EVALUATION OF THE EFFECTIVENESS OF AN ORIFICE SHELTER AT MCNARY DAM, COLUMBIA RIVER, 1999

by

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Report of Research

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EXECUTIVE SUMMARY

During the 1999 spring and summer juvenile salmonid outmigrations, we evaluated an orifice shelter at McNary Dam (Columbia River) by conducting orifice passage efficiency (OPE) tests and descaling evaluations. These tests were conducted in Turbine Units 3 and 4. Test units were equipped with extended-length submersible bar screens (ESBS), partially raised operating gates, and inlet flow vanes. Dip-basket efficiency tests were also conducted.

We tested the orifice shelter from 1 May through 2 June for yearling and from 4 June through 16 July for subyearling chinook salmon (*Oncorhynchus tshawytscha*). Although orifice passage efficiency was variable during both the spring and summer outmigrations, tests with yearling chinook salmon showed significantly higher passage without the orifice shelter (62 vs. 49%), while tests with subyearling chinook salmon indicated that there was an interaction between test and control, with OPE higher with the orifice shelter in Unit 3 (85 vs. 68%) and lower in Unit 4 (40 vs. 59%). The orifice shelter did not have any measurable effect on descaling for either test series (grand means of 6.4 and 3.7%, for yearling and subyearling chinook salmon respectively).

Dip-basket efficiency tests on 28 May in Slots 3A and 4A with yearling chinook salmon resulted in a recapture efficiency of 100%. Marked fish were recovered in nearly the same condition as when they were released, and descaling and mortality due to handling was minimal.

Debris accumulation on the vertical barrier screens (VBSs), especially during the summer outmigration, did not appear to be reduced through the use of the orifice shelter, based on the frequency with which we had to clean the VBS.

CONTENTS

INTRODUCTION

McNary Dam, at River Kilometer 467 (River Mile 292) on the Columbia River, was completed in 1954. It is the first dam downstream from the confluence of the Columbia and Snake Rivers, influencing anadromous fish migrations from both river systems. It is equipped with 14 turbine units, 22 spillbays, a navigation lock, and a juvenile fish bypass system. The juvenile fish bypass system collects downstream migrating salmonids either for transport to release sites below Bonneville Dam or for bypass to the river below McNary Dam. Extended-length bar screens (ESBSs) are used to divert juvenile salmonids from turbines into gatewells from which the juveniles volitionally exit through bypass orifices and enter the bypass channel (Fig. 1).

The ESBS also diverts debris into the gatewells, and this can create problems for salmonids as well as for the continued operation of the bypass system. Aquatic vegetation and other small pieces of debris impinged on the vertical barrier screens (VBS) create areas of high velocity through the screen, which can impinge juveniles on the VBS (Fig. 1).

Studies conducted at the U.S. Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, have indicated that a device called an orifice shelter will alter flow patterns near the surface of the gatewell to continuously circulate flow in the vicinity of the orifices. It is theorized that this circulation pattern may reduce debris accumulation in the gatewell and subsequently reduce the amount of debris that collects on the VBS.

The orifice shelter is positioned 1 ft (30.8 cm) below the gatewell orifices, extends the full horizontal length of the gatewell, and projects 20 in (50.8 cm) into the width of the gatewell (Fig. 1). The research objective for 1999 was to evaluate the orifice shelter by monitoring orifice passage efficiency and descaling for yearling and subyearling chinook salmon (*Oncorhynchus tshawytscha*).

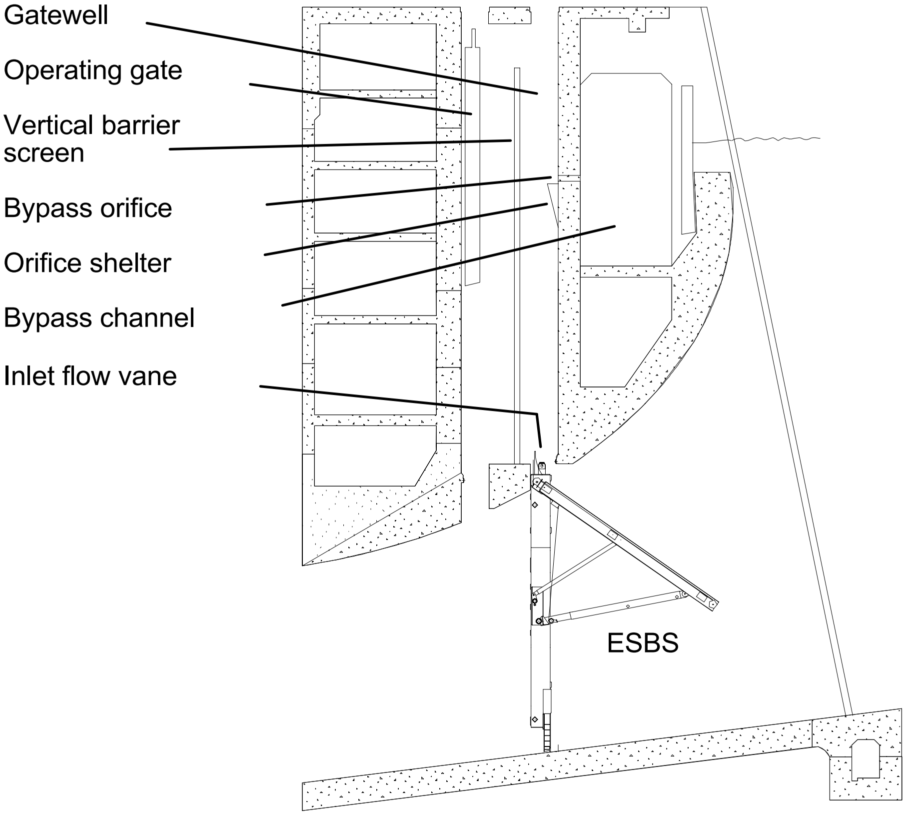

Figure 1. Cross-section of McNary Dam showing the orifice and the placement of the orifice shelter used for the orifice passage efficiency tests during the spring and summer outmigrations, 1999.

EVALUATE THE EFFECTS OF AN ORIFICE SHELTER ON ORIFICE PASSAGE EFFICIENCY AND DESCALING FOR YEARLING AND SUBYEARLING CHINOOK SALMON

Approach

Orifice passage efficiency (OPE) tests and descaling measurements were conducted in Gatewells 3A and 4A located near the south end of the powerhouse. Guided fish were confined to the bulkhead slot by the VBS which separated the bulkhead slot (upstream side) from the operating gate slot (downstream side) of the gatewell (Fig. 1). Each gatewell has two 12-in (0.3-m) bypass orifices which empty into the bypass channel. The orifices can be opened or closed from the bypass gallery by an air-operated slide gate.

The methods for determining OPE were similar to those used in previous OPE studies evaluating the ESBSs (Brege et al. 1997, 1998). Prior to the start of a test, each gatewell was dipnetted to remove any residual fish. A dip-basket similar to that described by Swan et al. (1979) was used to collect fish from the gatewells. The fish were anesthetized with tricaine methanesulfonate (MS-222) and examined. Groups of about 100 juvenile salmonids per OPE replicate were caudal-fin clipped and held in a release canister for a minimum of 1 hour to monitor short-term mortality.

Yearling hatchery chinook salmon and subyearling chinook salmon were used as test fish during the spring and summer, respectively. Descaled or injured fish were not included in the marked groups. Marked fish were released from the canister, which was positioned in the center of and at the entrance to the test gatewells, 80 ft (24.4 m) below the surface.

The north orifice was closed and the south orifice was open during all OPE tests. Test units were operated at the standard load of about 60 MW during each OPE test. Orifice discharge into the juvenile bypass channel was monitored twice a day to ensure orifices were open and not plugged with debris. A typical OPE test lasted 21 hours, beginning at 2000 h on one day and ending at 1700 h the next day. Orifice passage efficiency was calculated as the number of clipped fish that exited the gatewell divided by the total number released. The test design provided for 20 OPE measurements in each of the test slots during both the spring and summer juvenile salmonid outmigration. The OPE data was analyzed by two-way ANOVA.

Descaling of fish captured during OPE tests was monitored using standard Fish Transportation Oversight Team descaling criteria (Ceballos et al. 1993). Paired *t*-tests (paired by day) were used for analysis of descaling associated with orifice shelters. We determined that 20 descaling tests during both spring and summer would be required to detect differences of 5.8% or more for yearling chinook salmon and 4.7% or more for subyearling chinook salmon. These calculations were based on descaling research at McNary Dam in 1995 (McComas et al. 1997).

The gatewell dipnetting technique for OPE relies on the assumptions that 1) all fish remaining in the gatewell at the end of a test are captured by the dip net, and 2) fish that exit the gatewell do so through the gatewell orifice. To ensure the reliability of the first assumption and monitor the movement of marked fish within the gatewell, dip-basket efficiency tests were conducted. During these tests, fish were marked, held for 1 hour in the release canister, and then released in the gatewell with both orifices closed. Several hours later the gatewell was dipnetted and the catch examined and enumerated. We conducted these tests on 28 May in Slots 3A and 4A. All of the marked fish were recovered with no increase in descaling or injury.

Results and Discussion

Yearling Fish

Testing for OPE began 1 May and ended 2 June when numbers of yearling chinook salmon dropped at the end of the spring outmigration. Appendix Table 1 lists the numbers of OPE tests conducted and of fish marked and recovered for each. We were unable to conduct OPE tests from 8 May through 18 May because large numbers of both yearling chinook and sockeye salmon (*O. nerka*) were passing. Average daily passage at McNary Dam during this period exceeded 200,000 fish, and testing during this period would have required anesthetizing and examining as many as 15,000 juvenile fish daily, since all fish are removed from a gatewell at the end of an OPE test.

We were unable to conduct paired tests during the first week of operation, since we could not move the orifice shelter on a daily basis. We conducted 10 OPE tests with the orifice shelter in Gatewell 3A and 7 OPE tests with the orifice shelter in Gatewell 4A (Fig. 2). Statistical analysis was conducted using two-factor ANOVA (Appendix Table 2). The logistical difficulties resulted in a series of tests that were poorly spaced through time. It is not known if the observed differences may be time related, and since the test design was not balanced through time (e.g., Gatewell 3A was the test unit for the first 6 days, then after a long delay an alternating series of tests were conducted). For these reasons we recommend that the results be viewed with caution.

Although OPE was variable, mean OPE was significantly higher in the control gatewell than in the treatment gatewell (62 vs. 49%) (F = 4.59; df = 1, 28; P = 0.041). Descaling data for the tests showed no obvious problems for either test condition (grand mean = 6.4%). Descaling data and daily fish collection data are shown in Appendix Table 3.

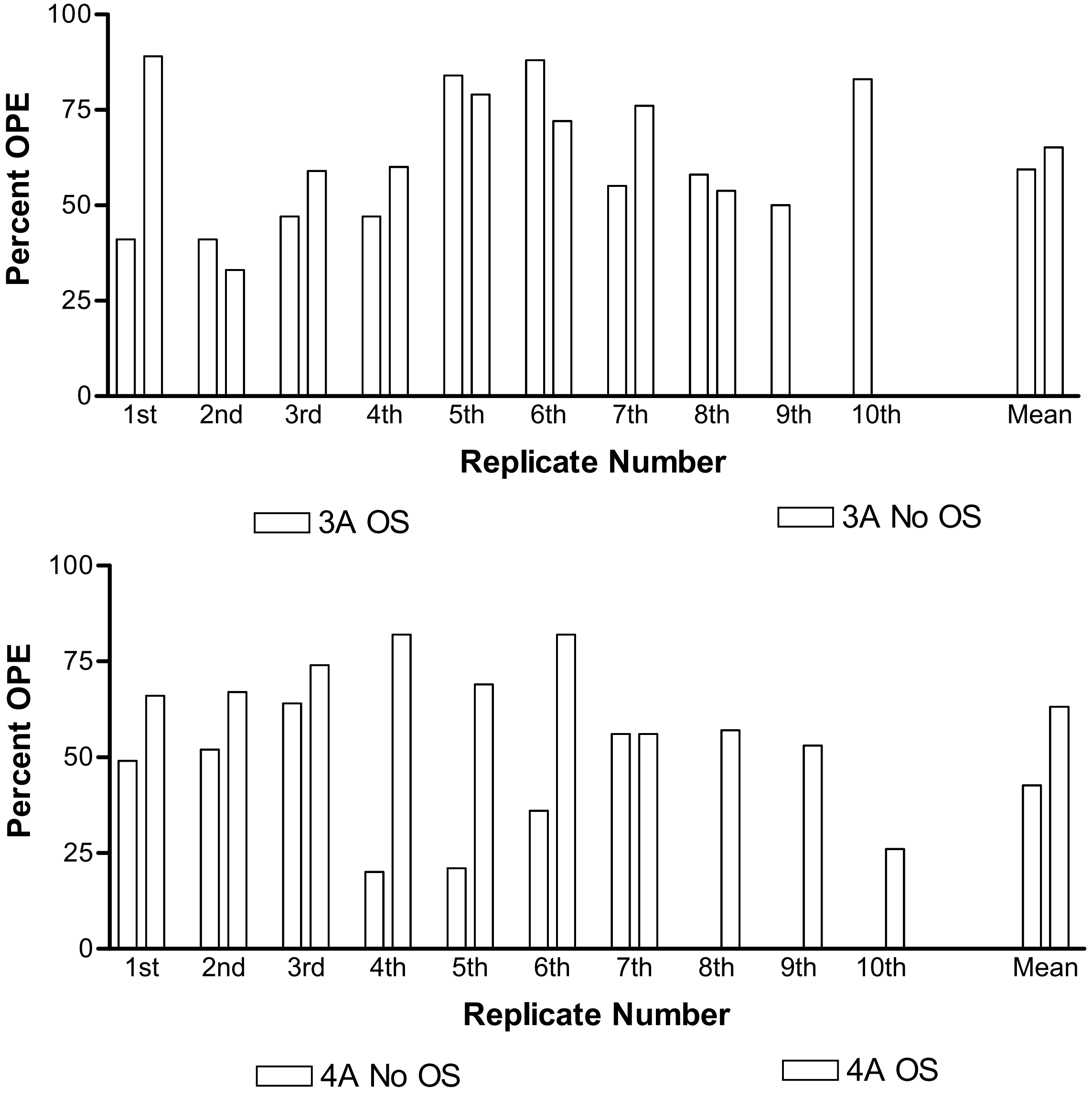

Figure 2. Orifice passage efficiency (OPE) data for tests using yearling chinook salmon in Gatewells 3A and 4A with and without the orifice shelter (OS) at McNary Dam, 1999.

Subyearling Fish

Summer tests were conducted from 4 June through 16 July, after which rising water temperature and large numbers of adult shad in the gatewells precluded further testing. During the summer outmigration we were able to alternate the orifice shelter between the two gatewells on a daily basis. We examined a total of 48,664 subyearling chinook salmon.

Statistical analysis for the subyearling chinook data was a two-factor randomized block ANOVA (Appendix Table 4) with two consecutive days considered a block. Although OPE was again variable (Fig. 3), a significant interaction was detected between turbine and treatment (F = 13.40; df = 1, 33; P = 0.001): mean OPE in the treatment gatewell was higher than that of the control gatewell in Unit 3 (85 vs. 68%), but lower than that of the control gatewell in Unit 4 (40 vs. 59%). Descaling results for subyearling chinook showed no significant differences among gatewells for test or control conditions (grand mean = 3.7%).

Head Differential in the Gatewells

The disparity in OPE results between the two turbine units did not allow us to conclusively determine the overall effectiveness of the orifice shelters at McNary Dam. But additional information collected during the tests may help to address this question. During the OPE tests, we monitored water elevation between the upstream and downstream portions of the gatewells. As explained previously, the VBS divides the gatewell into an upstream slot (with the orifices that lead to the juvenile bypass channel) and downstream slot (which has the operating gate) (Fig. 1). Turbine operation at 60 MW produces a head differential between the upstream and downstream slots (1 ft (30.8 cm)).

During turbine operation, debris collects in the gatewell and passes through the orifice or impinges upon the VBS. Debris buildup on the VBS further alters the head differential and eventually requires the VBS to be cleaned. During the summer, the major type of debris is aquatic vegetation, and VBS cleaning is frequently required. During the OPE tests we cleaned the VBS in the adjacent gatewells in Turbine Units 3 and 4 (“B” and “C” gatewells) as often as we cleaned the VBS in the “A” gatewell, which was the gatewell with the orifice shelter. We had no quantitative measurement for the amount of debris, but our observations and the similar frequency with which we had to clean the gatewells suggested that the orifice shelter did not substantially alter debris accumulation on the VBS.

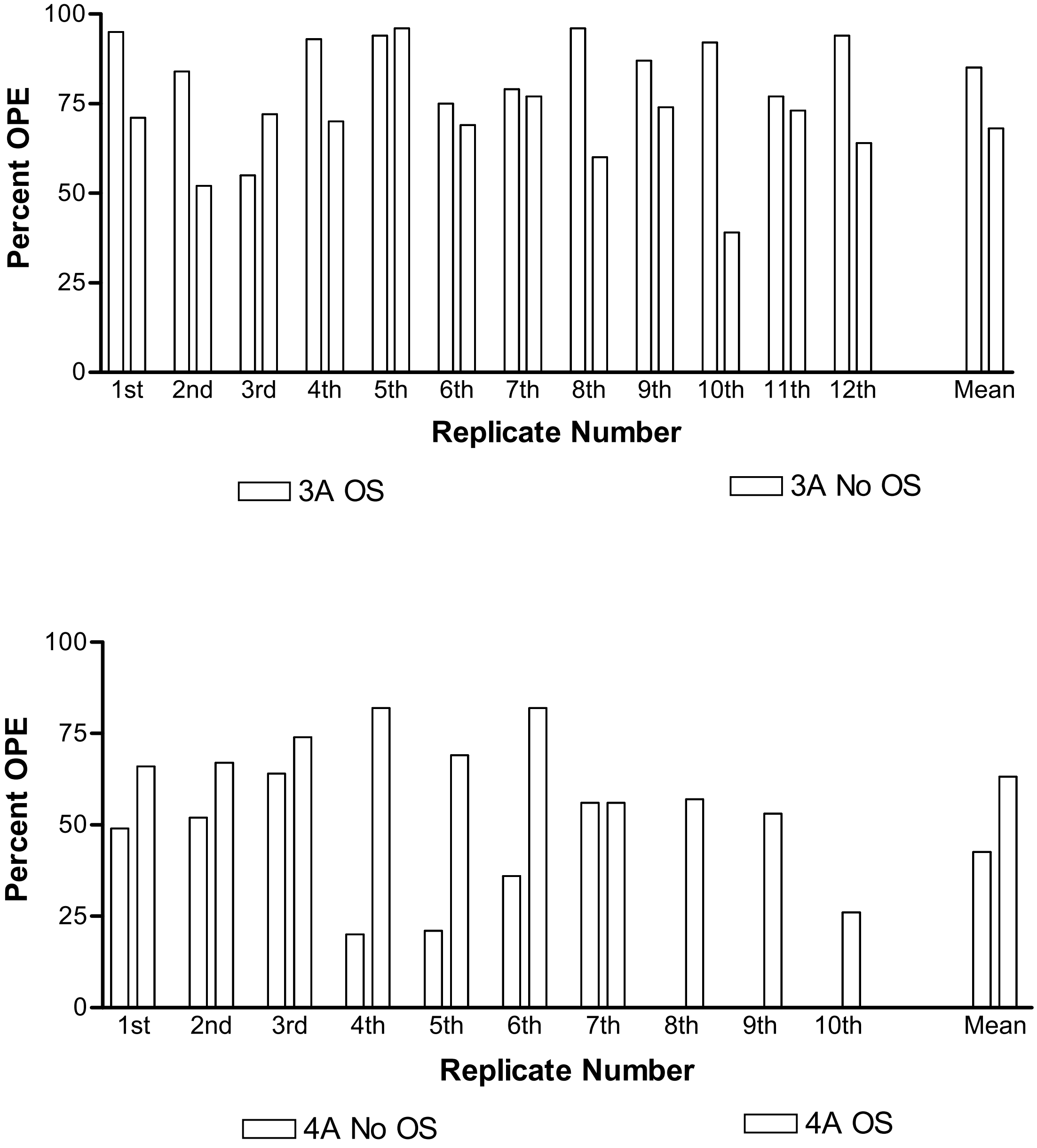

Figure 3. Orifice passage efficiency (OPE) data for tests using subyearling chinook salmon in Gatewells 3A and 4A with and without the orifice shelter (OS) at McNary Dam, 1999.

CONCLUSIONS

1) Tests using yearling chinook salmon produced a control mean OPE (without the orifice shelter) that was significantly higher than the treatment mean OPE (62 vs. 49%).

2) Tests using subyearling chinook salmon indicated that there may have been a confounding effect related to the gatewell; mean OPE with the orifice shelter (treatment) was higher than the mean OPE without the orifice shelter (control) in Unit 3 (85 vs. 68%) but lower than mean OPE without the orifice shelter in Unit 4 (40 vs. 59%).

3) The orifice shelter did not have any measurable effect on descaling for yearling or subyearling chinook salmon (grand means of 6.4 and 3.7%, respectively).

4) The frequency of cleaning required to keep the VBS free of debris indicated that the orifice shelter did not substantially alter the accumulation of debris on the VBS.

ACKNOWLEDGMENTS

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APPENDIX

Orifice Passage Efficiency and Descaling Data Tables

Appendix Table 1. Orifice passage efficiency (OPE) data from tests at McNary Dam, 1999.

Unit 3 Slot A

Test date	Orifice shelter	Number marked	Number recovered	OPE(%)	Unit load in MW
Yearling chinook					
01 May	Yes	100	59	41	60
02 May	Yes	100	59	41	60
03 May	Yes	100	53	47	60
04 May	Yes	100	53	47	60
06 May	Yes	100	16	84	60
07 May	Yes	100	12	88	60
21 May	Yes	100	45	55	60
23 May	Yes	100	42	58	60
25 May	Yes	100	50	50	60
28 May	Yes	100	17	83	60
05 May	No	100	11	89	60
20 May	No	100	67	33	60
22 May	No	100	41	59	60
24 May	No	100	40	60	60
26 May	No	100	21	79	60
27 May	No	100	28	72	60
01 Jun	No	50	12	76	60
02 Jun	No	65	30	54	60
Subyearling chinook					
05 Jun	Yes	100	5	95	60
07 Jun	Yes	100	16	84	60
23 Jun	Yes	100	45	55	60
25 Jun	Yes	100	7	93	60
27 Jun	Yes	100	6	94	60
29 Jun	Yes	100	25	75	60
02 Jul	Yes	100	21	79	60
08 Jul	Yes	100	4	96	60
10 Jul	Yes	100	13	87	60
12 Jul	Yes	100	8	92	60
14 Jul	Yes	100	23	77	60
16 Jul	Yes	100	6	94	60
04 Jun	No	100	29	71	60
06 Jun	No	100	48	52	60
22 Jun	No	100	28	72	60
24 Jun	No	100	30	70	60
26 Jun	No	100	4	96	60
28 Jun	No	100	31	69	60
01 Jul	No	100	23	77	60
07 Jul	No	100	40	60	60
09 Jul	No	100	26	74	60
11 Jul	No	100	61	39	60
13 Jul	No	100	27	73	60
15 Jul	No	100	36	64	60

Appendix Table 1. Continued.

Unit 4, Slot A

Test date	Orifice shelter	Number marked	Number recovered	OPE(%)	Unit load in MW
Yearling chinook					
20 May	Yes	100	51	49	60
22 May	Yes	100	48	52	60
24 May	Yes	100	36	64	60
26 May	Yes	100	80	20	60
27 May	Yes	100	79	21	60
01 Jun	Yes	100	64	36	60
02 Jun	Yes	100	44	56	60
01 May	No	100	34	66	60
02 May	No	100	33	67	60
03 May	No	100	26	74	60
04 May	No	100	18	82	60
05 May	No	100	31	69	60
06 May	No	100	18	82	60
21 May	No	100	44	56	60
23 May	No	100	43	57	60
25 May	No	100	47	53	60
28 May	No	100	74	26	60
Subyearling chinook					
04 Jun	Yes	100	29	71	60
06 Jun	Yes	100	35	65	60
22 Jun	Yes	100	25	75	60
24 Jun	Yes	100	53	47	60
26 Jun	Yes	100	57	43	60
28 Jun	Yes	100	54	46	60
01 Jul	Yes	100	70	30	60
07 Jul	Yes	100	82	18	60
09 Jul	Yes	100	65	35	60
11 Jul	Yes	100	84	16	60
13 Jul	Yes	100	74	26	60
15 Jul	Yes	100	95	5	60
05 Jun	No	75	28	63	60
07 Jun	No	100	30	70	60
23 Jun	No	100	17	83	60
25 Jun	No	100	26	74	60
27 Jun	No	100	31	69	60
29 Jun	No	100	40	60	60
02 Jul	No	100	20	80	60
08 Jul	No	100	42	58	60
10 Jul	No	100	66	34	60
12 Jul	No	100	38	62	60
14 Jul	No	100	67	33	60
16 Jul	No	100	83	17	60

Appendix Table 2. Statistical analysis of the orifice passage efficiency data collected for yearling chinook salmon at McNary Dam, 1999.

Analysis of variance for OPE, using adjusted SS for tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Unit	1	0.0190	0.0330	0.0330	1.17	0.288
Treatment	1	0.1292	0.1292	0.1292	4.59	0.041
Unit*treatment	1	0.0405	0.0405	0.0405	1.44	0.240
Error	28	0.7876	0.7876	0.0281		
Total	31	0.9764				

Least squares means for OPE

Unit	Mean	Standard error
3A	0.5904	0.0423
4A	0.5256	0.0423
Treatment		
C	0.6221	0.0423
T	0.4940	0.0423

Analysis of variance for descaling, using adjusted SS for tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Unit	1	0.0001	0.00002	0.00002	0.01	0.910
Treatment	1	0.0020	0.0020	0.0020	1.10	0.303
Unit*Treatment	1	0.00004	0.00004	0.00004	0.02	0.877
Error	28	0.0514	0.0514	0.0018		
Total	31	0.0536				

Least squares means for descaling

Unit	Mean	Standard error
3A	0.0637	0.0108
4A	0.0654	0.0108
Treatment		
C	0.0725	0.0108
T	0.0565	0.0108

Appendix Table 3. Descaling data and total salmonid collection from orifice passage efficiency tests at McNary Dam, 1999. Tests were conducted in Turbine Unit Gatewells 3A and 4A. Desc = number of descaled fish, Catch = total number of fish examined, % = percentage fish descaled.

Unit 3, Gatewell A

Test	**Subyearling chinook**			**Yearling chinook**			**Steelhead**			**Coho**			**Sockeye**		
date	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**
30 Apr	2	10	20.0	34	337	10.1	2	18	11.1	0	6	0.0	1	11	9.1
01 May	0	5	0.0	8	201	4.0	0	13	0.0				0	10	0.0
02 May	0	3	0.0	17	177	9.6	0	9	0.0	0	1	0.0	1	34	2.9
03 May	0	1	0.0	15	232	6.5	1	12	8.3				2	61	3.3
04 May				10	217	4.6	1	29	3.4				6	40	15.0
05 May	0	2	0.0	8	340	2.4	0	7	0.0				4	60	6.7
06 May				12	475	2.5	0	13	0.0				5	168	3.0
07 May				8	456	1.8	0	11	0.0				8	480	1.7
19 May	0	12	0.0	28	274	10.2	1	19	5.3				14	214	6.5
20 May	2	15	13.3	42	607	6.9	2	33	6.1	1	6	16.7	43	225	19.1
21 May				3	105	2.9	0	6	0.0	1	4	25.0	1	48	2.1
22 May	1	29	3.4	61	576	10.6	1	20	5.0	0	34	0.0	43	259	4.9
23 May	0	11	0.0	8	375	2.1	0	8	0.0	1	10	10.0	9	117	7.7
24 May	1	42	2.4	47	788	6.0	1	66	1.5	1	21	4.8	32	187	17.1
25 May	0	21	0.0	15	579	2.6	2	55	3.6	0	17	0.0	9	74	12.2
26 May	2	53	3.8	27	281	9.6	0	31	0.0	0	7	0.0	48	359	13.4
27 May	1	69	1.4	2	16	12.5	0	4	0.0	0	2	0.0	17	117	14.5
28 May	0	78	0.0	2	17	11.8	0	3	0.0	0	15	0.0	1	18	5.6
01 Jun	1	93	1.1	5	20	25.0	0	26	0.0	1	7	14.3	1	18	5.6
02 Jun	9	322	2.8	1	26	3.8	0	4	0.0	0	4	0.0	0	5	0.0
03 Jun	8	349	2.3	0	2	0.0	0	1	0.0	0	2	0.0	1	7	14.3
04 Jun	15	414	3.6	0	9	0.0	0	2	0.0	1	11	9.1	0	15	0.0
05 Jun	0	16	0.0	0	0	-.-	0	1	0.0	0	0	-.-	0	1	0.0
06 Jun	11	227	4.8	0	15	0.0	0	3	0.0	0	3	0.0	1	7	14.3
07 Jun	8	187	4.3	0	4	0.0	0	1	0.0	0	6	0.0	1	3	33.3

Appendix Table 3. Continued.

Unit 3, Gatewell A

Test	**Subyearling chinook**			**Yearling chinook**			**Steelhead**			**Coho**			**Sockeye**		
date	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**	**Desc**	**Catch**	**%**
21 Jun	9	539	1.7				0	1	0.0				0	1	0.0
22 Jun	9	1,275	0.7	0	1	0.0	0	1	0.0	0	0		0	1	0.0
23 Jun	11	1,336	0.8	0	4	0.0	0	1	0.0	1	1	100.0	0	1	0.0
24 Jun	11	969	1.1	0	1	0.0									
25 Jun	3	422	0.7												
26 Jun	11	1,144	1.0												
27 Jun	15	934	1.6	0	2	0.0	0	2	0.0	0	1	0.0			
28 Jun	29	1,287	2.3										0	1	0.0
29 Jun	19	787	2.4	0	1	0.0	0	1	0.0						
30 Jun	11	308	3.6	0	2	0.0							0	1	0.0
01 Jul	11	218	5.0	0	6	0.0	0	1	0.0						
02 Jul	6	75	8.0												
07 Jul	20	389	5.1	1	10	10.0				0	1	0.0	1	2	50.0
08 Jul	1	32	3.1	0	1	0.0									
09 Jul	8	204	3.9												
10 Jul	4	136	2.9	0	1	0.0							0	1	0.0
11 Jul	4	123	3.3	0	1	0.0									
12 Jul	7	89	7.9				0	1	0.0						
13 Jul	14	215	6.5												
14 Jul	6	141	4.3	0	6	0.0	0	1	0.0						
15 Jul	1	84	1.2	0	2	0.0									
16 Jul	7	201	3.5										0	1	0.0
19 Jul	27	333	8.1	0	9	0.0									

Appendix Table 3. Continued.

Unit 4, Gatewell A

Test	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
date	Desc	Catch	%	Desc	Catch	%	Desc	Catch	%	Desc	Catch	%	Desc	Catch	%
01 May	0	10	0.0	40	566	7.1	1	21	4.8	0	6	0.0	3	32	9.4
02 May	0	18	0.0	28	528	5.3	0	33	0.0	1	5	20.0	8	75	10.7
03 May	0	6	0.0	45	733	6.1	2	40	5.0	0	4	0.0	11	169	6.5
04 May	0	7	0.0	53	836	6.3	1	46	2.2	0	4	0.0	11	132	8.3
05 May	1	10	10.0	66	1,083	6.1	0	10	0.0	0	3	0.0	22	200	11.0
06 May	0	3	0.0	59	1,265	4.6	0	26	0.0	0	5	0.0	30	244	12.3
07 May				6	213	2.8				0	1	0.0	15	226	6.6
20 May	1	12	8.3	21	608	3.5	2	32	6.3	1	14	7.1	54	466	11.6
21 May	1	17	5.9	90	1,383	6.5	3	40	7.5	0	32	0.0	37	245	15.1
22 May	1	22	4.5	43	900	4.8	1	34	2.9	1	29	3.4	25	141	17.7
23 May	2	20	10.0	88	1,611	5.5	1	51	2.0	1	70	1.4	47	297	15.8
25 May	1	37	2.7	88	557	15.8	0	85	0.0	4	49	8.2	26	135	19.3
26 May	7	119	5.9	44	877	5.0	3	97	3.1	1	70	1.4	85	397	21.4
27 May	10	151	6.6	15	77	19.5	0	20	0.0	1	29	3.4	35	135	25.9
28 May	14	192	7.3	18	137	13.1	4	67	6.0	12	86	14.0	21	81	25.9
01 Jun	8	195	4.1	1	28	3.6	1	16	6.3	0	4	0.0	1	9	11.1
02 Jun	7	507	1.4	0	22	0.0	0	4	0.0	0	5	0.0	1	14	7.1
03 Jun	30	805	3.7	1	17	5.9	0	4	0.0	2	34	5.9	1	23	4.3
04 Jun	6	265	2.3	2	13	15.4	0	11	0.0	4	41	9.8	2	12	16.7
05 Jun	12	231	5.2	3	21	14.3	1	6	16.7	7	49	14.3	3	18	16.7
06 Jun	6	226	2.7	0	13	0.0	0	5	0.0	1	5	20.0	2	8	25.0
07 Jun	24	480	5.0	4	28	14.3	0	3	0.0	7	21	33.3	1	6	16.7

Appendix Table 3. Continued.

Unit 4, Gatewell A

Test	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
date	Desc	Catch	%	Desc	Catch	%	Desc	Catch	%	Desc	Catch	%	Desc	Catch	%
22 Jun	11	735	1.5	0	3	0.0	0	3	0.0				0	1	0.0
23 Jun	17	908	1.9	0	2	0.0	0	1	0.0				1	1	100.0
24 Jun	17	1,962	0.9	0	1	0.0	0	1	0.0				0	2	0.0
25 Jun	18	1,379	1.3	0	3	0.0	0	1	0.0	0	2	0.0			
26 Jun	30	1,796	1.7	0	1	0.0				0	2	0.0			
27 Jun	37	1,495	2.5	0	2	0.0									
28 Jun	31	2,730	1.1	0	10	0.0				0	1	0.0			
29 Jun	164	1,775	9.2	1	8	12.5				0	2	0.0	0	1	0.0
30 Jun	73	863	8.5	0	1	0.0				0	1	0.0			
01 Jul	19	735	2.6	0	14	0.0	0	1	0.0	0	1	0.0	1	1	100.0
02 Jul	39	487	8.0	1	5	20.0	0	1	0.0	0	1	0.0			
07 Jul	151	3,011	5.0	3	41	7.3	0	3	0.0	0	1	0.0			
08 Jul	8	208	3.8	0	4	0.0				0	1	0.0			
09 Jul	37	830	4.5	0	2	0.0									
10 Jul	52	648	8.0	1	8	12.5									
11 Jul	29	441	6.6	0	8	0.0				1	1	100.0	1	2	50.0
12 Jul	93	1,713	5.4	0	9	0.0	0	1	0.0						
13 Jul	53	1,526	3.5	0	7	0.0									
14 Jul	27	767	3.5	0	8	0.0	0	2	0.0	0	1	0.0			
15 Jul	16	413	3.9	0	13	0.0	0	1	0.0						
16 Jul	48	870	5.5	0	6	0.0									

Appendix Table 4. Statistical analysis of the orifice passage efficiency data collected for subyearling chinook salmon at McNary Dam, 1999.

Analysis of variance for OPE, using adjusted SS for tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	11	0.4310	0.4310	0.0392	1.36	0.236
Unit	1	0.9020	0.9020	0.9020	31.38	0.000
Treatment	1	0.0010	0.0010	0.0010	0.04	0.853
Unit*treatment	1	0.3852	0.3852	0.3852	13.40	0.001
Error	33	0.9487	0.9487	0.0288		
Total	47	2.6679				

Least squares means for OPE

Unit	Treatment	Mean	Standard error
3A	C	0.6808	0.0489
3A	T	0.8508	0.0489
4A	C	0.5858	0.0489
4A	T	0.3975	0.0489

Analysis of variance for descaling, using adjusted SS for tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	11	0.0115	0.0115	0.0010	3.34	0.004
Unit	1	0.0008	0.0008	0.0008	2.65	0.113
Treatment	1	0.0008	0.0008	0.0008	2.65	0.113
Unit*treatment	1	0.0010	0.0010	0.0010	3.21	0.082
Error	33	0.0104	0.0104	0.0003		
Total	47	0.0246				

Least squares ,means for descaling

Unit	Mean	Standard error
3A	0.0329	0.0037
4A	0.0413	0.0037
Treatment		
C	0.0413	0.0037
T	0.0329	0.0037