLECTION AND BYPASS SYSTEMS AT BONNEVILLE DAM

Preliminary Report

by

Michael H. Gessel
Bruce H. Monk
and
John G. Williams

Financed by
U.S. Army Corps of Engineers
Contract DACW57-87-F-0322

and

Coastal Zone and Estuarine Studies Division
Northwest and Alaska Fisheries Center
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112

October 1987

INTRODUCTION

Studies to evaluate the Bonneville Dam Second Powerhouse fingerling collection and bypass system began during the 1983 field season. Results from these initial tests indicated that fish guiding efficiency (FGE) of the submersible traveling screens (STS) was very poor (<30%) for yearling chinook salmon. By 1986, sufficient modifications were made to the powerhouse to achieve FGE values greater than 70% through the use of a lowered STS, streamlined trashracks, and intake ceiling extensions.

In 1987, the National Marine Fisheries Service was contracted by the U.S. Army Corps of Engineers to continue the evaluation of the fingerling collection and bypass systems at Bonneville Dam. The 1987 research had the following primary objectives:

1. Conduct FGE and vertical distribution tests to evaluate the following methods of improving FGE and STS effectiveness:

   a. Streamlined trashracks

   b. Lowered STS

   c. Intake ceiling extensions

   d. Illuminated trashracks

   e. Small external deflector

2. Operate the First and Second Powerhouse DSM facilities to obtain information on fish quality related to the FGE studies and collect data for the continued evaluation of the collection and bypass systems.

3. Determine if the temporal distribution of smolt migrations passing Bonneville Dam can be defined through the use of the existing collection facilities at the First and Second powerhouses.

OBJECTIVE I - EVALUATION OF METHODS OF IMPROVING STS EFFECTIVENESS AT THE SECOND POWERHOUSE

Approach

The FGE and vertical distribution tests were conducted during two phases: (1) 21 April to 3 June targeting yearling chinook salmon and (2) 14 July to 1 August targeting subyearling chinook salmon. Data for other species were collected as available. Testing for FGE was conducted in Units 12A and 12B, while simultaneous vertical distribution data to obtain measures of theoretical fish guiding efficiency (TFGE) were collected in Unit 13B. All tests began at approximately 2000 h; duration was dependent upon fish numbers, but generally was 1.5-3.0 h. Unit discharge was approximately 18,000 cfs for the early phase, but due to low tailwater levels, tests with subyearlings were conducted with a discharge of about 14,000 cfs. All testing was done with existing fyke nets and net frames, and all tests were conducted using principles and guidelines developed during past STS studies.

Three series of tests were conducted with yearlings. The first compared the best 1986 test condition [lowered STS, streamlined trashracks, and intake ceiling extensions in adjacent gatewells (11C, 12A, 12B, 12C, 13A, and 13B)] with ceiling extensions in alternate gatewells (11A, 11C, 12B, 13A, 13C, and 14B). Each of these configurations was tested under two powerhouse operating modes (four units and six or seven units). The second series was conducted to determine if lights influence fish passage into and within the turbine intake. The 250-watt, mercury vapor lights were placed in Unit 12B on the intake ceiling, the ceiling extension, and in the trashrack. The following is a brief description of the placement of these lights (40 in total) (Fig.1):

> Intake ceiling - four lights, two rows 5 and 10 ft from the gatewell opening and approximately 7 ft from each intake wall.

Ceiling extension - four lights, two rows 5 and 10 ft from the trashrack and on the same line as the intake ceiling lights.

Trashrack - 16 lights on each of the top two trashrack sections. The lights were mounted to the four horizontal streamlined members of each trashrack.

The third test series was conducted to determine the effect of a short external deflector on FGE. Three deflectors were used (Units 12A, 12B, and 12C); each was a solid steel plate that extended from the trashrack upstream approximately 6 ft along the estimated flow line and was positioned at Elevation 20.0 (msl) when tested (Fig. 1).

Tests with subyearlings were conducted to determine what effect the alternate intake ceiling extension pattern had on FGE for these fish and also to test the different light conditions. In addition, a special test was conducted to determine if removal of the trashracks directly upstream from the STS would improve FGE and STS effectiveness. The theory behind this test was that the proximity of the STS and trashracks (<3 m at the Second Powerhouse compared to 6 m at others) may be causing an avoidance problem.

Figure 1 is a cross-section of a turbine intake at the Second Powerhouse and depicts the modifications tested during the 1987 field season (Table 1).

Table 1.--Traveling screen fish guiding efficiency (FGE) tests on yearling and subyearling chinook salmon conducted at Bonneville Dam Second Powerhouse during the 1987 field season.

Test no.	Date(s) of tests	Test unit	Turbine units	Flow load (Kcfs)	STS lowered position	Lights in Unit 12B	Small external deflector	Internal deflector	Intake ceiling extensions[a]/	Percentages FGE	Percentages Descaling	% TFGE	% STS effectiveness
1	21,24,25,26 April	12A	11,12 13,18	18	30-inch	None		None	Adjacent	35.0	3.6	65	54
		12B								32.1	4.2	65	50
2	28,29,30 April	12A	11,12 13,18	18	30-inch	None		None	Alternate	52.5	11.6	67	78
		12B								42.1	10.9	67	63
3	1,2,3 May	12A	11,12 13,14 16,17,18	18	30-inch	None		None	Alternate	72.1	8.5	84	86
		12B								60.0	11.0	84	72
4	5,6 May	12A	11,12 13,14 16,17,18	18	30-inch	None		None	Adjacent	47.1	8.6	73	63
		12B								50.5	8.2	73	69
5	7 May	12A	11,12 13,14 16,17,18	18	30-inch	Intake ceiling (4), ceiling extension (4) top trashrack (2)		None	Adjacent	36.6	8.7	78	47
		12B								45.4	13.6	78	58
6	11,12,13 May	12A	11,12 13,18	18	30-inch	None		None	Adjacent	43.4	12.8	64	68
		12B								43.4	14.4	64	68
7	15 May	12A	11,12 13,18	18	30-inch	All lights were on (38 total)		None	Alternate	48.0	18.3	76	64
		12B								56.2	12.9	76	74
8	16 May	12A	11,12 13,18	18	30-inch	None		None	Alternate	74.9	9.0	83	91
		12B								59.9	15.4	83	73
9	17 May	12A	11,12 13,18	18	30-inch	Intake ceiling (3)		None	Alternate	54.5	18.5	64	86
		12B								55.1		64	86
10	18 May	12A	11,12 13,18	18	30-inch	Ceiling extension (4)		None	Alternate	39.4		71	55
		12B								25.7	14.0	71	37
11	19 May	12A	11,12 13,18	18	30-inch	Top trashrack section (15)		None	Alternate	54.6	16.8	70	78
		12B								47.7		70	68
12	20 May	12A	11,12 13,18	18	30-inch	Second trashrack section (16)		None	Alternate	33.8	7.8	64	53
		12B								24.5	15.6	64	39
13	26 May	12A	11,12 13,18	18	30-inch	Intake ceiling (3)		None	Alternate	63.3	3.7	65	97
		12B								46.5	5.4	65	72
14[b]/	27 May	12A	11,12 13,18	18	30-inch	Intake ceiling (3)		None	Alternate	67.2	7.1	78	86
		12B								64.6	5.1	78	83

Table 1.--(cont.)

Test no.	Date(s) of tests	Test unit	Turbine units	Flow load (Kcfs)	STS lowered position	Lights in Unit 12B	Small external deflector	Internal deflector	Intake ceiling extensions a/	Percentages FGE	Percentages Descaling	% TFGE	% STS effectiveness
15	28 May	12A	11,12 13,18	18	30-inch	None		None	Alternate	60.7	4.3	64	95
		12B								42.0		64	65
16	29 May	12A	11,12 13,18	18	30-inch	None	Yes	None	Alternate	63.0		79	80
		12B								54.0		79	68
17	30 May	12A	11,12 13,18	18	30-inch	Intake Ceiling (2)	Yes	None	Alternate	61.2		63	98
		12B								64.0		63	102
18	31 May	12A	11,12 13,18	18	30-inch	Intake Ceiling (2) Top Trashrack Section (15)	Yes	None	Alternate	44.1		66	66
		12B								70.3		66	105
19	1 June	12A	11,12 13,18	18	30-inch	Intake Ceiling (2) Top Trashrack, 1st Row, Middle 2 (2)	Yes	None	Alternate	41.9		76	55
		12B								74.8		76	99
20c/	2 June	12A	11,12 13,18	18	30-inch	Intake Ceiling (2) Both Trashracks (31)	Yes	None	Alternate	29.5		66	45
		12B								66.7		66	101
21	3 June	12A	11,12 13,18	18	30-inch	Intake Ceiling (2)	Yes	None	Alternate	54.4		63	86
		12B								67.3		63	106
22	14 July	12A	11,12 13,18	16.5	30-inch	None	Yes	None	Alternate	30.0	5.3	47	64
		12B								34.0	4.3	47	72
23	15 July	12A	11,12 13,18	14	30-inch	None	Yes	None	Alternate	22.4		44	50
		12B								16.7		44	39
24	16 July	12A	11,12 13,18	14	30-inch	Intake Ceiling (2) Top Trashrack 1st Row, Middle 2 (2)	Yes	None	Alternate	12.1	6.7	37	32
		12B					No			17.3	4.2	37	46
25	17 July	12A	11,12 13,18	14	30-inch	None	Yes	None	Alternate	9.7		26	39
		12B					No			16.1		26	62
26	18 July	12A	11,12 13,18	14	30-inch	Intake Ceiling (3) Top Trashrack (15)	Yes	None	Alternate	2.1		38	5
		12B					No			15.3		38	40
27	19 July	12A	11,12 13,18	14	30-inch	Intake Ceiling (3)	Yes	None	Alternate	10.6		34	32
		12B					No			16.6	8.3	34	50
28	20 July	12A	11,12 13,18	14	30-inch	Second Trashrack Section (16)	Yes	None	Alternate	1.3		33	3
		12B					No			8.6		33	28

Table 1.--(cont.)

Test no.	Date(s) of tests	Test unit	Turbine units	Flow load (Kcfs)	STS lowered position	Lights in Unit 12B	Small external deflector	Internal deflector	Intake ceiling extensions[a]	Percentages FGE	Percentages Descaling	% TFGE	% STS effectiveness
29	21 July	12A[d]	11,12 13,18	14	30-inch	Intake Ceiling (1)	Yes	None	Alternate	19.1	6.1	30	64
		12B					No			13.4		37	35
30	22 July	12A[d]	11,12 13,18	14	30-inch	Intake Ceiling	Yes	None	Alternate	15.8		33	48
		12B[d]					No			15.7		33	48
31	23 July	12A[d]	11,12 13,18	14	30-inch	None	No	None	Alternate	14.1		29	48
		12B[d]					No			13.6		29	48
32	24 July	12A	11,12 13,18	14	30-inch	None	No	None	Alternate	16.5		38	45
		12B					No			15.4		38	40
33	28 July	12A	11,12 13,18	14	30-inch	Intake Ceiling (2)	No	None	Alternate	9.9		38	26
		12B					No			19.3		38	50
34	29 July	12A	11,12 13,18	14	30-inch	Intake Ceiling (2) Battery Strobe on STS 12B	No	None	Alternate	20.3		41	49
		12B					No			16.0		41	39
35[e]	30 July, 1 Aug	12A[d]	11,12 13,18	14	48-inch	None	No	Yes	Alternate	15.5		53	38[f]
		12B[d]			30-inch		No	None		19.6		45	44
36[e]	31 July	12A[d]	11,12 13,18	14	48-inch	110 volt strobe light on STS 12B	No	Yes	Alternate	37.0		56	77[g]
		12B[d]			30-inch		No	None		15.7		40	40

a/ Adjacent - extensions in front or Units 12A and 12B.
Alternate - extension in front of Unit 12B, none in front of Unit 12A.
b/ Ice and trash sluiceway was closed for remaining FGE tests.
c/ Streamlined trashrack sections (3) installed in Unit 12C.
d/ Angle of STS was 65°.
e/ Top two trashrack sections were removed from Unit 12A for this test.
f/ Small numbers of fish <125 for this test.
g/ STS effectiveness for these tests includes gap net percentage, since these fish are also intercepted by the STS.

Results

Table 1 lists the FGE, TFGE, STS effectiveness (FGE/TFGE), and descaling percentages for each FGE test.

Yearling Chinook Salmon

Tests comparing the two intake ceiling extension configurations under the different powerhouse operating modes indicated that the alternate gatewell pattern with seven units operating (Test 3) gave the highest FGE (72 and 60%) and STS effectiveness (86 and 72%) for Units 12A and 12B, respectively. Test 2 (same configuration with four units operating) had FGEs of 52 and 42%, while STS effectiveness was 78 and 63% (12A and 12B, respectively).

Tests with the intake ceiling extensions adjacent to each other (combined data Tests 1, 4, and 6) indicate that FGE (45 and 46%) and STS effectiveness (66 and 68%) are similar in Units 12A and 12B using either powerhouse operating mode. These results are lower than those from 1986, possibly because the 1987 tests were conducted early in the field season (April) whereas the 1986 tests were conducted towards the end of May. Tests in April were predominantly on fish from Carson National Fish Hatchery whereas those in May were from upriver. Data collected at other projects have indicated that hatchery fish early in the migration are often less smolted and deeper in the water column resulting in lower FGEs. Later in the migration more migrants are smolted with corresponding increases in FGE. Also, during the 1987 tests, the ice and trash sluiceway was open from 21 April through 26 May. In 1986, the sluiceway was closed. The open sluiceway was monitored by sonar equipment (COE personnel) to estimate fish passage through this area. The sluiceway is adjacent to Unit 11 and operates by skimming water from the surface. This operation could possibly effect FGE results especially if those fish passing through the sluiceway would normally be guided by an STS if the sluiceway was closed.

Using the alternate ceiling extension configuration, Unit 12A (without the intake ceiling extension) not only had higher FGE but also collected more fish than Unit 12B (ratio A/B = 1.67:1). The ratio for fish numbers in the two slots with the ceiling extensions adjacent was nearly equal (ratio A/B = 0.96:1). A possible cause for the higher FGE and larger numbers of fish in Unit 12A is the presence of a vortex that developed between the intake ceiling extensions during all tests with the ceiling extensions in the alternate configuration.

Based on the higher FGEs obtained with the ceiling extensions in the alternate configuration, FGE testing was conducted with this pattern during the remainder of the 1987 field season.

Tests conducted with the mercury vapor lights indicated that these lights do have some effect on yearling chinook salmon, and in some instances a combination of lights on the trashrack and intake ceiling appeared to enhance FGE as well as alter the ratio of fish entering Units 12A and 12B. As in past years, very little replication occurred with these tests, therefore, we are not able to make any definitive statements. However, a comparison of FGE and the increase in proportion of fish in Unit 12B for several light tests (Table 2) are an indication that lights may have some potential for increasing FGE.

Tests using the small external deflector (Fig. 1) indicated little, if any, increase in FGE was provided by this device.

Table 2.--Comparison of the FGE and STS effectiveness and ratio of the number of fish in Units 12A and 12B under various light conditions tested at Bonneville Dam Second Powerhouse, 1987.

Date	Unit	Light pattern	% FGE	% STS effect.	Ratio (12A/12B)
5/1-	12A	None	72	86	
5/3	12B	"	60	72	1.67:1
5/15	12A	None	48	64	
	12B	All lights on	56	74	0.61:1
5/16	12A	None	75	91	
	12B	"	60	73	1.93:1
5/17	12A	None	55	86	
	12B	Intake ceiling (3)	55	86	1.44:1
5/30	12A	None	61	98	
	12B	Intake ceiling (2)	64	102	1.12:1
5/31	12A	None	44	66	
	12B	Intake ceiling (2) + top trashrack (15)	44	66	0.54:1
6/1	12A	None	42	55	
	12B	Intake ceiling (2) + top trashrack (2)	75	99	1.02:1

Subyearling Chinook Salmon

Testing with subyearling chinook salmon indicated that FGE averaged a very poor 16%, and STS effectiveness was generally less than 50%. None of the conditions tested when valid numbers of fish were present showed a marked improvement when compared to other test results.

The tests with the trashrack sections removed (Test 35) gave no indication that this configuration improved FGE or STS effectiveness.

The lower tailwater in July of 1987 compared to 1986 may have been partially responsible for the lack of effectiveness of the devices tested. Unit discharge during July was only 14,000 cfs compared to the usual July discharge of 16,500 cfs and spring discharges of 18,000 cfs. Previous FGE testing at other dams has shown a reduction in FGE during low discharges with their resulting lower velocities. The one test on 14 July 1987 when discharge was 16,500 cfs tends to support this hypothesis (FGE was 34%, nearly double that of tests run at 14,000 cfs).

Results from light tests indicated that dramatic changes could be produced. In some tests, the lights were so effective at attracting fish to Unit 12B that Unit 12A STS guided almost none (Tests 26 and 28--FGEs in Unit 12A of 2.1 and 1.3% respectively). Although, these results did not show an increase in FGE, they indicated that subyearlings could be influenced by these lights. Also, the test with the 110 volt strobe light (Test 36) showed a large increase in FGE (15.5 to 37%) for Unit 12A, although fish numbers were very low (<125).

OBJECTIVE II - CONTINUED EVALUATION OF THE FIRST AND AND SECOND POWERHOUSE DSM AND INDEXING FACILITIES

Second Powerhouse

The random sampler in the Second Powerhouse downstream migrant system (DSM) provides the means to examine the condition of salmonids passing through the downstream migrant system. Since 1983 we have used this sampler to enumerate fish collected in the system by species, measure descaling and mortality, and record marks daily throughout the sampling season. This was continued throughout the 1987 field season.

During most weeks in 1987, the random sampler has operated Monday through Friday, 24 h/day. From 9 March to 4 September, the random sampler operated for a total of 2,438 h or an average of almost 94 h/week. Estimates of total weekly passage (by species) were calculated by multiplying the daily catch by 10 [random sample efficiency is 10% (Krcma et al. 1984)] and expanding this number to a 7-day week (Table 3). These numbers represent a passage rate for a reduced powerhouse operating level similar to 1985 and 1986 when usually only three or four of the existing eight turbines were operating.

As of 31 August, a total of 16,593 juvenile salmonids have been captured, of which 12,028 were examined for descaling, injury, and brands. Table 4 gives the weighted percentages for descaling and mortality through 4 September for all five species. Brand information was collected daily and forwarded to the Fish Passage Center. As in previous years, sockeye salmon exhibited the highest rate of descaling and mortality.

Table 3.--Total salmonid passage estimates at Bonneville Dam Second Powerhouse DSM, 1987.

Week	Yearling chinook	Subyearling chinook	Coho	Sockeye	Steelhead	Total
9-Mar	140	158	87	17	0	402
16-Mar	175	437	52	70	52	786
23-Mar	507	4,235	1140	52	17	4951
30-Mar	0	385	0	0	0	385
6-Apr	56	154	14	0	14	238
12-Apr	21,140	4,186	70	84	882	26,362
20-Mar	13,440	7,630	157	0	192	21,419
27-Mar	18,497	2,275	3,080	35	1,505	25,392
5-May	19,040	3,010	23,887	52	2,800	48,789
11-May	12,180	5,792	22,417	997	2,940	44,326
19-May	19,985	6,247	9,607	3,885	4,165	43,889
26-May	1,794	11,440	5,498	1,561	746	21,039
1-Jun	1,365	12,127	4,497	4,602	892	23,483
8-Jun	70	2,275	805	210	18	3,378
15-Jun	18	717	192	0	0	927
22-Jun	18	2,555	52	0	18	2,643
30-Jun	0	8,900	344	0	0	9,244
7-Jul	51	5,080	76	0	0	5,207
13-Jul	140	5,530	53	0	18	5,741
20-Jul	228	4,182	53	0	18	4,481
27-Jul	175	717	18	0	35	945
4-Aug	0	560	0	0	0	560
10-Aug	0	53	0	0	0	53
17-Aug	0	35	0	0	0	35
24-Aug	0	315	0	0	0	315
31-Aug	0	595	0	0	0	595
Totals	109,019	89,590	71,098	11,565	14,312	295,602

Table 4.--Rates of descaling and mortality at Bonneville Dam DSM samplers--First and Second Powerhouses (through August 31).

Location	Yearling chinook Desc. %	Yearling chinook Mort. %	Subyearling chinook Desc. %	Subyearling chinook Mort. %	Coho Desc. %	Coho Mort. %	Sockeye Desc. %	Sockeye Mort. %	Steelhead Desc. %	Steelhead Mort. %
-1st PH.	3.7	0.1	2.0	3.7	3.2	0.1	25.5	0.2	4.1	0.0
2nd PH.	5.7	1.5	1.7	1.8	4.8	0.7	21.2	15.6	3.8	1.5

First Powerhouse

Studies were continued in 1987 to complete the evaluation of the juvenile salmonid bypass and indexing facility at the First Powerhouse. From 13 March to 4 September the random sampler operated for 237 h. A total of 151,416 juvenile salmonids were captured, and of these, 15,992 were examined for descaling, mortality, and brands.

To operate the sampler at the First Powerhouse, the flow in the DSM bypass channel must be in a northerly direction (the sampler is at the north end of the bypass). However, because of various mechanical breakdowns, the flow in the channel had to be reversed to a southerly direction for 80 out of 172 days between 13 March and 4 September. Table 5 gives a brief outline of the problems encountered. At the time of this report, the bypass channel and sampler were operating and the major problems seem to have been resolved.

Normal sampler operation at the First Powerhouse was a 20-min sample per hour for 8 h, 3 days/week; and for 24 hours, 2 days/week. The 24-h samples (diels) will be used to expand the numbers captured and derive an estimate of total numbers of juvenile salmonids passing the First Powerhouse. At the time of this report, passage data are still being collected; a complete analysis of these data will be provided in the 1987 Bonneville Dam final report.

Samples at the First Powerhouse can be collected using the following: (1) the entire sample flume to intercept the full width of the channel or (2) a sub-sample flume which intercepts approximately 20% of the channel width. Studies were carried out this year (using yearling and subyearling chinook salmon and steelhead) to determine the actual pecentage of each species intercepted by the sub-sampler and to determine if these percentages could be used to expand the total number captured to estimate the number of

Table 5.--Availability of the Bonneville Dam First Powerhouse DSM sampling facility during the 1987 outmigration (through August 30).

Date	Bypass Direction North	Bypass Direction South	Comments
3/13		X	Initial sampling started
3/14		X	Emergency relief valve stuck closed (while on automatic operation). DSM channel flooded and trashrack motor immersed.
3/16	X		Emergency relief valve fixed. Sampler in operation.
3/18		X	Motor on trash sweep had to be replaced.
3/19	X		Sampler in operation
3/22		X	Add-in gate valve failed.
3/25	X		Sampler in operation.
5/18		X	Couplers to screw jacks failed (while in automatic operation). Inclined screen could not be operated.
6/1	X		Sampler in operation.
6/11		X	Trash sweep gear box failed. Shaft had to be replaced.
6/19	X		Sampler in operation.
7/6		X	Couplers to screw jacks failed (while in automatic operation) Inclined screen could not be operated.
8/30	X		Sampler in operation.

fish passing through the DSM channel. These data are being analysed; the complete results and a discussion will be provided in the final report.

GENERAL CONCLUSIONS

1. FGEs of over 70% were achieved in Unit 12A (w/o ceiling extension) and FGE of 60% in Unit 12B (w/ceiling extension) for tests with seven units operating.

2. Tests with mercury vapor lights indicated the lights have some potential in improving FGE.

3. The small external deflector did not appear to increase FGE.

4. Removing the upper three trashrack sections did not appear to increase FGE or STS effectiveness.

GENERAL RECOMMENDATIONS

1. Continue FGE studies to evaluate additional methods of improving FGE (lights, increased porosity guiding device, etc.).

2. Continue vertical distribution tests in conjunction with the FGE tests.

LITERATURE CITED

Krcma, R. F, M. H. Gessel, W. D. Muir, C. S. McCutcheon, L. G Gilbreath, and B. H. Monk.
1984. Evaluation of the juvinile collection and bypass system at Bonneville Dam, 1983. U.S. Dep. of Commer., Natl. Oceanic and Atmos. Admin., Natl. Mar. Fish Serv., Northwest and Alaska Fish. Cent., Seattle, WA 56p. plus Appendix (Report to U.S. Army Corps of Engineers, Contract DACW57 -83-F-0315).