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September 1996

Coastal Zone and Estuarine Studies Division

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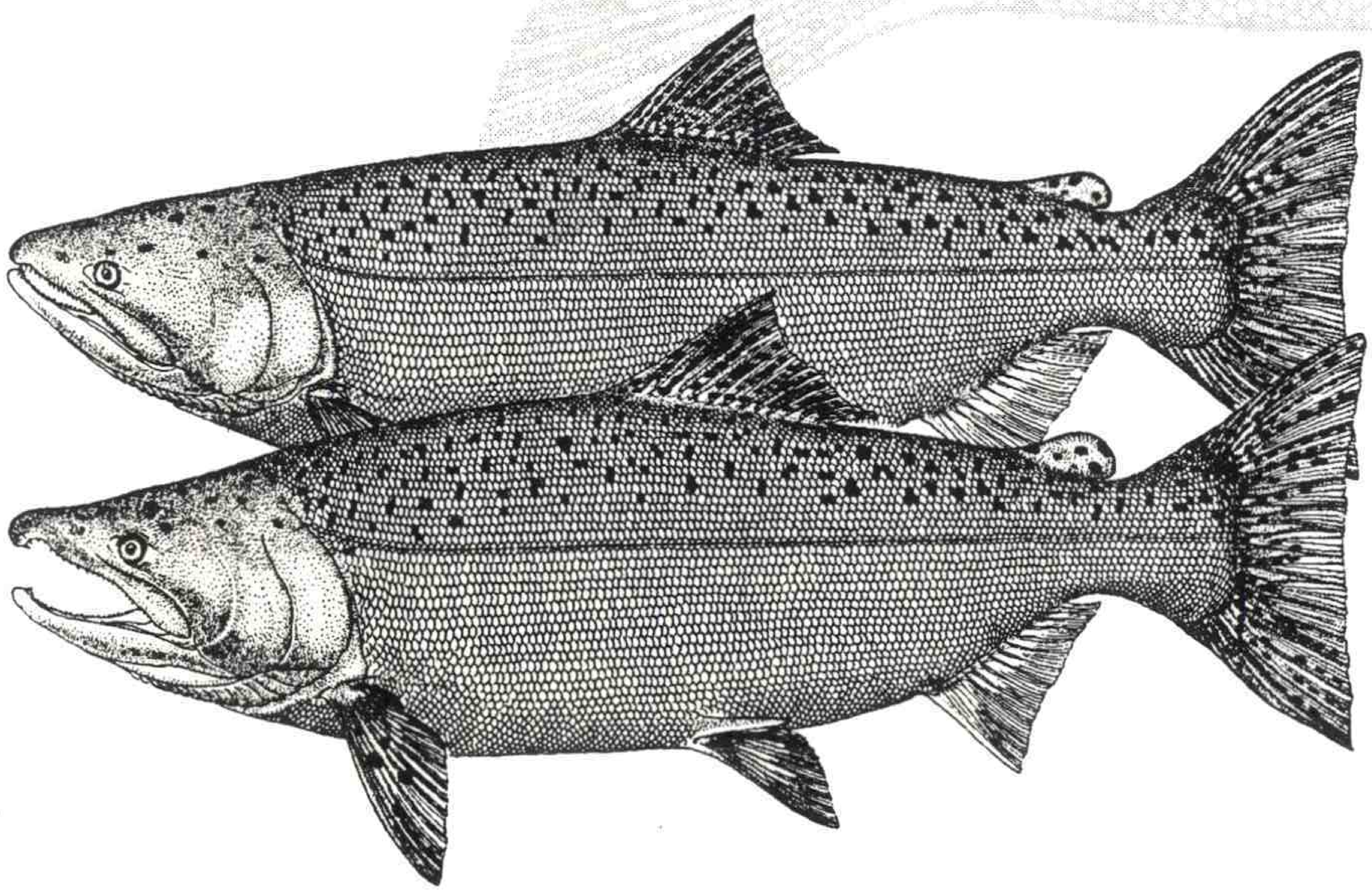

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EXECUTIVE SUMMARY

Descaling estimates were obtained for yearling chinook salmon and steelhead collected from slots in Turbine Units 4 and 5 at Little Goose Dam. Turbine Unit 4 (test unit) was equipped with prototype extended-length bar screens, inlet flow vanes, and two types of vertical barrier screens (VBS I and II); Turbine Unit 5 (control unit) was equipped with standard-length submersible traveling screens and modified balanced-flow vertical barrier screens. We also evaluated orifice passage efficiency for yearling chinook salmon in Slots A and B of Turbine Unit 4. In summary, we determined:

1) With the inlet flow vane in place, there was no significant difference in descaling for yearling chinook salmon or steelhead between VBS I and II or between either of these VBSs and the control slot.

2) Descaling of yearling chinook salmon was significantly lower with the inlet flow vane than without it (1.9 vs. 5.5%), but steelhead descaling was not significantly different (1.7 vs. 1.3%).

3) Orifice passage efficiency for yearling chinook salmon averaged over 90% in the two slots tested (20-hour tests).

INTRODUCTION

In 1993, the National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers (COE) initiated studies at Little Goose Dam to evaluate the effectiveness of extended-length submersible traveling screens and bar screens (ESTSs and ESBSs) (Fig. 1). Fish guidance efficiency (FGE) and descaling tests were conducted to compare the performance of extended-length screens to that of standard-length submersible traveling screens (STSs) that are currently an integral part of juvenile fish bypass systems at hydroelectric dams on the Snake and Columbia Rivers.

The results of prototype extended-length screen tests at Little Goose Dam during the spring outmigrations of 1993 and 1994 indicated that FGEs of 80 and 90% were attainable for yearling chinook salmon *(Oncorhynchus tshawytscha)* and steelhead *(O. mykiss)*, respectively, with no increase in descaling (Gessel et al. 1994, 1995). Of the guidance screens evaluated, the ESBS with a 25% perforated plate porosity performed the best in terms of FGE and descaling.

Extended-length screens divert approximately twice the flow into the gatewell as an STS. This increase can create turbulent flows within the slot and areas of high flow through the vertical barrier screen (VBS) (Fig 1). Model studies conducted at the COE's Waterways Experiment Station (WES) have indicated that a VBS with variable porosity perforated plate on the downstream side would provide even flows through its entire surface area. Preliminary tests with these new VBS designs were conducted at McNary Dam in 1994 (McComas et al. 1995).

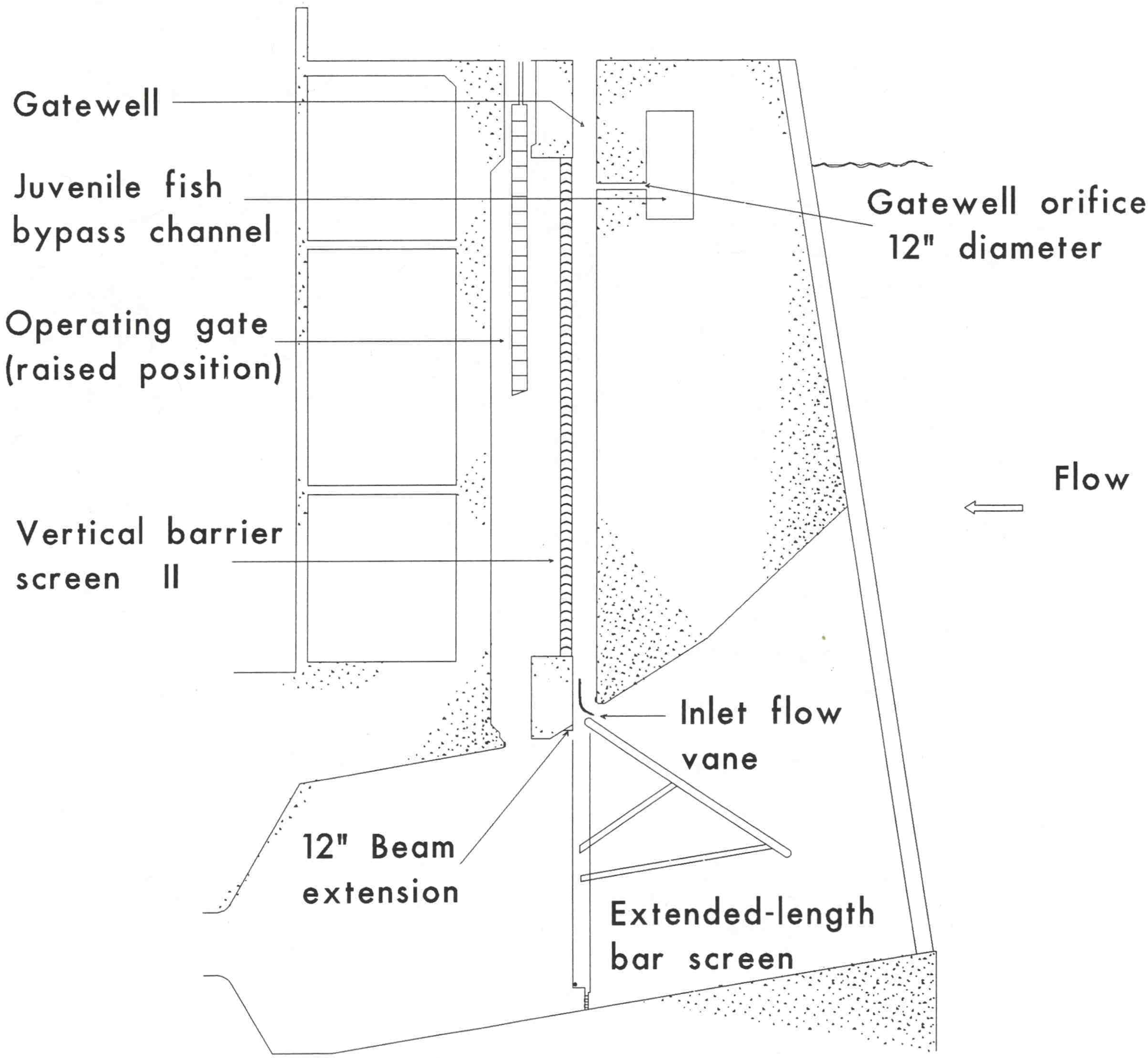


Figure 1. Cross section of a turbine intake showing the extended-length bar screen, inlet flow vane, and VBS II at Little Goose Dam, 1995.

Operating gates were removed during the tests conducted in unit 4.

During the late summer of 1994, additional model studies were conducted at WES to determine the best VBS design for Little Goose Dam. These studies indicated two VBS designs should be considered and the addition of an inlet flow vane to the ESBS (Fig. 1). The 1995 study at Little Goose Dam was designed to test these structures by monitoring fish condition during the juvenile salmonid outmigration.

Specific research objectives for 1995 were:

1) Evaluate descaling with VBS I and II, with and without the inlet flow vane.

2) Estimate orifice passage efficiency with an ESBS, VBS I, and inlet flow vane.

OBJECTIVE 1: EVALUATE DESCALING WITH VBS I AND II, WITH AND WITHOUT THE INLET FLOW VANE

Approach

Extended-length bar screens were tested in Slots A and B of Turbine Unit 4. An ESBS was also placed Slot 4C to maintain uniform flows within the test unit. An STS and a modified balanced-flow vertical barrier screen were used in Slot 5B as a control for descaling monitoring. Placement of test screens was as follows:

Turbine unit/slot	Screen type	Perforated plate porosity (%)
4A	ESBS	25
4B	ESBS	25
4C	ESTS	25
5B	STS	48

Water flows into Turbine Unit 4 were maintained at approximately 18,300 cfs. This corresponded to a screen-approach velocity of around 2.5 fps with turbine power loads of about 135 MW.

The test slots in Turbine Unit 4 contained the new types of VBSs that had been designed for use with extended-length guiding devices. Vertical barrier screen I was placed in Slot 4A, and VBS II in Slot 4B. Both VBSs consisted of eight panels with each panel approximately 10 feet in height. The porosity of all panels of VBS I was 20%. For VBS II, the porosity (from top to bottom) was 20, 20, 25, 25, 20, 20, 25, and 25%. An inlet flow vane (Fig. 1) was used on an alternate-day basis in each of the test slots.

The STS in Slot 5B was operated at the standard elevation, and screen angle was 55° throughout the tests. The ESBSs in Slots 4A and 4B were lowered 1 foot and also set at the 55° angle. In Slots 4A and 4B, a 1-foot beam extension was mounted to the concrete beam separating the upstream and downstream gate slots so that the gap between the screen and the concrete beam was the same for both the ESBS and the STS. All operating gates were either fully raised or removed.

All juvenile salmonids collected from the gatewells were examined for fish condition using standard Fish Transportation Oversight Team descaling criteria (Ceballos et al. 1992). At approximately 1600 and 2200 h each test day, a dip basket was used for a clean-out dip and to collect fish for descaling examination, respectively. Descaling data were collected throughout the field season from 19 April to 6 June.

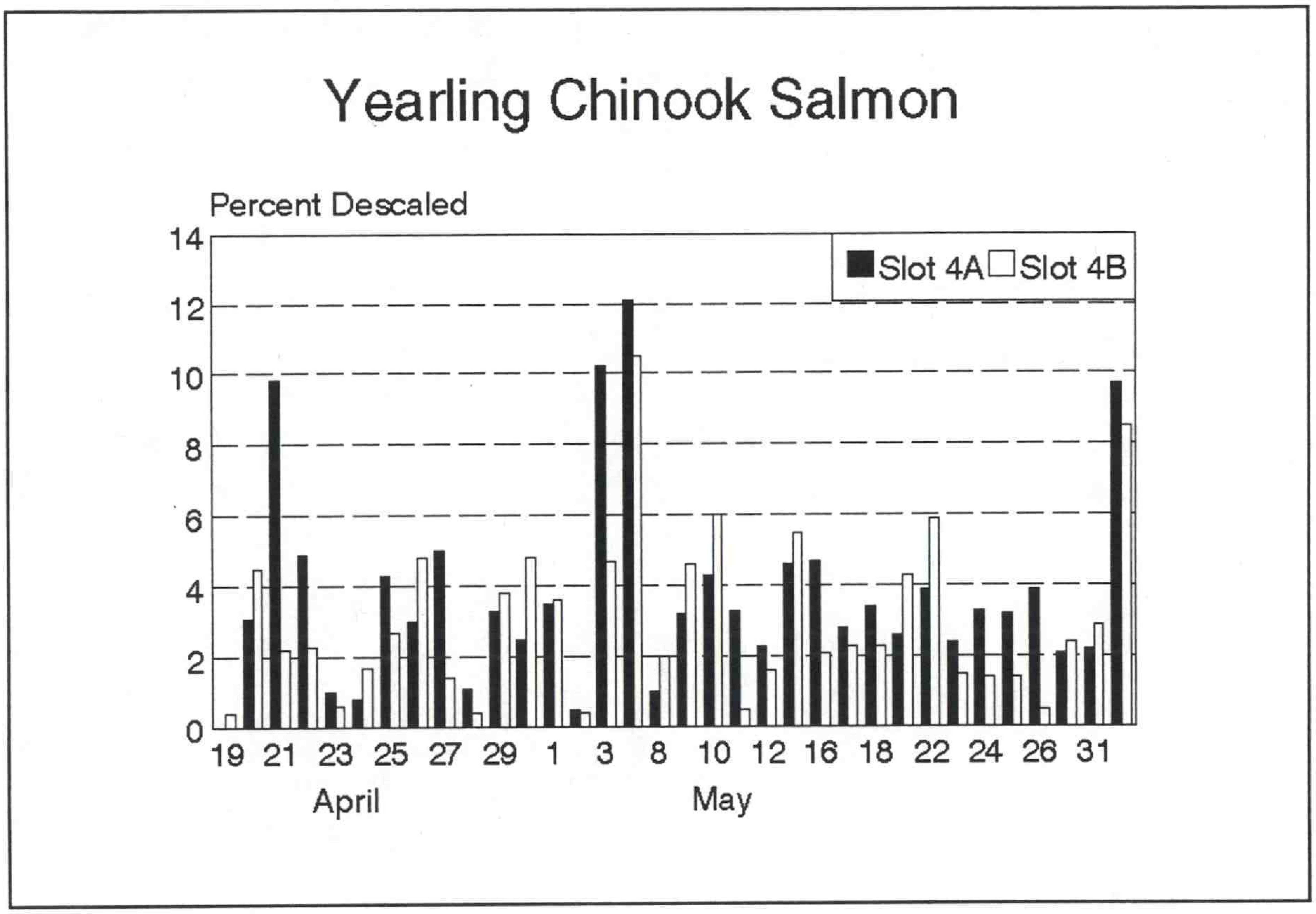
Mean descaling percentages for yearling chinook salmon and steelhead were statistically analyzed with a randomized block, two-factor ANOVA and a comparison of the means. First, we compared the two VBS designs, tested with and without the inlet flow vane early in the outmigration (20 April-8 May), with a randomized block two-factor ANOVA where each 2-day period was considered a block. Second, we compared the three slots for all days when the inlet flow vanes were used in Slots 4A and 4B. Significance was established at $\alpha = 0.05$.

Results and Discussion

Appendix Table 1 contains summaries of daily collection totals for wild and hatchery yearling chinook salmon and steelhead. Daily yearly chinook salmon and steelhead collections for the descaling tests are listed in Appendix Table 2 and the incidental catch of juvenile sockeye salmon and lamprey during descaling tests is summarized in Appendix Table 3. Figure 2 shows the daily descaling data for yearling chinook salmon and steelhead in the test slots.

Yearling Chinook Salmon

There was no significant interaction between VBS and inlet flow vane ($F = 0.64$; df = 1, 21; $P = 0.4340$) and no significant difference in descaling between VBS I and VBS II ($F = 1.08$; df = 1, 21; $P = 0.3100$), but descaling was significantly lower ($F = 16.60$; df = 1, 21; $P = 0.0010$) with the inlet flow vane (1.9 versus 5.5%). With the inlet flow vane, descaling was not significantly different ($F = 1.30$; df = 2, 36; $P = 0.2845$) among VBS I, VBS II, and the control slot (2.8, 2.7, and 2.1%, respectively).



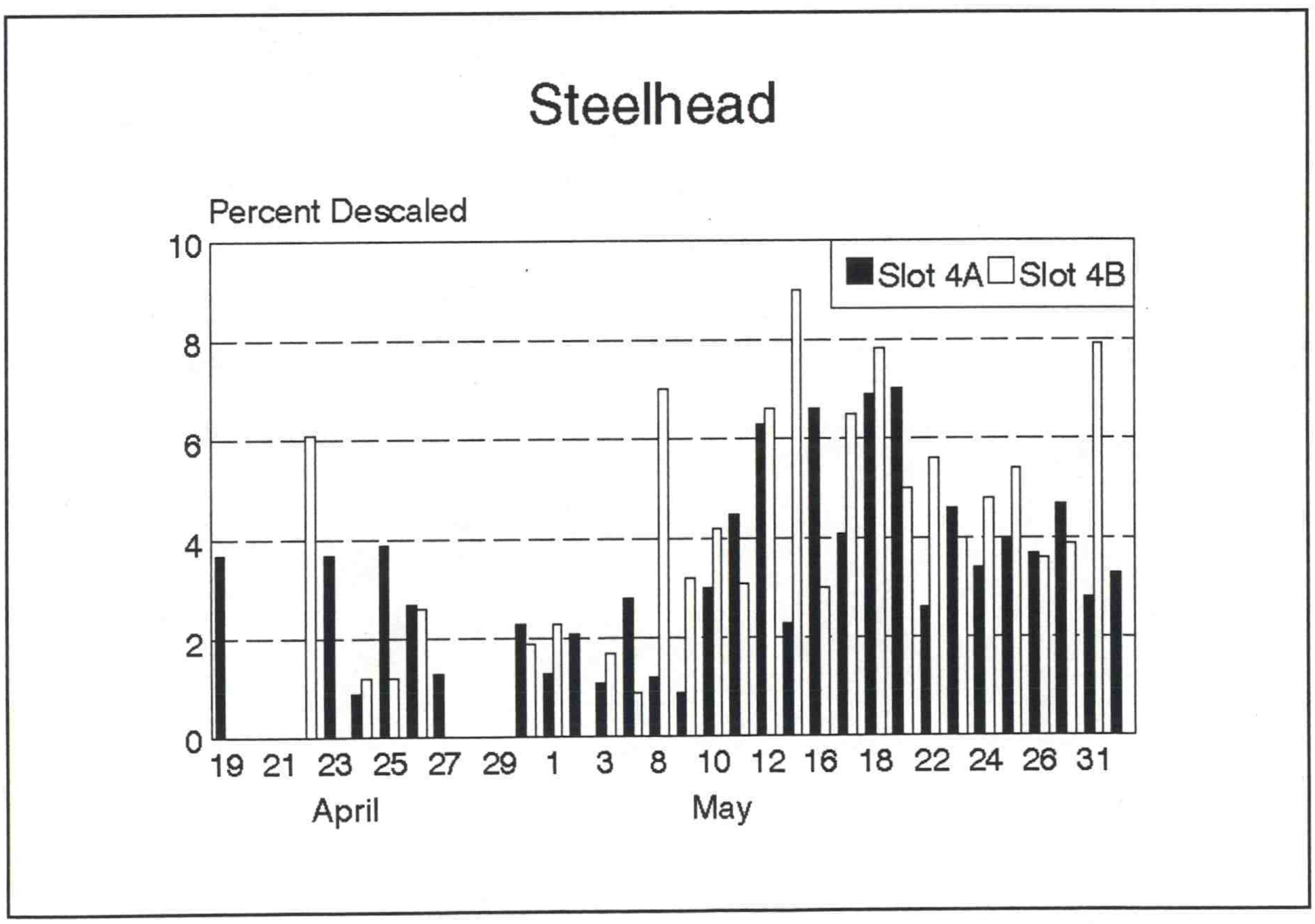


Figure 2. Daily descaling data for yearling chinook salmon and steelhead from the test slots at Little Goose Dam, 1995.

Steelhead

There was no significant interaction between the VBS and inlet flow vane (F = 0.04; df = 1, 20; P = 0.8500), no significant difference in descaling between VBS I and VBS II (F<0.001; df = 1, 20; P = 0.9870), and no significant difference (F = 0.45; df = 1, 20; P = 0.05110) with or without the inlet flow vane (1.7 versus 1.3%). With the inlet flow vane, descaling was not significantly different (F = 1.27; df = 2, 30; P = 0.9870) between VBS I, VBS II, and the control slot (3.7, 4.8, and 3.6%, respectively).

Additional Observations

A portion of the COE's 1995 extended-length screen evaluation at Little Goose Dam was directed toward the use of hydroacoustics to estimate FGE. In conjunction with this research, NMFS agreed to provide counts of the fish that were diverted into the gatewells. These data were not to be used to estimate FGE, but to indicate the veracity of the hydroacoustic estimates. We scheduled this gatewell dipping in Slot 4B, and intended to dip only during the early portion of the outmigration so fewer fish would be handled.

We closed both orifices in Slot 4B and collected fish from 2200 h on 22 April until 1600 h on 23 April. On 23 April, injured and dead smolts were observed at the surface in the test slot, and we eventually collected 576 yearling chinook salmon and 49 steelhead mortalities. All of the fish that were removed from the slot were held in fish tanks with flowing water for about 8 hours. Those that subsequently died were included in our mortality total and the remainder (estimated to be an additional 300-400 fish) were released. Our mortality total also included fish that were collected at the juvenile bypass facility during the late evening hours of 23 April and the early morning hours of 24 April.

It appears that flow conditions within the test slot may adversely affect some of the smolts *if they are unable to exit through the orifices volitionally*. The exact nature of the adverse effects is not known, but we feel the probable cause is the increased flow into and throughout the slot. The increased flow, coupled with the lack of an exit point (the orifices were closed) may have eventually tired the fish to the degree that they began to make contact with the VBS and became severely descaled.

It is important to note that both orifices were closed only for test purposes. Under normal operating procedures, one orifice in each slot will always be open. The installation of extended-length screens at both Little Goose and Lower Granite Dams dictates that particular attention be directed toward ensuring an orifice is always open and clear of debris in each slot.

OBJECTIVE 2: ESTIMATE ORIFICE PASSAGE EFFICIENCY WITH AN ESBS, VBS I, AND INLET FLOW VANE

Orifice passage efficiency (OPE) is an estimate of the percentage of migrants that enter a slot and exit through an orifice during a selected time frame (usually about 24 hours). These tests were originally scheduled for Little Goose Dam, but were moved to Lower Granite Dam for the 1995 spring outmigration because the juvenile fish bypass channel there is large enough to accommodate an orifice trap. Although OPE results at Lower Granite were quite high (>90%) for both yearling chinook salmon and steelhead, these tests were only conducted with VBS II. Because we had the opportunity at Little Goose Dam to evaluate OPE with VBS I, we conducted a short series of tests near the end of the spring outmigration. Fish numbers were lower at this time and we were still collecting descaling information, so no additional fish were handled.

Approach

Approximately 70-100 hatchery yearling chinook salmon were selected for release into each of the test slots (4A and 4B) for each OPE test. A partial clip of either the upper or lower lobe of the caudal fin was used to identify the marked fish (alternating each day). The fish were dipped from gate slots, marked, and held until release at 2000 h each night. The fish were released from a cylinder mounted to a metal framework.[1] This allowed us to make each release at the same depth and same location in the two slots (15 m in depth and 2 m from the north end of the gate slot). The next day (1600 h), the slots were dipped and the catch examined for marked fish that had failed to exit through the orifice.

Results

We made a total of 11 releases for OPE estimates (6 in Slot 4A and 5 in Slot 4B) from 1 to 6 June. A total of 660 of 666 marked fish (99.1% OPE) exited Slot 4A, and 403 of 428 marked fish (94.2% OPE) exited Slot 4B during the test period. Individual OPE tests are listed in Table 1.

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[1] Same release cyclinder that was used for OPE tests at Lower Granite Dam during spring 1995.

OPE tests were conducted near the upper end of the maximum operating pool.

Table 1. Orifice passage efficiency results for yearling chinook salmon at Little Goose Dam, 1995.

	Slot 4A		Slot 4B	
Date	**Number released**	**OPE (%)**	**Number released**	**OPE (%)**
1 June	105	100.0		
2 June	81	100.0	85	82.4
3 June	100	96.0	100	94.0
4 June	100	99.0	71	97.2
5 June	100	100.0	92	95.7
6 June	80	98.8	80	100.0
Totals	666		428	
Average		99.1		94.2

CONCLUSIONS

1. Yearling chinook salmon descaling was significantly lower with the inlet flow vane than without it (1.9 versus 5.5%).
2. Yearling chinook salmon descaling was not significantly different among the control slot and test slots with either vertical barrier screen I or II and the inlet flow vane (2.1, 2.8, and 2.7%, respectively).
3. Steelhead descaling was not significantly different with or without the inlet flow vane (1.7 versus 1.3%).
4. Steelhead descaling was not significantly different among the control slot and test slots with either vertical barrier screen I or II and the inlet flow vane (3.6, 3.7, and 4.8%, respectively).
5. Orifice passage efficiency for yearling chinook salmon averaged over 90% with extended-length bar screens, VBS I and II, and inlet flow vanes.
6. The operation of turbine units equipped with extended-length screens requires that an orifice always be open in each slot to ensure the timely and volitional exit of fish.

ACKNOWLEDGMENTS

We express our appreciation to all of the U.S. Army Corps of Engineers personnel at Little Goose Dam for their assistance and cooperation in this study.

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Appendix Table 1. Hatchery and wild yearling chinook salmon and steelhead collected during descaling tests at Little Goose Dam, 1995.

	Yearling chinook salmon				Steelhead			
Date	Hatchery	Wild[a]	Total	Percent wild[b]	Hatchery	Wild	Total	Percent wild[b]
19 April	237	321	558	57.5	29	25	64	39.1
20 April	281	298	579	51.5	29	36	65	55.4
21 April	233	185	418	44.3	67	20	87	23.0
22 April	136	118	254	46.5	60	20	80	25.0
23 April	172	106	278	38.1	39	13	52	25.0
24 April	138	111	249	44.7	174	20	194	10.3
25 April	254	67	321	20.9	153	10	163	6.1
26 April	214	107	321	33.3	104	6	110	5.4
27 April	323	100	423	23.6	100	3	103	2.9
28 April	587	98	685	14.3	86	3	89	3.4
29 April	969	107	1076	9.9	253	8	261	3.1
30 April	683	136	819	16.6	387	16	403	4.0
1 May	543	94	637	14.8	189	5	194	2.6
2 May	529	92	621	14.8	134	8	142	5.6
3 May	329	78	407	19.2	499	65	564	11.5
4 May	882	138	1020	13.5	232	32	264	12.1
8 May	698	56	754	7.4	159	21	180	11.7
9 May	721	74	795	9.3	567	79	646	12.2
10 May	578	78	656	11.9	723	36	759	4.7
11 May	615	81	696	11.6	1187	119	1306	9.1
12 May	493	94	587	16.0	569	43	612	7.0
15 May	461	67	528	12.7	350	43	393	10.9
16 May	508	84	592	14.2	597	111	708	15.7
17 May	527	118	645	18.3	468	88	556	15.8
18 May	449	48	497	9.7	335	52	387	13.4
19 May	444	134	578	23.2	204	18	222	8.1
22 May	501	117	618	18.9	278	61	339	18.0
23 May	384	78	462	16.9	240	29	269	10.8
24 May	662	137	799	17.1	390	74	464	15.9
25 May	449	101	550	18.4	82	18	100	18.0
26 May	793	218	1011	21.6	281	50	331	15.1
30 May	330	79	409	19.3	92	19	111	17.1
31 May	444	195	639	30.5	174	16	190	8.4
1 June	344	197	541	36.4	160	20	180	11.1
2 June	133	241	374	64.4	49	7	56	12.5
3 June	210	165	375	44.0	24	3	27	12.5
4 June	352	280	632	44.3	199	30	229	13.1
5 June	224	166	390	42.6	30	5	35	14.3
6 June	44	6	50	12.0	28	2	30	6.7

[a]The estimated number of wild yearling chinook salmon is based on the assumption that all hatchery fish had either the adipose fin clipped or a ventral fin clipped.

[b]These percentages are only for the fish NMFS personnel dipped and handled for our descaling estimates.

Appendix Table 2. Descaling data from studies conducted at Little Goose Dam, 1995.

Test date	Yearling chinook salmon Total catch	Yearling chinook salmon Number descaled	Yearling chinook salmon Percent descaled	Steelhead Total catch	Steelhead Number descaled	Steelhead Percent descaled
Unit 4, Slot A (25% ESBS) VBS I						
19 April	82	0	0.0	27	1	3.7
20 April	65	2	3.1	28	0	0.0
21 April	102	10	9.8	44	0	0.0
22 April	82	4	4.9	31	0	0.0
23 April	103	1	1.0	27	1	3.7
24 April	133	1	0.8	110	1	0.9
25 April	211	9	4.3	77	3	3.9
26 April	134	4	3.0	75	2	2.7
27 April	140	7	5.0	78	1	1.3
28 April	186	2	1.1	50	0	0.0
29 April	244	8	3.3	44	0	0.0
30 April	160	4	2.5	132	3	2.3
1 May	227	8	3.5	79	1	1.3
2 May	210	1	0.5	47	1	2.1
3 May	127	13	10.2	179	2	1.1
4 May	314	38	12.1	71	2	2.8
8 May	224	2	1.0	83	1	1.2
9 May	317	10	3.2	220	2	0.9
10 May	278	12	4.3	271	8	3.0
11 May	240	8	3.3	242	11	4.5
12 May	176	4	2.3	205	10	6.3
15 May	87	4	4.6	86	2	2.3
16 May	192	9	4.7	244	16	6.6
17 May	212	6	2.8	197	8	4.1
18 May	178	6	3.4	101	7	6.9
19 May	230	6	2.6	86	6	7.0
22 May	207	8	3.9	117	3	2.6
23 May	166	4	2.4	65	3	4.6
24 May	239	8	3.3	59	2	3.4
25 May	222	7	3.2	25	1	4.0
26 May	228	9	3.9	54	2	3.7
30 May	141	3	2.1	43	2	4.7
31 May	134	3	2.2	36	1	2.8
1 June	124	12	9.7	30	1	3.3
4 June	28	1	3.6	0	0	0.0
5 June	37	2	5.4	0	0	0.0

Appendix Table 2. Continued.

Test date	Yearling chinook salmon Total catch	Yearling chinook salmon Number descaled	Yearling chinook salmon Percent descaled	Steelhead Total catch	Steelhead Number descaled	Steelhead Percent descaled
Unit 4, Slot B (25% ESBS) VBS II						
19 April	270	1	0.4	19	0	0.0
20 April	132	6	4.5	27	0	0.0
21 April	133	3	2.2	15	0	0.0
22 April	172	4	2.3	49	3	6.1
23 April	175	1	0.6	25	0	0.0
24 April	119	2	1.7	84	1	1.2
25 April	110	3	2.7	86	1	1.2
26 April	187	9	4.8	35	1	2.6
27 April	283	4	1.4	25	0	0.0
28 April	230	1	0.4	26	0	0.0
29 April	160	6	3.8	30	0	0.0
30 April	166	8	4.8	104	2	1.9
1 May	222	7	3.6	42	1	2.3
2 May	232	1	0.4	44	0	0.0
3 May	150	7	4.7	120	2	1.7
4 May	410	43	10.5	112	1	0.9
8 May	200	4	2.0	43	3	7.0
9 May	239	11	4.6	157	5	3.2
10 May	200	12	6.0	236	10	4.2
11 May	178	1	0.5	229	7	3.1
12 May	189	3	1.6	152	10	6.6
15 May	235	13	5.5	201	18	9.0
16 May	146	3	2.1	203	6	3.0
17 May	258	6	2.3	185	12	6.5
18 May	171	4	2.3	116	9	7.8
19 May	140	6	4.3	80	4	5.0
22 May	254	15	5.9	128	7	5.6
23 May	132	2	1.5	100	4	4.0
24 May	217	3	1.4	62	3	4.8
25 May	138	2	1.4	37	2	5.4
26 May	205	3	0.5	56	2	3.6
30 May	167	4	2.4	51	2	3.9
31 May	140	4	2.9	38	3	7.9
1 June	117	10	8.5	32	0	0.0
4 June	134	8	6.0	28	1	10.9
5 June	80	6	7.5	10	0	0.0

Appendix Table 2. Continued.

Test date	Yearling chinook salmon Total catch	Yearling chinook salmon Number descaled	Yearling chinook salmon Percent descaled	Steelhead Total catch	Steelhead Number descaled	Steelhead Percent descaled
Unit 5, Slot B (48% STS) Standard VBS						
19 April	206	3	1.5	6	0	0.0
20 April	382	13	3.4	10	1	10.0
21 April	183	2	1.1	28	2	7.1
22 April	no fish collected					
23 April	no fish collected					
24 April	no fish collected					
25 April	no fish collected					
26 April	no fish collected					
27 April	no fish collected					
28 April	270	9	3.3	13	0	0.0
29 April	138	1	0.7	180	2	1.1
30 April	203	4	2.0	78	1	1.3
1 May	188	3	1.6	73	1	1.4
2 May	179	3	1.7	51	0	0.0
3 May	130	5	3.8	265	5	1.9
4 May	296	5	1.7	81	0	0.0
8 May	332	3	0.9	54	1	1.9
9 May	239	6	2.5	269	8	3.0
10 May	178	2	1.1	252	10	4.0
11 May	87	4	4.6	566	20	3.5
12 May	222	5	2.3	255	13	5.1
15 May	206	4	1.9	106	7	6.6
16 May	254	6	2.4	261	12	4.6
17 May	175	4	2.3	174	4	2.3
18 May	148	1	0.7	170	3	1.8
19 May	208	8	3.8	56	2	3.6
22 May	157	3	1.9	94	0	0.0
23 May	164	1	0.6	104	13	12.5
24 May	216	6	2.8	148	10	6.8
25 May	190	3	1.6	38	0	0.0
26 May	81	5	6.2	50	2	4.0
30 May	101	0	0.0	17	0	0.0
31 May	78	7	9.0	25	1	4.0
1 June	no fish collected					
4 June	154	10	6.5	28	0	0.0
5 June	115	10	8.7	28	17	60.7

Appendix Table 3. Incidental catch of sockeye salmon juveniles and lamprey juveniles (ammocetes) collected during descaling tests at Little Goose Dam, 1995.

Date	Sockeye	Lamprey
19 April		1
21 April		2
24 April		1
28 April	2	
29 April	1	
1 May	1	
3 May	1	
11 May		6
15 May		9
16 May	1	112
17 May		62
18 May		4
19 May	1	1
23 May		1
24 May	1	
25 May	2	
26 May	2	
30 May		1
31 May	2	
2 June	1	
3 June	2	
4 June	1	
5 June	3	
Totals	21	200