Studies to evaluate the effectiveness of vertical barrier screens and outlet flow-control devices at McNary Dam, 1997

Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

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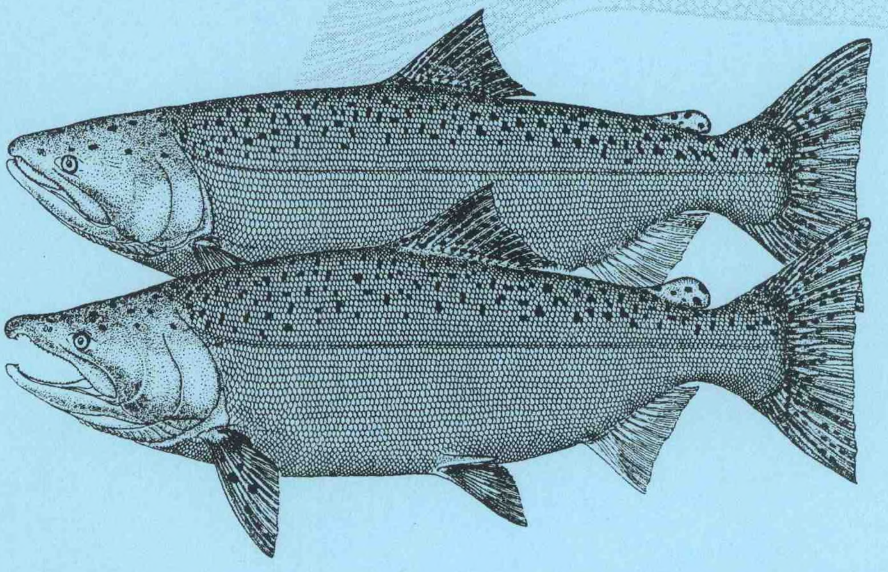

STUDIES TO EVALUATE THE EFFECTIVENESS OF VERTICAL BARRIER SCREENS AND OUTLET FLOW-CONTROL DEVICES AT MCNARY DAM, 1997

by

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CONTENTS

EXECUTIVE SUMMARY

During the 1997 spring and summer juvenile salmonid outmigrations, descaling evaluations and orifice passage efficiency (OPE) tests using a mark and release method were conducted at McNary Dam. Descaling and OPE tests were conducted in Turbine Units 4 and 5 which were equipped with extended-length submersible bar screens (ESBSs) and inlet flow vanes. Tests evaluated two vertical barrier screen (VBS) designs (a prototype test VBS and the existing VBS), and a lowered vs. raised position for an outlet flow-control (OFC) device. During spring, turbine loads were alternated daily between 60 and 75 MW in both test units; during summer tests, Unit 4 was operated at 60 MW and Unit 5 was held near 80 MW. In addition, dip-basket efficiency tests were conducted during the spring season.

During spring tests with yearling chinook salmon, there was a statistically significant difference in OPE between the low and high load condition (mean OPEs of 62.8 and 93.6%, respectively) for both VBS types. No difference in OPE was found between the test and existing VBS types. During OFC evaluations, OPE was significantly higher at the high load than at the low load (means of 87.9 and 68.5%, respectively) and with the OFC lowered vs. OFC raised (means of 83.4 and 73.0%, respectively). Descaling during VBS evaluations was significantly higher at the high load than at the low load (means of 17. 1 and 6.7%, respectively); this was also true for OFC evaluations (9.2 and 4.5%, respectively). No difference in descaling was found with regard to OFC position.

During summer tests, OPE for subyearling chinook salmon was significantly higher for the test VBS than for the existing VBS (means of 93.4 and 76.5%, respectively) at the high load, but there was no difference at the low load. OPE was significantly higher at the high load than at the

low load with both OFC positions. No differences were found in descaling for either VBS type or turbine load. During OFC evaluations, OPE was significantly higher at the high load than at the low load (means of 87.8 and 74. 1%, respectively) and with the OFC lowered vs. raised (means of 84.2 and 77.7%, respectively). Descaling was significantly higher with the lowered OFC than with the raised OFC at the high turbine load (means of 4.5 and 2.0%, respectively), but there was no difference at low turbine load.

Recapture efficiency tests on 17 May in Slots 4A and 5A with yearling chinook salmon resulted in a recapture efficiency of 98.5%. Marked fish were recovered in nearly the same condition as when they were released. Descaling and mortality due to handling was minimal.

INTRODUCTION

McNary Dam, at River Kilometer 467 (River Mile 292), is operated by the U.S. Army Corps of Engineers (COE), and is the fourth hydroelectric project from the mouth of the Columbia River. It is also the first dam downstream from the confluence of the Columbia and Snake Rivers, influencing anadromous fish migrations from both river systems. Completed in 1953, McNary Dam is equipped with 14 turbine units, 22 spillbays, a navigation lock, and fish bypass systems. McNary Dam contains a modern juvenile fish bypass system to collect downstream outmigrating salmonids for transport to release sites below Bonneville Dam or to bypass them to the river below the dam. Studies beginning in 1991 and continuing to the present have shown that extended-length submersible bar screens (ESBSs), currently in use in turbine intakes at McNary Dam, divert juvenile salmonids away from turbines to the bypass system much more efficiently than previously used shorter guidance screens (Brege et al. 1992, McComas et al. 1993, 1994) (Fig. 1). Additionally, inlet flow control vanes and ceiling beam extensions have further increased the effectiveness of the ESBS.

As a result of these studies, the U.S. Army Corps of Engineers installed the ESBS guidance system in the turbine intakes at McNary Dam in 1996. However, due to a re-evaluation of the emergency turbine safety procedures, the turbine operating gates were required to remain in the gate slots instead of being removed entirely from the slots (the operating condition for which the ESBS guidance system was developed). The presence of an operating gate in the gate slot changes the hydraulic conditions within the gatewell. To determine the effects of a partially removed (raised) operating gate within the gate slot, flows were modeled at the COE's Waterways Experiment Station (WES). The results of these model studies indicated that the

McNary Dam cross section

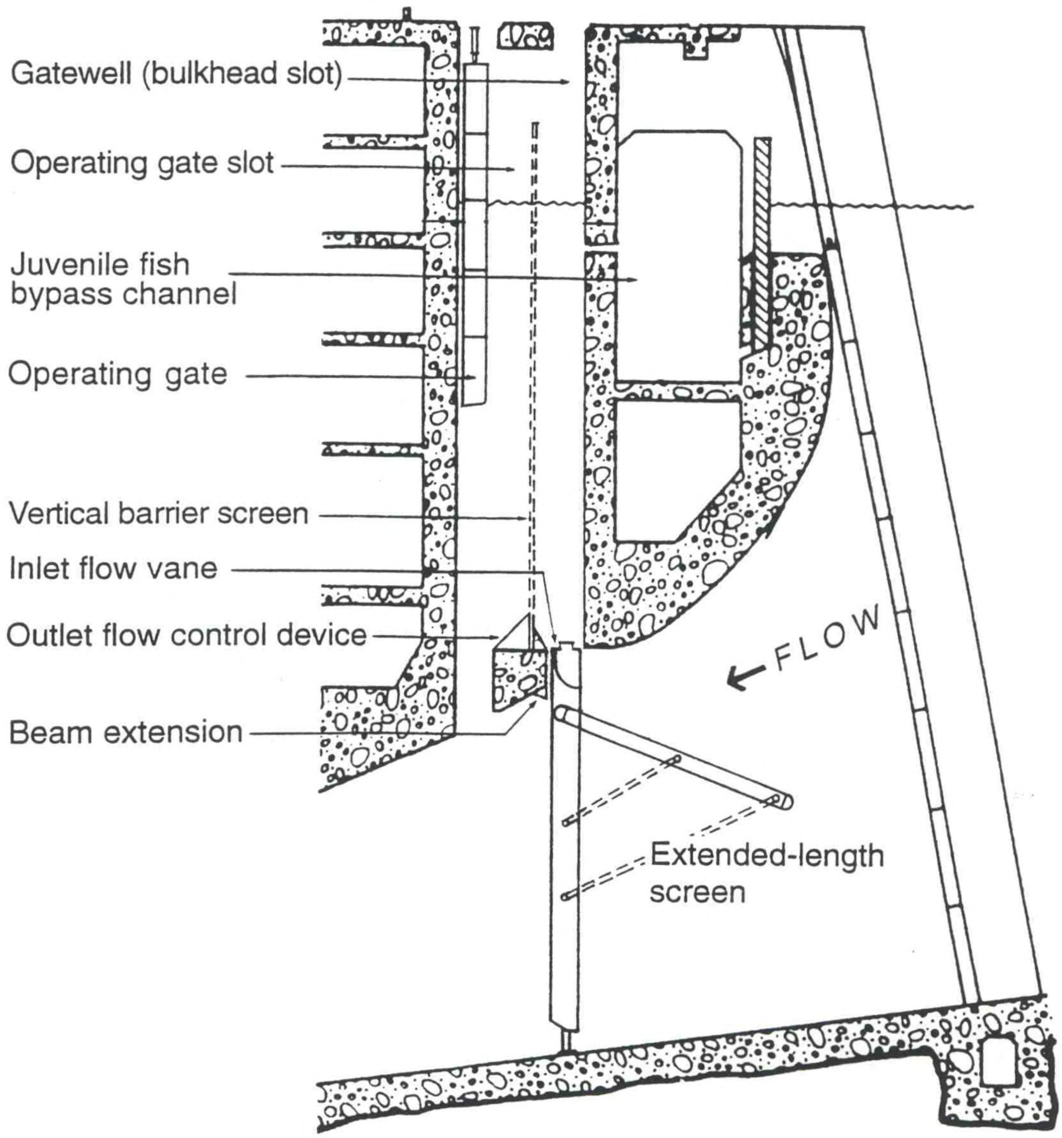

Figure 1. Cross section of turbine unit at McNary Dam with extended-length bar screen, outlet flow-control device, inlet flow vane, and operating gate in place. Outlet flow-control device is shown in the lowered (off) position.

presence of the operating gate can have a substantial effect on flow distribution through the vertical barrier screen (VBS) which in turn may affect debris accumulation, blockage, damage to the VBS, and the potential for injury to fish diverted into the gatewell. Turbine units at McNary Dam are normally run with operating gates installed in a raised position in the downstream gate slots. We evaluated the effects on juvenile salmonid orifice passage efficiency (OPE) and descaling of a modified VBS with perforated plate designed to distribute flow more evenly when used with an ESBS and the operating gate in the gate slot. In addition, we evaluated outlet flow-control devices, which can be used to regulate flows into the gatewell and help control debris accumulations, to determine the effects of these devices on OPE and juvenile salmonid descaling at different turbine-unit loads.

Research objectives for 1997:

1) During spring and summer juvenile salmonid outmigrations, evaluate the effects of a VBS with a newly designed perforated plate arrangement (used with an ESBS, inlet flow vane, beam extension, and operating gate in the gate slot) and different turbine-unit loadings on descaling and OPE.
2) During spring and summer juvenile salmonid outmigrations, evaluate the effects of outlet flow-control devices and different turbine-unit loadings on descaling and OPE.

Spring testing for the above objectives occurred between 26 April and 31 May for the 1997 season. Summer testing was conducted between 17 June and 19 July.

OBJECTIVE 1: EVALUATE THE EFFECTS OF A VBS WITH NEWLY DESIGNED PERFORATED PLATE (USED WITH AN ESBS, INLET FLOW VANE, BEAM EXTENSION, AND OPERATING GATE IN THE GATE SLOT) AND DIFFERENT TURBINE-UNIT LOADING ON DESCALING AND OPE

Approach

Orifice passage efficiency and descaling measurements were conducted to evaluate the effects of a VBS with a newly designed perforated plate arrangement in Slots 4A and 5A (located near the center of the McNary Dam powerhouse). At the same time, the effects of outlet flow-control devices were evaluated in Slots 4B and 5B (discussed under Objective 2). Guided fish were confined to the upstream bulkhead slot by the VBS that separated the bulkhead slot from the downstream gate slot (Fig. 1). The front of each VBS panel was covered with monofilament mesh and the back with either partially open perforated steel plate to control flow or solid plate to block flow through the screen section. The VBS, originally designed for use with submersible traveling screens (STSs), consisted of three basic sections, each of which extended across the full 19-ft (5.8-m) width of the gate slot. The framework of each of the three main sections consisted of a matrix of six rows by four columns, the front surface monofilament mesh, the back either solid or perforated plate of various porosities (Fig. 2). The existing VBS was backed primarily by 20% open perforated plate with solid plate at the top and bottom, while the test VBS had 20% open perforated plate in the center section with the top section being more open and the bottom section less open. Configurations for the VBSs used were modeled by WES prior to testing at the dam. The percent porosity configurations of backing plate for the existing VBS were as follows: lower 1/3 section, 0 (solid), 9 , 9, 20, 20, and 20%; middle 1/3 section, 20, 20, 20, 20,

EXISTING VBS CONFIGURATION

		A	B	C	D
UPPER VBS ASSEMBLY	UF	SOLID	SOLID	SOLID	SOLID
	UE	8%	8%	8%	8%
	UD	20%	20%	20%	20%
	UC	20%	20%	20%	20%
	UB	20%	20%	20%	20%
	UA	20%	20%	20%	20%
MIDDLE VBS ASSEMBLY	MF	20%	20%	20%	20%
	ME	20%	20%	20%	20%
	MD	20%	20%	20%	20%
	MC	20%	20%	20%	20%
	MB	20%	20%	20%	20%
	MA	20%	20%	20%	20%
LOWER VBS ASSEMBLY	LF	20%	20%	20%	20%
	LE	20%	20%	20%	20%
	LD	20%	20%	20%	20%
	LC	9%	9%	9%	9%
	LB	9%	9%	9%	9%
	LA	SOLID	SOLID	SOLID	SOLID

COLUMNS A–D

TEST VBS CONFIGURATION

		A	B	C	D
UPPER VBS ASSEMBLY	UF	SOLID	SOLID	SOLID	SOLID
	UE	15%	15%	15%	15%
	UD	15%	15%	15%	15%
	UC	25%	25%	25%	25%
	UB	25%	25%	25%	25%
	UA	25%	25%	25%	25%
MIDDLE VBS ASSEMBLY	MF	20%	20%	20%	20%
	ME	20%	20%	20%	20%
	MD	20%	20%	20%	20%
	MC	20%	20%	20%	20%
	MB	20%	20%	20%	20%
	MA	20%	20%	20%	20%
LOWER VBS ASSEMBLY	LF	9%	9%	9%	9%
	LE	9%	9%	9%	9%
	LD	9%	9%	9%	9%
	LC	15%	15%	15%	15%
	LB	15%	15%	15%	15%
	LA	SOLID	SOLID	SOLID	SOLID

Figure 2. Porosity configurations for existing and test vertical barrier screens (VBSs) evaluated at McNary Dam, 1997.

20, and 20%; upper 1/3 section, 20, 20, 20, 20, 8, and 0% (solid). The configurations of backing plate for the test VBS were as follows: lower 1/3 section, 0 (solid), 15, 15, 9, 9, and 9%; middle 1/3 section, 20, 20, 20, 20, 20, and 20%; upper 1/3 section, 25, 25, 25, 15, 15, and 0% (solid).

Discharge (flow) through Units 4 and 5 was alternated daily between 12 and 16 thousand cubic feet per second (kcfs). Megawatt (MW) loadings at these discharges were approximately 60 and 80 MW depending on unit head. At certain times during the spring season, 16 kcfs flow through the unit produced only 72 MW due to low hydraulic head at the dam. Hydraulic head at McNary Dam averages about 70 feet under normal operating conditions, but can vary several feet due to changing water elevations in the upstream reservoir.

Each of the gatewells had two 12-in (0.3-m) juvenile fish bypass orifices. These orifices emptied into the open bypass channel (Fig. 1). The orifices could be opened or closed from the bypass gallery by an air-operated slide gate. The orifices were located on 42-in (1.1-m) centers from the ends of the gate slot at elevation 330 ft. Normal operating pool for the reservoir varies between elevations 335 and 340 ft, averaging 337.5 ft (103 m). The normal drawdown due to turbine loading is 1 ft (0.3 m), resulting in an average orifice submergence of 6.5 ft (2 m).

Methods for determining OPE were similar to those used in previous OPE studies with traveling screens (Brege et al. 1997a, 1997b). Test slots were dipnetted prior to the start of a test to remove any residual fish (Swan et al. 1979). The turbine units were run continuously during the month-long test period. Test slots were dipnetted daily and the collected fish were anesthetized with tricaine methanesulfonate (MS-222) and examined. From the collected fish, 100 juvenile salmonids per OPE replicate were caudal fin clipped and held in the release canister for one hour to monitor short-term mortality. Obviously injured fish were the only fish not included in the marked group. Marked fish were released in the center of the test gatewells, 30 ft (9.1 m) below the surface (Absolon, In prep.), and allowed to exit the gatewells through the juvenile fish bypass orifice. The north orifice was closed and the south orifice was open during all OPE tests. Turbine loads were alternated between the 60 and 80 MW daily with changes made at the conclusion of each OPE test. The orifice discharge into the ice/trash sluiceway was monitored twice a day to make sure the orifices were not plugged or closed inadvertently. At a specified time each test day, all fish were dipnetted from the gatewells. A typical OPE test lasted 22 hours, beginning at 2000 h on one day and ending at 1800 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 gatewell dipnetting technique for OPE relies on the assumptions that the fish survive the marking process in good condition, that fish exiting the gatewell do so via the bypass orifice, and that all of the fish remaining in the gatewell are captured by the dip net. To ensure the reliability of these assumptions, dipnet efficiency tests were conducted periodically throughout the spring and summer outmigration. During these tests fish were marked, held for one hour in the release canister to monitor immediate mortality, and then released in the gatewell with both orifices closed. Several hours later the gatewell was dipnetted and the catch examined and enumerated.

Descaling of fish was monitored using standard Fish Transportation Oversight Team descaling criteria (Ceballos et al. 1993). Fish condition in Slot 4A and 5A, containing either the test or existing VBS, was compared during the same time period. Juvenile salmonids were not classified as descaled if scale regeneration had begun. Fish with bird marks or fungal growth were not included as descaled. Head injuries, such as folded operculums and eye injuries, were recorded. The objective was to determine whether the test conditions were adversely impacting fish condition, so injuries which had obviously occurred at some time prior to the test were not included. The test design provided for 20 OPE measurements in each of the test slots during both the spring and summer juvenile salmonid outmigrations.

Extended-length bar screens equipped with inlet flow vanes similar to those tested during OPE tests in 1995 at The Dalles Dam were used in all test slots (Brege et al. 1997b).

Results and Discussion

Yearling Fish

Testing for OPE began 26 April and ended 31 May when fish numbers dropped at the end of the spring outmigration (Appendix Table 1). During the spring season, for both Objectives 1 and 2, we handled the following numbers of juvenile salmonids during OPE and descaling tests: 1,579 subyearling chinook salmon, 12,778 yearling chinook salmon, 10,736 steelhead, 5,449 coho salmon, and 1,682 sockeye salmon, for a total of 32,224 fish. We marked and released 6,701 yearling chinook salmon (included in the above count) during our spring OPE tests. Seasonal OPE for yearling chinook salmon is shown in Figure 3.

Test Units 4 and 5 were operated on alternate days at 60 and 75-80 megawatts (MW) with an approximate discharge of 12 and 16 thousand cubic feet per second (kcfs) during the test period. During the daily test sequence flow through the units remained relatively constant but electrical output varied due to changes in hydraulic head caused by forebay/tailrace water levels.

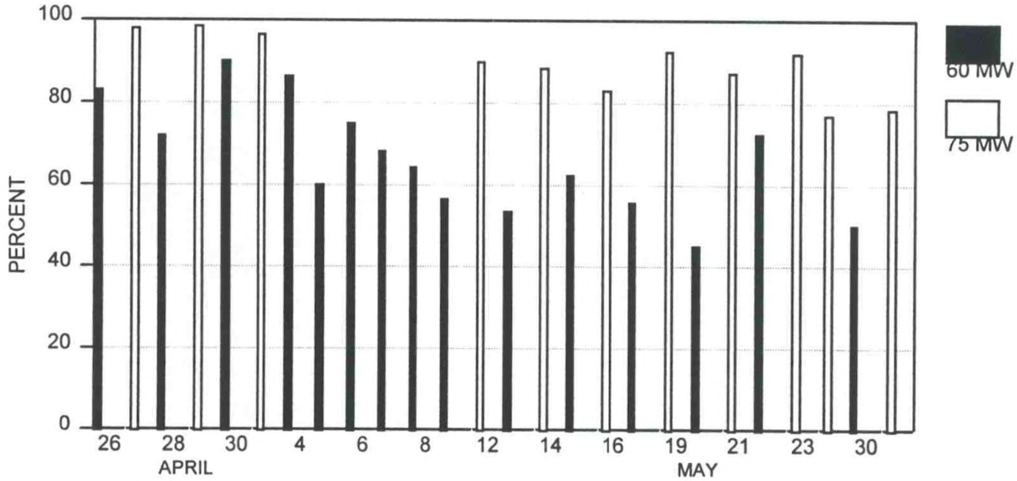

Figure 3. Yearling chinook salmon seasonal orifice passage efficiency (OPE) under 60 and 75 MW loads at McNary Dam, 1997 (all slots combined).

During the fourth week of April average total river flow rose above the 400 kcfs level and by the middle of May reached over 500 kcfs. With normal 60 MW loading at McNary Dam only 160 kcfs (13 operating turbine units times approximately 12 kcfs/unit) can be discharged through the powerhouse. Average amount of daily river flow that was spilled exceeded the amount of flow going through the powerhouse during the entire spring outmigration.

Anomalies in OPE data indicate unit bias was present. During the spring, seasonal mean OPEs in Slots 4A, 4B, 5A, and 5B were 88.0, 80.4, 62.5, and 72.9%. Although test conditions were alternated throughout the season, major differences in OPE means were recorded.

Data were analyzed using an analysis of variance (ANOVA) technique due to uneven sample sizes for different groups and included date as a covariant. Means listed are "Least Square Means" from the ANOVA calculations and may vary slightly from "raw means" obtained through arithmetic manipulations. Actual figures for the ANOVA calculations are found in Appendix Table 3.

During the spring tests with yearling chinook salmon, there was a significant difference in OPE between the low and high load condition (means of 62.8 and 93.6%, respectively) for both VBS types. No difference in OPE was found between the test and existing VBS types. Descaling during VBS evaluations was higher at the high load than at the low load (means of 17.1 and 6.7%, respectively).

Dipbasket efficiency tests on 17 May in Slots 4A and 5A with yearling chinook salmon resulted in a recapture efficiency of 100 and 97%, respectively. There was no descaling or mortality due to handling.

Subyearling Fish

Testing for OPE began 17 June and ended 19 July when fish numbers dropped at the end of the summer outmigration (Appendix Table 1). During the summer season, we handled the following numbers of juvenile salmonids during OPE and descaling tests: 90,265 subyearling chinook salmon, 253 yearling chinook salmon, 130 steelhead, 217 coho salmon, and 575 sockeye salmon, for a total of 91,440 fish. We marked and released 7,201 subyearling chinook salmon (included in the above count) during our summer OPE tests. Subyearling chinook salmon made up 99% of the summer catch. Seasonal OPE for subyearling chinook salmon is shown in Figure 4.

Test Unit 4 was operated at 60 MW with an approximate discharge of 12 kcfs during the test period. Test Unit 5 was operated at 80 MW with an approximate discharge of 16 kcfs during the test period.

Near record river flow passed McNary Dam in June 1997. During the beginning of the summer outmigration, average daily river flows approached 600 kcfs. Spill discharge was double that of the powerhouse for the first three weeks of June. During the last week of June and nearly all of July, river flow was approximately 300 kcfs with spill flow nearly equal to powerhouse flow. Average total river flow at the end of July dropped to 200 kcfs, with spill continuing through August.

During the summer, seasonal average OPEs in Slots 4A, 4B, 5A, and 5B were 57.4, 74.1, 85.0, and 87.8%. Since OPE tests during spring indicated a unit bias towards higher OPE in Unit 4, the finding of higher OPE in Unit 5 during summer tests further suggested that the higher turbine load produces higher OPE.

During summer tests, OPE for subyearling chinook salmon was significantly higher for the test VBS than for the existing VBS (means of 93.4 and 76.5%, respectively) at the high load, but

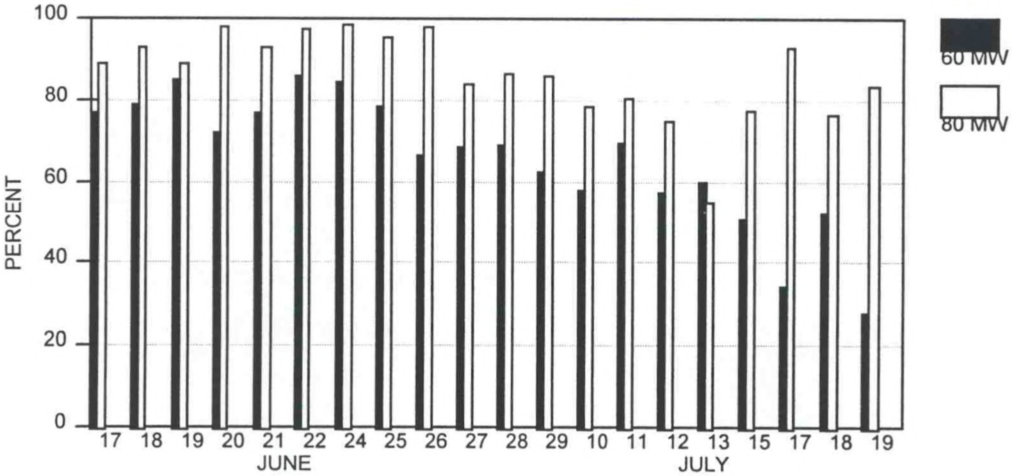

Figure 4. Subyearling chinook salmon seasonal orifice passage efficiency (OPE) under 60 and 80 MW loads at McNary Dam, 1997 (A and B Slots combined).

there was no difference at the low load. No differences were found in descaling for either VBS type or turbine load.

OBJECTIVE 2: EVALUATE THE EFFECTS OF OUTLET FLOW-CONTROL DEVICES AND DIFFERENT TURBINE-UNIT LOADINGS ON DESCALING AND OPE

Approach

Descaling and OPE tests were conducted to evaluate the effects of outlet flow-control devices in Slots 4B and 5B. Methods used for OPE and descaling were identical to those described under Objective 1. The outlet flow-control devices (Fig. 1) were located on the downstream upper surface of the ceiling beam extensions of Slots 4B and 5B. The position of the flow-occluding louver was alternated weekly between the raised (on) and lowered (off) position. The raised position reduces the flow of water through the downstream gate slot while the lowered or stored position has no effect on flow through the downstream gate slot.

Results and Discussion

Yearling Fish

Fish numbers handled during these tests have been included in the catch summary under Objective 1. The loads on test Units 4 and 5 were alternated daily with 60 MW on one day and 75-80 MW on the following day through the entire spring season. Approximate discharges were 12 and 16 kcfs for the low and high load conditions. During the test period, flow through the test units was relatively constant but electrical output varied due to changes in hydraulic head caused by forebay/tailrace water levels.

During OFC evaluations, OPE was higher at the high load than at the low load (seasonal means were 87.9 and 68.5%, respectively) and with the OFC lowered vs. raised (seasonal means were 83.4 and 73.0%, respectively). No difference in descaling was found with regard to OFC position.

These results compare favorably with 1995 yearling chinook salmon OPEs of 79 and 78% for north and south orifices at McNary Dam, respectively, and 80 and 68% for west and east orifices, respectively, at The Dalles Dam using ESBSs and the same mark/recapture method (McComas et al. 1997, Brege et al. 1997b).

Subyearling Fish

Fish numbers handled during these tests have been included in the results and discussion under Objective 1.

Test Unit 4 was operated at 60 MW with an approximate discharge of 12 kcfs during the test period. Test Unit 5 was operated at 80 MW with an approximate discharge of 16 kcfs during the test period.

During OFC evaluations, OPE was higher at the high load than at the low load (means of 87.8 and 74.1%, respectively) and with the OFC lowered vs. raised (means of 84.2 and 77.7%, respectively). OPE was higher at the high load than at the low load with both OFC positions. Descaling was significantly higher with the lowered OFC than with the raised OFC at the high turbine load (means of 4.5 and 2.0%, respectively), but there was no difference at low turbine load.

These results are comparable to 1995 subyearling chinook salmon OPEs of 95 and 99% for north and south orifices, respectively, at McNary Dam, but were somewhat higher than OPEs of 86 and 63% for west and east orifices, respectively, at The Dalles Dam using ESBSs and the same mark/recapture method (McComas et al. 1997, Brege et al. 1997b).

SUMMARY

1) Mean OPE for yearling chinook salmon was higher at the 75 MW load than at the 60 MW load, 93.6 and 62.8%, respectively. The difference, 30.8%, was statistically significant.

2) No difference in OPE for yearling chinook salmon was found between the test and existing VBS types.

3) Mean OPE for yearling chinook salmon was higher with the OFC lowered than with the OFC raised, 83.4 and 73.0%, respectively.

4) Mean descaling for yearling chinook salmon was higher at the 75 MW load than at the 60 MW load for both VBS types, 17.1 and 6.7%, respectively, and during OFC evaluations, 9.2 and 4.5%, respectively.

5) Mean OPE for subyearling chinook salmon with the test VBS was higher than with the existing VBS at the 72-80 MW load, 93.4 and 76.5%, respectively. The difference, 16.9%, was statistically significant.

6) Mean OPE for subyearling chinook salmon was higher at the 72-80 MW load than at the 60 MW load for both OFC positions.

7) No difference in descaling for subyearling chinook salmon was found between the test and existing VBS types.

8) Mean descaling for subyearling chinook salmon was higher for the lowered OFC than for the raised OFC at the 80 MW load, 4.5 and 2.0%, respectively, but there was no difference at the 60 MW load. The difference, 2.5%, was statistically significant.

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REFERENCES

Absolon, R. F., and D. A. Brege. In prep. Release cannister for introducing marked fish into turbine unit gatewells at hydroelectric dams.

Brege, D. A., R. F. Absolon, B. P. Sandford, and D. B. Dey. 1997a. Studies to evaluate the effectiveness of extended-length screens at John Day Dam, 1996. Report to the U.S. Army Corps of Engineers, Delivery Order E96960028, 21 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112-2097.)

Brege, D. A., R. F. Absolon, B. P. Sandford, and D. B. Dey. 1997b. Studies to evaluate the effectiveness of extended-length screens at The Dalles Dam, 1995. Report to the U.S. Army Corps of Engineers, Delivery Order E96930030, 24 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112-2097.)

Brege, D. A., S. J. Grabowski, W. D. Muir, S. R. Hirtzel, S. J. Mazur, and B. P. Sandford. 1992. Studies to determine the effectiveness of extended traveling screens and extended bar screens at McNary Dam, 1991. Report to the U.S. Army Corps of Engineers, Delivery Order E86910060, 32 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112-2097.)

Ceballos, J. R., S. W. Pettit, J. L. McKern, R. L. Boyce, and D. F. Hurson. 1993. Fish Transportation Oversight Team Annual Report--FY 1992. Transport operations on the Snake and Columbia Rivers. NOAA Tech. Memo. NMFS F/NWR-32. 75 p. plus Appendices.

McComas, R. L., D. A. Brege, W. D. Muir, B. P. Sandford, and D. B. Dey. 1993. Studies to determine the effectiveness of extended-length submersible bar screens at McNary Dam, 1992. Report to U.S. Army Corps of Engineers, Delivery Order E86910060, 34 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112-2097.)

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

McComas, R. L., B. P. Sandford, and D. B. Dey. 1997. Orifice passage efficiency and descaling studies at McNary Dam, 1995. Report to U.S. Army Corps of Engineers, Delivery Order E86910060, 20 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112-2097.)

Swan, G. A., R. F. Krcma, and W. E. Farr. 1979. Dipbasket for collecting juvenile salmon and trout in gatewells at hydroelectric dams. Prog. Fish-Cult. 41(1):48-49.

APPENDIX TABLES

Appendix Table 1. Orifice passage efficiency (OPE) data from tests at McNary Dam, 1997.

Unit 4, Slot A

Test Date	VBS, Test or Existing[1]	Number marked	Number recovered	OPE(%)	Unit Load in MW
Spring Tests					
26 April	E	50	0	100	60
27 April	E	50	0	100	75
28 April	E	50	0	100	60
29 April	E	50	0	100	75
30 April	E	50	0	100	60
1 May	E	50	0	100	75
4 May	T	50	0	100	60
5 May	T	50	--	--	60
6 May	T	50	0	100	60
7 May	T	100	0	100	60
8 May	T	100	7	93	60
9 May	T	100	7	93	60
12 May	E	50	0	100	75
13 May	E	50	8	84	60
14 May	E	100	0	100	75
15 May	E	75	26	65	60
16 May	E	100	0	100	75
17 May	E	75	44	41	60
19 May	T	50	0	100	75
20 May	T	75	14	81	60
21 May	T	75	0	100	75
22 May	T	75	7	91	60
23 May	T	75	--	--	75
29 May	T	50	19	62	75
30 May	T	50	25	50	60
31 May	T	50	24	52	75
Summer Tests					
17 June	T	50	22	56	60
18 June	T	50	18	64	60
19 June	T	47	14	70	60
20 June	T	50	24	52	60
21 June	T	106	48	55	60
22 June	T	100	27	73	60
24 June	E	100	16	84	60
25 June	E	100	22	78	60
26 June	E	100	37	63	60
27 June	E	100	50	50	60
28 June	E	100	50	50	60
29 June	E	100	53	47	60
10 July	T	100	57	43	60
11 July	T	100	26	74	60
12 July	T	100	56	44	60
13 July	T	100	57	43	60
15 July	E	100	40	60	60
17 July	E	100	46	54	60
18 July	E	100	38	62	60
19 July	E	100	74	26	60

[1] Vertical Barrier Screen (VBS) Configuration: T = Test VBS, E = Existing VBS.

Appendix Table 1. Continued.

Unit 4, Slot B

Test Date	OFC, Raised or Lowered[2]	Number marked	Number recovered	OPE(%)	Unit Load in MW
Spring Tests					
26 April	L	50	0	100	60
27 April	L	50	0	100	75
28 April	L	49	1	98	60
29 April	L	50	0	100	75
30 April	L	50	0	100	60
1 May	L	50	0	100	75
4 May	R	50	0	100	60
5 May	R	50	--	--	60
6 May	R	50	16	68	60
7 May	R	100	47	53	60
8 May	R	100	23	77	60
9 May	R	100	29	71	60
12 May	L	50	1	98	75
13 May	L	50	14	72	60
14 May	L	100	12	88	75
15 May	L	75	13	83	60
16 May	L	100	9	91	75
17 May	L	75	15	80	60
19 May	R	50	10	80	75
20 May	R	75	57	24	60
21 May	R	75	23	69	75
22 May	R	75	14	81	60
23 May	R	75	--	--	75
29 May	R	50	15	70	75
30 May	R	50	29	42	60
31 May	R	50	8	84	75
Summer Tests					
17 June	R	50	1	98	60
18 June	R	50	3	94	60
19 June	R	49	0	100	60
20 June	L	50	4	92	60
21 June	L	100	1	99	60
22 June	L	100	1	99	60
24 June	R	100	15	85	60
25 June	R	100	21	79	60
26 June	R	100	30	70	60
27 June	L	100	13	87	60
28 June	L	100	12	88	60
29 June	L	100	22	78	60
10 July	R	100	27	73	60
11 July	R	100	35	65	60
12 July	L	100	29	71	60
13 July	L	100	23	77	60
15 July	R	100	59	41	60
17 July	R	100	86	14	60
18 July	L	100	58	42	60
19 July	L	100	71	29	60

[2] Outlet flow control (OFC) device configuration: R = OFC in raised position, L = OFC in lowered position.

Appendix Table 1. Continued.

Unit 5, Slot A

Test Date	VBS, Test or Existing	Number marked	Number recovered	OPE(%)	Unit Load in MW
Spring Tests					
26 April	T	50	20	60	60
27 April	T	50	2	96	75
28 April	T	50	31	38	60
29 April	T	50	2	96	75
30 April	T	48	18	62	60
1 May	T	54	2	96	75
4 May	E	50	24	52	60
5 May	E	50	24	52	60
6 May	E	50	30	40	60
7 May	E	100	47	53	60
8 May	E	100	71	29	60
9 May	E	50	40	20	60
12 May	T	50	8	84	75
13 May	T	50	35	30	60
14 May	T	100	6	94	75
15 May	T	75	52	31	60
16 May	T	100	16	84	75
17 May	T	75	48	36	60
19 May	E	50	2	96	75
20 May	E	75	61	19	60
21 May	E	75	9	88	75
22 May	E	75	27	64	60
23 May	E	75	11	85	75
29 May	E	50	1	98	75
30 May	E	50	22	56	60
31 May	E	50	2	96	75
Summer Tests					
17 June	E	50	3	94	72
18 June	E	50	4	92	72
19 June	E	50	3	94	72
20 June	E	50	0	100	72
21 June	E	100	12	88	72
22 June	E	100	2	98	72
24 June	T	100	1	99	74
25 June	T	100	1	99	77
26 June	T	100	0	100	80
27 June	T	100	1	99	80
28 June	T	100	0	100	80
29 June	T	100	0	100	80
10 July	E	100	31	69	80
11 July	E	100	34	66	80
12 July	E	100	31	69	80
13 July	E	100	73	27	80
15 July	T	100	38	62	80
17 July	T	100	11	89	80
18 July	T	100	22	78	80
19 July	T	100	24	76	80

Appendix Table 1. Continued.

Unit 5, Slot B

Test Date	OFC, Raised or Lowered	Number marked	Number recovered	OPE(%)	Unit Load in MW
<u>Spring Tests</u>					
26 April	R	50	14	72	60
27 April	R	50	2	96	75
28 April	R	50	24	52	60
29 April	R	50	1	98	75
30 April	R	50	1	98	60
1 May	R	50	5	90	75
4 May	R	50	3	94	60
5 May	R	50	16	68	60
6 May	L	50	4	92	60
7 May	L	100	33	67	60
8 May	L	100	42	58	60
9 May	L	50	29	42	60
12 May	R	50	11	78	75
13 May	R	50	36	28	60
14 May	R	100	28	72	75
15 May	R	75	22	71	60
16 May	R	100	43	57	75
17 May	R	75	26	65	60
19 May	L	50	3	94	75
20 May	L	75	33	56	60
21 May	L	75	6	92	75
22 May	L	75	35	53	60
23 May	L	75	1	99	75
29 May	L	50	11	78	75
30 May	L	50	24	52	60
31 May	L	50	8	84	75
<u>Summer Tests</u>					
17 June	L	50	8	84	72
18 June	L	50	3	94	72
19 June	L	50	8	84	72
20 June	R	50	2	96	72
21 June	R	100	2	98	72
22 June	R	100	3	97	72
24 June	L	100	2	98	75
25 June	L	100	8	92	77
26 June	L	100	4	96	80
27 June	R	100	31	69	80
28 June	R	100	27	73	80
29 June	R	100	28	72	80
10 July	L	100	12	88	80
11 July	L	100	5	95	80
12 July	R	99	19	81	80
13 July	R	100	17	83	80
15 July	L	100	7	93	80
17 July	L	100	3	97	80
18 July	R	100	25	75	80
19 July	R	100	9	91	80

Appendix Table 2. Descaling data from orifice passage efficiency and descaling tests at McNary Dam, 1997.

Unit 4, Slot A

Test date[1]	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
25 April(E)					2	0.0		1	0.0						
26 April(E)					2	0.0		1	0.0						
27 April(E)					2	0.0		2	0.0						
28 April(E)				1	5	20.0		2	0.0		1	0.0			
29 April(E)					2	0.0		2	0.0						
30 April(E)								6	0.0						
1 May(E)					3	0.0		1	0.0						
3 May(T)					1	0.0		3	0.0					1	0.0
4 May(T)					3	0.0		2	0.0						
5 May(T)				1	12	8.3		10	0.0		1	0.0			
6 May(T)				2	39	5.1	3	92	3.3		4	0.0		2	0.0
7 May(T)				1	51	2.0		29	0.0		7	0.0		5	0.0
8 May(T)				8	63	12.7	2	16	12.5	2	11	18.2			
9 May(T)		1	0.0	6	69	8.7	1	17	5.9		2	0.0	1	12	8.3
11 May(E)				4	49	8.2		30	0.0		6	0.0	2	12	16.7
12 May(E)				2	26	7.7	2	23	8.7		1	0.0		1	0.0
13 May(E)				4	54	7.4	6	30	20.0	2	10	20.0	1	7	14.3
14 May(E)				12	38	31.6	9	41	22.0	2	5	40.0			
15 May(E)				35	204	17.2	15	187	8.0		8	0.0	2	22	9.1
16 May(E)				11	36	30.6	21	151	13.9					1	0.0
17 May(E)				16	294	5.4	20	252	7.9	3	28	10.7	1	6	16.7
19 May(T)				1	8	12.5	2	27	7.4						
20 May(T)		1	0.0	19	249	7.6	8	101	7.9	41	334	12.3	1	4	25.0
21 May(T)					10	0.0		5	0.0		4	0.0		1	0.0
22 May(T)		2	0.0	10	100	10.0	1	25	4.0	19	196	9.7	1	4	25.0
23 May[2]															
28 May(T)	1	91	1.1		4	0.0		4	0.0		3	0.0		9	0.0
29 May(T)	9	118	7.6	18	241	7.5		111	0.0	13	171	7.6	18	72	25.0
30 May(T)	13	273	4.8	3	90	3.3	1	20	5.0	2	56	3.6	2	32	6.2
31 May(T)	5	60	8.3	7	146	4.8		34	0.0	2	66	3.0	5	28	17.8
16 June(T)	5	228	2.2	3	28	10.7	1	8	12.5	1	11	9.1	7	23	30.4

[1] Vertical barrier screen (VBS) configuration: T = Test VBS, E = Existing VBS.
[2] No data collected due to turbine unit malfunction.

Appendix Table 2. Continued.

Unit 4, Slot A

Test date	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
17 June(T)	2	200	1.0	1	5	20.0		1	0.0		7	0.0		9	0.0
18 June(T)	3	55	5.5		1	0.0		1	0.0				1	8	12.5
19 June(T)	5	384	1.3		7	0.0					3	0.0	2	12	16.7
20 June(T)	9	1155	0.8	1	5	20.0		1	0.0		2	0.0		11	0.0
21 June(T)	15	1654	0.9		4	0.0		1	0.0	1	2	50.0		3	0.0
22 June(T)	16	2182	0.7		2	0.0					1	0.0	2	14	14.3
23 June(E)	2	260	0.8												
24 June(E)	24	2851	0.8		1	0.0							1	2	50.0
25 June(E)	17	2216	0.8		1	0.0							2	5	40.0
26 June(E)	11	1275	0.9					1	0.0				1	4	25.0
27 June(E)	16	2540	0.6	1	2	50.0		1	0.0		1	0.0			
28 June(E)	20	2496	0.8	1	2	50.0								1	0.0
29 June(E)	27	2347	1.2		1	0.0								4	0.0
30 June[3]															
9 July[3]															
10 July(T)	25	1326	1.9										1	5	20.0
11 July(T)	44	980	4.5	1	1	100.0		1	0.0				1	10	10.0
12 July(T)	67	3074	2.2					2	0.0				1	19	5.3
13 July(T)	17	1386	1.2		1	0.0		2	0.0					16	0.0
14 July[4]															
15 July(E)	9	692	1.3					1	0.0				1	9	11.1
16 July[4]															
17 July(E)	11	459	2.4		1	0.0							1	2	50.0
18 July(E)	15	315	4.8												
19 July(E)	16	547	3.0												

[3] Sampling discontinued due to large fish numbers.

[4] Dipnet for recruitment only.

Appendix Table 2. Continued.

Unit 4, Slot B

Test date[5]	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
25 April(L)				18	70	25.7	1	8	12.5	2	17	11.8			
26 April(L)					4	0.0		1	0.0						
27 April(L)					2	0.0		5	0.0						
28 April(L)				1	47	2.1		6	0.0						
29 April(L)					2	0.0		3	0.0						
30 April(L)								2	0.0						
1 May(L)					2	0.0		4	0.0						
3 May(L)		1	0.0	1	28	3.6		7	0.0		1	0.0			
4 May(R)					24	0.0		9	0.0					1	0.0
5 May(R)				3	44	6.8	2	22	9.1		5	0.0		2	0.0
6 May(R)				7	91	7.7	2	112	1.8		9	0.0		8	0.0
7 May(R)				8	96	8.3	3	61	4.9		7	0.0	1	4	25.0
8 May(R)				3	79	3.8	2	35	5.7	1	10	10.0		4	0.0
9 May(R)				4	58	6.9	2	51	3.9		7	0.0	1	18	5.6
11 May(L)		1	0.0	5	56	8.9	1	25	4.0	3	13	23.1	7	59	11.9
12 May(L)		1	0.0	12	64	18.8	4	43	9.3	4	22	18.2	3	30	10.0
13 May(L)				2	44	4.5	2	39	5.1		3	0.0		7	0.0
14 May(L)				15	90	16.7	3	46	6.5		5	0.0	2	4	50.0
15 May(L)				2	73	2.7	1	54	1.9		1	0.0		11	0.0
16 May(L)				5	98	5.1	5	42	11.9					4	0.0
17 May(L)		26	0.0	1	93	1.1	6	52	11.5		6	0.0	1	2	50.0
19 May(R)		5	0.0	29	337	8.6	9	232	3.9	33	402	8.2		2	0.0
20 May(R)		2	0.0	5	278	1.8		36	0.0	5	169	3.0		3	0.0
21 May(R)		2	0.0	12	209	5.7	7	89	7.9	41	371	11.1		1	0.0
22 May(R)		2	0.0		46	0.0		14	0.0		12	0.0		1	0.0
23 May[2]															
28 May(R)		60	0.0	2	23	8.7		9	0.0	1	6	16.7	2	15	13.3
29 May(R)		4	0.0	2	69	2.9		54	0.0	1	36	2.8	11	44	25.0
30 May(R)	5	100	5.0	2	56	3.6	1	16	6.2	1	26	3.8	2	22	9.1
31 May(R)		2	0.0	4	27	14.8		10	0.0	1	15	6.7	2	10	20.0
16 June(R)		54	0.0		1	0.0		2	0.0				1	8	12.5
17 June(R)		118	0.0		1	0.0								2	0.0
18 June(R)		8	0.0					1	0.0		1	0.0		3	0.0
19 June(R)	5	194	2.6		3	0.0		1	0.0		1	0.0		7	0.0

[5] Outlet flow-control (OFC) device configuration: R = Raised OFC, L = Lowered OFC.

Appendix Table 2. Continued.

Unit 4, Slot B

Test date	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
20 June (L)	2	628	0.3										1	7	14.2
21 June (L)	1	638	0.16					2	0.0		1	0.0	1	2	50.0
22 June (L)	3	797	0.4											3	0.0
23 June[4]															
24 June (L)	13	1254	1.0											3	0.0
25 June (R)	8	1183	0.7		2	0.0								1	0.0
26 June (R)	5	821	0.6		1	0.0		1	0.0				2	9	22.2
27 June (L)	7	881	0.8		1	0.0								3	0.0
28 June (L)	8	1054	0.8												
29 June (L)	6	684	0.9		1	0.0								2	0.0
30 June (R)	1	228	0.4												
9 July (R)	3	573	0.5												
10 July (R)	6	321	1.9											1	0.0
11 July (L)	10	627	1.6											1	0.0
12 July (L)	5	515	1.0											2	0.0
13 July (L)	19	1012	1.9	1	2	50.0								15	0.0
14 July (R)	12	177	6.8											2	0.0
15 July (R)	8	769	1.0											8	0.0
16 July (R)	58	675	8.6												
17 July (R)	4	618	0.6												
18 July (L)	7	297	2.3										1	3	33.3
19 July (L)	5	295	1.7												

Appendix Table 2. Continued.

Unit 5, Slot A

Test date	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
25 April[4]															
26 April(T)				19	159	11.9	2	15	13.3						
27 April(T)				6	69	8.7	23	384	6.0						
28 April(T)				9	193	4.7	6	127	4.7		2	0.0	1	11	9.1
29 April(T)				16	98	16.3	38	445	8.5		5	0.0		3	0.0
30 April(T)				8	183	4.4	6	164	3.7		5	0.0	1	4	25.0
1 May(T)				20	110	18.2	37	350	10.6	1	4	25.0		1	0.0
3 May(E)		2	0.0	8	177	4.5	1	40	2.5		6	0.0		4	0.0
4 May(E)		1	0.0	9	180	5.0	3	43	7.0		4	0.0		7	0.0
5 May(E)		2	0.0	9	126	7.1	3	74	4.1		7	0.0		9	0.0
6 May(E)				13	153	8.5	2	278	0.7		11	0.0		19	0.0
7 May(E)				8	153	5.2	1	100	1.0	4	29	14.0		14	0.0
8 May(E)				11	133	8.3	2	95	2.1	8	35	22.9	1	9	11.1
9 May(E)				14	250	5.6	3	111	2.7	3	19	15.8	3	44	6.8
11 May(T)				10	150	6.7	8	138	5.8	14	71	19.7	45	230	19.6
12 May(T)				36	162	22.2	36	376	9.6	30	99	30.3	4	35	11.4
13 May(T)				24	248	9.7	4	165	2.4	2	8	25.0	2	43	4.7
14 May(T)				67	330	20.3	36	438	8.2	8	25	32.0	2	14	14.3
15 May(T)		5	0.0	14	282	5.0	8	194	4.1	1	7	14.3	1	28	3.6
16 May(T)				42	228	18.4	32	442	7.2		4	0.0		8	0.0
17 May(T)		2	0.0	13	354	3.7	14	208	6.7	1	51	2.0		9	0.0
19 May(E)		10	0.0	42	224	18.8	9	208	4.3	85	484	17.6	1	3	33.3
20 May(E)		4	0.0	15	291	5.2	1	109	0.9	22	265	8.3	1	5	20.0
21 May(E)		7	0.0	14	166	8.4	6	95	6.3	29	402	7.2		5	0.0
22 May(E)	1	30	3.3	6	216	2.8	1	38	2.6	15	278	5.4		17	0.0
23 May(E)		7	0.0	15	140	10.7	1	27	3.7	10	82	12.2	5	18	28.0
28 May(E)	6	213	2.8	40	328	12.2	7	96	7.3	16	181	8.8	19	60	3.2
29 May(E)	3	12	25.0	6	36	16.7	11	127	8.7	8	43	18.6	1	7	14.3
30 May(E)	14	179	7.8	7	116	6.0	1	59	1.7	9	112	8.0	2	21	9.5
31 May(E)		3	0.0	6	22	27.3		39	0.0	5	20	25.0	2	4	50.0
16 June(E)		16	0.0		8	0.0		2	0.0		9	0.0	1	4	25.0
17 June(E)		62	0.0		3	0.0		1	0.0		2	0.0		8	0.0
18 June(E)	2	56	3.6		7	0.0		2	0.0				2	12	16.7
19 June(E)	9	389	2.3		1	0.0		3	0.0		2	0.0		14	0.0
20 June(E)		899	0.0		1	0.0		1	0.0					4	0.0
21 June(E)	9	1231	0.7					5	0.0		2	0.0		7	0.0

Appendix Table 2. Continued.

Unit 5, Slot A

Test date	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
22 June(E)	3	1301	0.2		1	0.0		2	0.0				1	6	16.7
23 June(T)	2	263	0.8												
24 June(T)	7	746	0.9										1	4	25.0
25 June(T)	2	431	0.5					1	0.0				1	3	33.3
26 June(T)	1	271	0.4		1	0.0							1	1	100.0
27 June(T)	3	480	0.6											1	0.0
28 June(T)	7	750	0.9		2	0.0									
29 June(T)	9	910	1.0										1	3	33.3
30 June[3]															
9 July[3]															
10 July(E)	28	1385	2.0		4	0.0							2	17	11.8
11 July(E)	44	1964	2.2		1	0.0		1	0.0					11	0.0
12 July(E)	114	2735	4.2		2	0.0							4	21	19.0
13 July(E)	71	2966	2.4	2	4	50.0							1	18	5.5
14 July[4]															
15 July(E)	32	1812	1.8										2	19	10.5
16 July[4]															
17 July(T)	33	775	4.2											2	0.0
18 July(T)	21	500	4.2											3	0.0
19 July(T)	11	295	3.8											4	0.0

Appendix Table 2. Continued.

Unit 5, Slot B

Test date	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
25 April[4]															
26 April(R)				5	142	3.5		18	0.0					4	0.0
27 April(R)				3	76	3.9	14	265	5.3				1	2	50.0
28 April(R)				5	116	4.3	1	42	2.4					6	0.0
29 April(R)				6	109	5.5	7	246	2.8		2	0.0		1	0.0
30 April(R)				1	34	2.9	1	21	4.8		3	0.0		1	0.0
1 May(R)				11	180	6.1	5	122	4.1		4	0.0		2	0.0
3 May(R)					11	0.0		34	0.0		1	0.0			
4 May(R)		1	0.0	1	38	2.6	1	71	1.4		4	0.0		1	0.0
5 May(R)		2	0.0	7	96	7.3	3	156	1.9		6	0.0		2	0.0
6 May(R)				3	39	7.7	2	183	1.1	1	6	16.7		1	0.0
7 May(R)				6	93	6.5		109	0.0	5	35	14.3		14	0.0
8 May(R)		1	0.0	6	97	6.2		92	0.0	6	21	28.6	1	11	9.1
9 May(R)				8	99	8.1	4	119	3.4	1	7	14.3		20	0.0
11 May(R)		1	0.0	16	266	6.0	9	271	3.3	5	54	9.3	41	354	11.6
12 May(R)		3	0.0	23	209	11.0	20	278	7.2	16	51	31.4	9	24	37.5
13 May(R)		1	0.0	11	96	11.5	6	138	4.3	2	10	20.0	1	24	4.2
14 May(R)		3	0.0	69	340	20.3	28	307	9.1	7	27	25.9	3	27	11.1
15 May(R)				10	155	6.5	11	162	6.8	1	2	50.0	1	11	9.1
16 May(R)	1	4	25.0	33	366	9.0	13	363	3.6	4	22	18.2		13	0.0
17 May(R)		2	0.0		133	0.0	4	93	4.3		7	0.0	2	9	22.2
19 May(L)		5	0.0	21	240	8.8	2	112	1.8	50	358	14.0		1	0.0
20 May(L)		5	0.0	6	216	2.9	1	33	3.0	1	67	1.5		1	0.0
21 May(L)		9	0.0	5	99	5.1	1	36	2.8	26	216	12.0	1	1	100.0
22 May(L)		6	0.0	5	99	5.1		32	0.0	1	52	1.9		1	0.0
23 May(L)					9	0.0		5	0.0		1	0.0		1	0.0
28 May[4]															
29 May(L)	1	72	1.4	3	96	3.1		67	0.0	2	71	2.8	3	21	14.3
30 May(L)	7	215	3.2		61	0.0		29	0.0	2	61	3.3	1	10	10.0
31 May(L)	1	20	5.0	5	73	6.8	1	35	2.8	4	45	8.9	3	16	18.7
16 June(L)		75	0.0	1	6	16.7		1	0.0	1	11	9.1		5	0.0
17 June(L)	3	121	2.5	1	20	5.0	1	6	16.7	4	55	7.3	10	29	34.5
18 June(L)	9	69	13.0	6	33	18.2	3	20	15.0	5	24	20.8	11	19	57.9
19 June(L)	16	403	4.0	9	36	25.0		14	0.0	8	45	17.8	12	30	40.0
20 June(R)	49	1028	4.8		13	0.0		11	0.0	4	15	26.7	1	5	20.0
21 June(R)	13	1221	1.1	2	10	20.0		6	0.0		10	0.0	3	6	50.0
22 June(R)	30	1009	3.0	2	4	50.0		6	0.0	2	7	28.6	5	13	38.5

Appendix Table 2. Continued.

Unit 5, Slot B

Test date	Subyearling chinook			Yearling chinook			Steelhead			Coho			Sockeye		
	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%	Desc.	Catch	%
23 June[4]															
24 June(L)	18	1472	1.2		1	0.0								8	0.0
25 June(L)	147	2382	6.2	1	2	50.0		7	0.0	1	3	33.3	3	6	50.0
26 June(L)	93	2307	4.0		5	0.0		5	0.0		1	0.0	4	7	57.1
27 June(R)	11	2856	0.4		3	0.0		1	0.0		1	0.0	1	2	50.0
28 June(R)	14	2467	0.6		2	0.0									
29 June(R)	43	4886	0.9		4	0.0		1	0.0				1	4	25.0
30 June(L)	3	309	1.0												
9 July[3]															
10 July(L)	13	698	1.9		1	0.0		1	0.0					3	0.0
11 July(R)	18	1070	1.7					2	0.0					6	0.0
12 July(R)	35	1147	3.0											4	0.0
13 July(R)	8	542	1.5											6	0.0
14 July(L)	16	441	3.6												
15 July[6]	132	1181	11.2		3	0.0		4	0.0				4	13	30.8
16 July[4]															
17 July(R)	49	734	6.7											6	0.0
18 July(R)	13	402	3.2											2	0.0
19 July(R)	4	165	2.4		1	0.0									

[6] Numerous adult fish in catch -- Descaling figures invalid.

Appendix Table 3. Analysis of variance calculations for orifice passage efficiency (OPE) and descaling data from tests at McNary Dam, 1997.

OPE for MW Load and VBS type - Yearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	2468.6	2468.6		
MW Load	1	10732.7	10732.7	22.01	<0.001
VBS	1	5.2	5.2	0.01	0.919
M x V	1	1337.1	1337.1	2.74	0.105
Error	43	20971.6	487.7		
Total	47	34126.4			

MW Load	Mean	SE
60	62.8	4.2
75	93.6	5.0

VBS Type	Mean	SE
Existing	78.5	4.6
New	77.9	4.6

OPE for MW Load and OFC condition - Yearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	4360.0	4360.0		
MW Load	1	4248.6	4248.6	18.04	<0.001
OFC	1	1259.0	1259.0	5.34	0.026
M x O	1	82.6	82.6	0.35	0.557
Error	43	10128.9	235.6		
Total	47	18790.7			

MW Load	Mean	SE
60	68.5	2.9
75	87.9	3.5

OFC Position	Mean	SE
Lowered	83.4	3.2
Raised	73.0	3.1

Appendix Table 3. Continued.

DESC for MW Load and VBS type - Yearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	47.45	47.45		
MW Load	1	944.38	944.39	31.19	<0.001
VBS	1	62.67	62.67	2.07	0.159
M x V	1	54.69	54.69	1.81	0.187
Error	36	1089.99	30.28		
Total	40	2058.30			

MW Load	Mean	SE
60	6.7	1.1
75	17.1	1.5

VBS Type	Mean	SE
Existing	13.2	1.2
New	10.5	1.4

DESC for MW Load and OFC condition - Yearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	15.46	15.46		
MW Load	1	214.91	214.91	12.21	0.001
OFC	1	2.75	2.75	0.16	0.695
M x O	1	0.68	0.68	0.04	0.846
Error	40	704.08	17.60		
Total	44	922.67			

MW Load	Mean	SE
60	4.5	0.8
75	9.2	1.1

OFC Position	Mean	SE
Lowered	7.1	1.0
Raised	6.6	0.9

Appendix Table 3. Continued.

DESC for MW Load and VBS type - Steelhead

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	62.87	62.87		
MW Load	1	175.63	175.63	10.80	0.002
VBS	1	27.89	27.89	1.72	0.199
M x V	1	41.94	41.94	2.58	0.118
Error	33	536.43	16.26		
Total	37	747.81			

MW Load	Mean	SE
60	3.7	0.9
75	8.3	1.1

VBS Type	Mean	SE
Existing	6.9	1.0
New	5.1	0.9

DESC for MW Load and OFC condition - Steelhead

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	7.908	7.908		
MW Load	1	42.805	42.805	4.30	0.046
OFC	1	0.353	0.353	0.04	0.852
M x O	1	1.593	1.593	0.16	0.692
Error	34	338.344	9.951		
Total	38	383.536			

MW Load	Mean	SE
60	2.9	0.7
75	5.1	0.8

OFC Position	Mean	SE
Lowered	4.1	0.8
Raised	3.9	0.7

Appendix Table 3. Continued.

OPE for Slot/MW Load and VBS type - Subyearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	4391.1	4391.1		
Slot/Load	1	7592.0	7592.0	47.35	<0.001
VBS	1	275.3	275.3	1.72	0.199
S x V	1	1247.6	1247.6	7.78	0.008
Error	35	5612.1	160.3		
Total	39	18146.5			

Slot/Load	VBS Type	Mean	SE
4A/60	New	54.2	4.1
4A/60	Existing	60.6	4.1
5A/72-80	New	93.4	4.1
5A/72-80	Existing	76.5	4.1

(New = Existing for 4A/60 MW and New > Existing for 5A/72-80 MW)

OPE for Slot/MW Load and OFC condition - Subyearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	4819.1	4819.1		
Slot/Load	1	1888.0	1888.0	8.19	0.007
OFC	1	417.3	417.3	1.81	0.187
S x O	1	2.8	2.8	0.01	0.912
Error	35	8067.8	230.5		
Total	39	15238.8			

Slot/MW Load	Mean	SE
4B/60	74.1	3.4
5B/72-80	87.8	3.4

OFC Position	Mean	SE
Lowered	84.2	3.4
Raised	77.7	3.4

Appendix Table 3. Continued.

DESC for Slot/MW Load and VBS type - Subyearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	33.753	33.753		
Slot/Load	1	0.035	0.035	0.02	0.879
VBS	1	0.560	0.560	0.37	0.544
S x V	1	4.650	4.650	3.11	0.086
Error	39	58.355	58.355		
Total	43	92.744			

Slot/Load	Mean	SE
4A/60	1.8	0.3
5A/72-80	1.7	0.3

VBS Type	Mean	SE
Existing	1.6	0.3
New	1.8	0.3

DESC for Slot/MW Load and OFC condition - Subyearling Chinook

ANOVA Source	DF	Sum of Squares	Mean Square	F	P
Date	1	0.469	0.469		
Slot/Load	1	52.237	52.237	13.64	0.001
OFC	1	15.512	15.512	4.05	0.051
S x O	1	16.397	16.397	4.28	0.046
Error	37	141.703	3.830		
Total	41	222.630			

Slot/Load	OFC Position	Mean	SE
4B/60	Lowered	1.0	0.6
4B/60	Raised	1.0	0.6
5B/72-80	Lowered	4.5	0.6
5B/72-80	Raised	2.0	0.6

(Lowered = Raised for Slot 4B, Lowered > Raised for Slot 5B)