Evaluation of the New Juvenile Salmonid Bypass System at Lower Monumental Dam, 1992

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INTRODUCTION

Juvenile fish passage facilities at Lower Monumental Dam on the Snake River have been upgraded to include standard-length submersible traveling screens (STS), modified balance flow vertical barrier screens, raised operating gates, and a new bypass collection channel and flume. The design changes were made to improve juvenile salmonid (Oncorhynchus spp.) passage and collection efficiency.

Submersible traveling screens are an integral part of the juvenile fish bypass systems at several Snake and Columbia River hydroelectric dams. In most cases, STSs effectively divert juvenile salmonids from turbine intakes into fish collection facilities (Fig. 1). In 1986, the National Marine Fisheries Service (NMFS) tested STSs in one turbine unit at Lower Monumental Dam to determine if it was feasible to incorporate them into the design for a juvenile salmonid bypass facility. Yearling chinook salmon (O. tshawytscha) fish guidance efficiency (FGE) was 60% with a stored (standard position) operating gate and 73% with a raised operating gate (Ledgerwood et al. 1987). Steelhead (O. mykiss) guidance was 78 and 83%, with a stored and raised operating gate, respectively. Subyearling chinook salmon FGE with a raised operating gate was low (35%), but similar to results at other dams.

In February 1992, the six turbine units at Lower Monumental Dam were fully equipped with STSs and research was conducted during the spring juvenile salmonid outmigration to determine the FGE and the orifice passage efficiency (OPE) of the new bypass system. The OPE tests were required to estimate the rate of passage of smolts

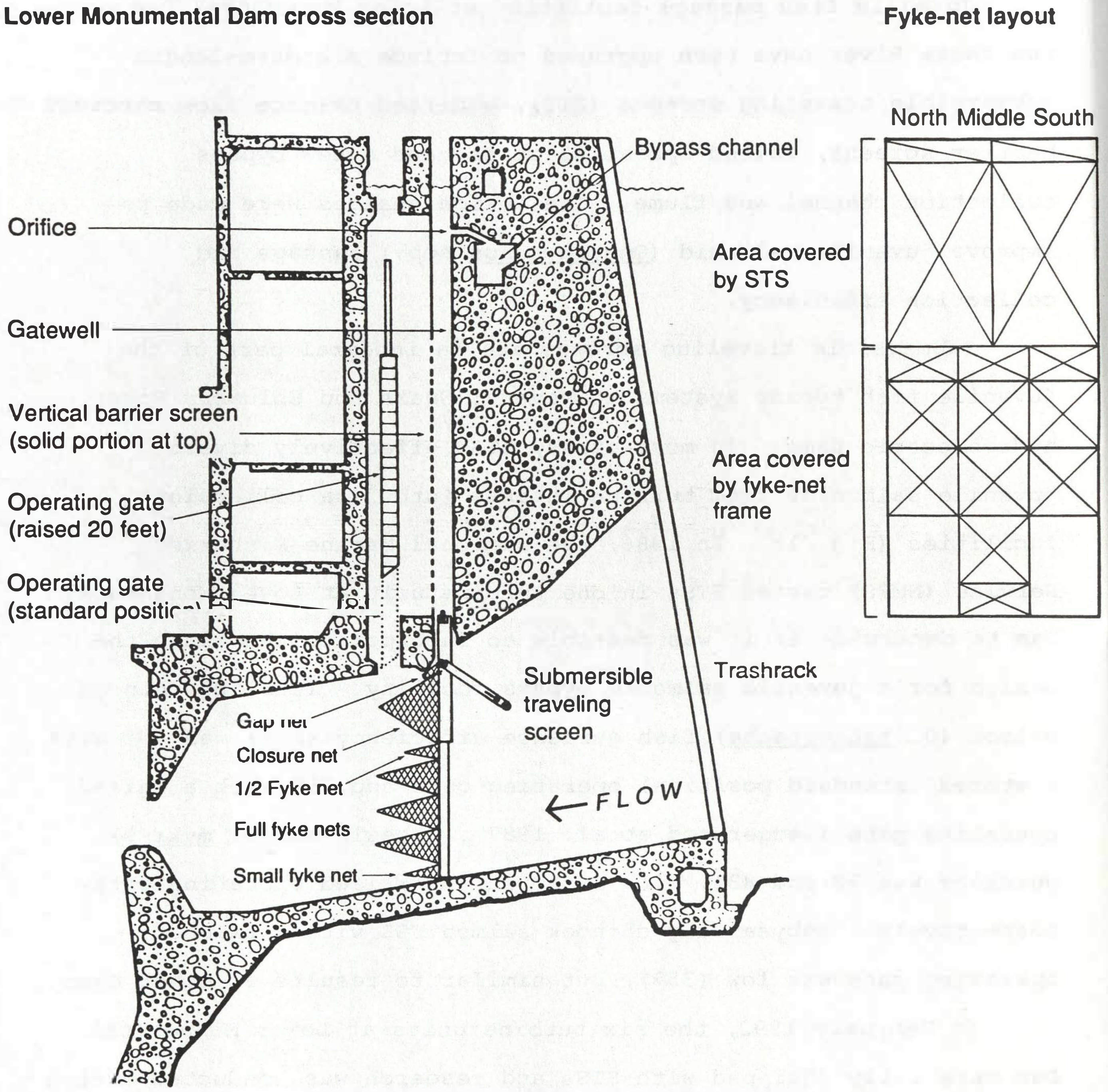

Figure 1.--Cross section of Lower Monumental Dam turbine intake showing submersible traveling screen (STS), raised and standard position operating gate, fyke-net layout, and associated structures.

as they entered and exited the gatewells (Fig. 1). The specific 1992 objectives were:

1) Determine the FGE of the STS during the spring juvenile salmonid migration.

2) Determine the effect of the STS on juvenile salmonid descaling.

3) Measure levels of smoltification in yearling chinook salmon collected in gatewells and from fyke nets at different depths within the turbine intake.

4) Determine orifice passage efficiency within the juvenile salmonid bypass system.

OBJECTIVE 1: FISH GUIDANCE EFFICIENCY OF THE STS

Approach

Methods for determining FGE were similar to those used in previous STS studies (Ledgerwood et al. 1987, Gessel et al. 1991). Fyke nets attached to a frame beneath the STS were used to collect the unguided fish, and a dipbasket collected guided fish from the gatewell (Fig. 1). FGE for each species was calculated as the gatewell catch divided by the total number of fish (by species) entering the turbine intake.

$$FGE = \frac{GW}{(GW + GN + FN)} \times 100\%$$

GW = gatewell catch
GN = gap-net catch
FN = fyke-net catch

Each test began about 2000 h and terminated when sufficient numbers of fish of the target species were collected in the gatewell, generally after 1-2 hours. At the end of each test, the test unit (Turbine Unit 3) was shut down, the fyke-net frame was raised, and the catch was removed from each net and placed in separate containers. The fish were counted by species and the gatewell catch examined for descaling and other injuries. Three series of five replicates each were conducted. Standard test conditions included a raised operating gate [raised at least 6 m (20 ft) or secured at deck level], a 0.8-m (30-in) lowered STS, and a 55° operating angle for the STS (Fig. 1).

Results and Discussion

Yearling Chinook Salmon and Steelhead

Testing for FGE began 27 April and ended on 22 May. The mean FGEs for yearling chinook salmon ranged from 64 to 75% (Table 1; detailed data in Appendix Table 1). The overall 69% FGE for yearling chinook salmon compared well to the 73% FGE with the prototype STS at Lower Monumental Dam in 1986. Mean FGE for steelhead in 1992 (>85% for tests with at least 50 fish) was higher than for yearling chinook salmon, which is consistent with results observed at other dams (Appendix Table 1).

Dipbasket Efficiency

Several releases of marked (partial clip of the upper caudal lobe) yearling chinook salmon were made to verify dipbasket efficiency. Of 146 marked fish, 141 were recaptured (96.6%).

Table 1.--Fish guidance efficiency of submersible traveling screen for yearling chinook salmon at Lower Monumental Dam, 1992.

Date	Mean FGE (%)	SD	n	95% CI (%)
27 Apr - 1 May	64	8	5	54 - 74
4 May - 8 May	68	11	5	55 - 81
18 May - 22 May	75	6	5	67 - 82
Overall	69	9	15	64 - 74

OBJECTIVE 2: JUVENILE SALMONID DESCALING

Approach

The external condition of smolts collected in the gatewells was continually monitored during FGE and OPE testing using standard Fish Transportation Oversight Team descaling criteria (Ceballos et al. 1992).

Results and Discussion

During the FGE studies, descaling for yearling chinook salmon and steelhead averaged 7.0 (95% CI = 4.8–9.1) and 6.4% (95% CI = 3.2–9.7), respectively. These levels of descaling were similar to levels of descaling reported for an STS at McNary Dam during the 1992 outmigration and estimates from other previous studies. While there is considerable uncertainty regarding the actual effects of descaling, there did not appear to be any unusual descaling problems with the STS tested at Lower Monumental Dam in 1992.

Descaling percentages for yearling chinook salmon and steelhead collected during OPE tests at Lower Monumental Dam in 1992 ranged from 1.4 to 26.9% (Table 2). We do not know the reason for the several instances of unusually high descaling during the OPE tests (e.g., 11 May, steelhead in Gatewells A and B).

OBJECTIVE 3: SMOLTIFICATION LEVELS

Research conducted by NMFS in cooperation with the U.S. Army Corps of Engineers (COE) has demonstrated that FGE not only changes from year to year and among dams, but can also change during the course of any year's outmigration (Swan et al. 1987; Giorgi et al. 1988; Muir et al. 1988, 1989, 1990). Data acquired at Lower

Table 2.--Descaling percentages for yearling chinook salmon and steelhead collected from the gatewells during orifice passage efficiency (OPE) tests at Lower Monumental Dam, 1992.

Date	Gatewell A Chinook (%)	Gatewell A Steelhead (%)	Gatewell B Chinook (%)	Gatewell B Steelhead (%)	Gatewell C Chinook (%)	Gatewell C Steelhead (%)
11 May	10.3	18.7	9.5	26.9	10.6	7.3
12 May	5.4	12.5	7.3	13.4	---[a]	10.6
13 May	9.3	12.9	6.2	13.7	5.7	8.6
14 May	9.0	11.6	5.5	9.4	10.9	12.2
22 May	6.0	9.1	6.2	10.1	7.6	8.8
23 May	9.0	5.2	14.5	7.9	---[a]	11.8
24 May	8.3	6.9	0	0	9.6	5.6
25 May[b]	---	---	---	---	---	---
26 May	1.6	4.4	1.4	3.0	3.9	6.3
27 May	8.2	3.4	5.5	4.5	---[a]	7.1
28 May	---[a]	4.8	---[a]	---[a]	9.7	4.4
29 May	8.5	4.2	11.9	4.4	---[a]	3.3

[a] Less than 50 fish were examined for descaling.
[b] No descaling data were compiled during this OPE test.

Granite and Little Goose Dams from 1985 to 1989 suggested that intraseasonal changes in FGE were associated with the changing physiological status of yearling chinook salmon; those fish within the population that were fully smolted were more susceptible to guidance by traveling screens.

The purpose of this study was to determine if seasonal changes in the physiological status of the migrant population were evident at Lower Monumental Dam and to assess whether those changes were related to concurrent FGE estimates.

Approach

To examine the relationship between fish guidance and smolt development, fish were collected during FGE tests and assayed for gill Na^+-K^+ ATPase. Twenty yearling chinook salmon were randomly sampled from the gatewell and 20 from all of the fyke nets combined, and these fish were placed on ice until gill samples could be taken. To ensure that any observed differences in gill Na^+-K^+ ATPase between live gatewell and dead fyke-net captured fish were not caused by deterioration of this enzyme in the dead fish, gatewell fish were killed and placed in water at ambient river temperature until the fyke nets were removed from the water. Fish were measured and gill filaments trimmed from the gill arch and then placed into 1.5-ml microcentrifuge tubes filled with a buffer solution containing sucrose, ethylenediamine, and imidazole (SEI). Gills that showed signs of excessive deterioration were discarded. Samples were immediately placed in an ice chest containing dry ice and were later stored in a freezer and held at <-70°C until assayed. After gill removal, fish were individually stored in labeled plastic bags and placed on dry ice for later analysis by the U.S. Fish and Wildlife Service for bacterial kidney disease (BKD). Assays for gill Na^+-K^+ ATPase were conducted using procedures described by Zaugg (1982) with minor modification.

To characterize the physiological status of the smolt population on each sample date, the mean Na^+-K^+ gill ATPase level was weighted by the number of smolts captured in the fyke nets and gatewell and averaged. A paired t-test was used to test for seasonal differences in enzyme levels in guided vs. unguided fish.

Results and Discussion

Yearling chinook salmon gill Na^+-K^+ ATPase activity changed little during the spring sampling period; however, sampling was restricted to a limited period during the outmigration because of Endangered Species Act (ESA) concerns (Table 3). Mean enzyme levels ranged from 26.2 to 35.7 μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$. There was no significant difference between gill Na^+-K^+ ATPase activity levels in guided (gatewell) vs. unguided (fyke net) yearling chinook salmon overall ($t = -1.75$, 3 df, $P = 0.178$) (Table 4).

Again because of ESA concerns, there were not enough sample dates to correlate FGE and gill Na^+-K^+ ATPase activity for yearling chinook salmon at Lower Monumental Dam in 1992. Statistical data for gill Na^+-K^+ ATPase results are presented in Appendix Table 2.

Table 3.--Number of yearling chinook salmon sampled in the gatewell and fyke nets (n), FGE results, and mean gill Na^{+}-K^{+} ATPase levels ($\mu mol\ P_i \cdot mg\ Prot^{-1} \cdot h^{-1}$) during smoltification studies at Lower Monumental Dam, 1992.

Date	n	FGE (%)	Gill Na^{+}-K^{+} ATPase
28 Apr	40	60	26.2
29 Apr	39	60	27.9
7 May	40	52	33.2
8 May	40	62	35.7

Table 4.--Mean Na^+-K^+ ATPase levels (μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) for guided (gatewell) and unguided (fyke nets) yearling chinook salmon at Lower Monumental Dam, 1992.

Date	Na^+-K^+ ATPase (mean) Gatewell	Fyke nets
28 Apr	23.7	30.1
29 Apr	27.3	28.9
7 May	31.8	34.7
8 May	35.9	35.3

OBJECTIVE 4: ORIFICE PASSAGE EFFICIENCY

Approach

At Lower Monumental Dam, each gatewell is equipped with two submerged, 0.3-m (12-in) diameter orifices that connect the gatewell to the fish bypass channel (Fig. 1). The orifices are located approximately 75 cm (30 in) from each corner of the gatewell (usually designated north and south). The fish bypass channel is situated in a cavity mined through the main structure of the dam, and there is insufficient space to attach a trap to the exit point of the orifices. Therefore, it was necessary to use an indirect method of estimating OPE. Similar constraints were encountered at John Day Dam and the indirect method was applied there successfully (Brege et al. 1987).

Flow through each of the turbine units at Lower Monumental Dam is supplied through three intake slots (A, B, and C) each with a separate gatewell. Slot A supplies about 28% of the turbine intake flow and Slots B and C provide about 35 and 37%, respectively. Because of their similar flow characteristics, the gatewells for Slots B and C (i.e., Gatewells B and C) were used for OPE tests. For each OPE test, both orifices in one gatewell and one of the two orifices in the other gatewell were closed and a comparison was made of the number of fish collected by dipbasket from each of the two gatewells. For example, if the Gatewell B orifices were closed (preventing any fish from exiting the gatewell) and 100 fish were collected, while in Gatewell C only the north orifice was open and 25 fish were collected, then OPE for the north orifice in Gatewell C would be 75% (based on the assumption that with a closed north orifice Gatewell C would also have contained about 100 fish).

On a 24-hour basis, orifices in Gatewells B and C were alternately closed and opened, the daily accumulation of fish was removed from the gatewells, and the number of fish (by species) determined. The two orifices in Gatewell A were closed for all tests, the fish collection monitored, and the data used as an indicator of potential discrepancies in fish numbers between gatewells. Two-sample t-tests were used to compare OPE between north and south orifices, between Gatewells B and C, and between relative numbers of fish in Gatewell A and either Gatewell B or C (depending upon which gatewell had both orifices closed). A 95% confidence interval was calculated (assuming OPE was normally distributed) for the seasonal OPE.

Since only one orifice of the total of four in Gatewells B and C could be opened for each 24-hour test, a total of 4 test days were required to complete one OPE replicate. Studies at John Day Dam indicated that nine replicates (total of 36 test days) were necessary to estimate OPE with a SE of about 4.5 (Brege et al. 1987).

Results and Discussion

A total of 12 OPE tests were conducted in Turbine Unit 4. Near the end of May we began collecting low numbers of subyearling chinook salmon from the gatewells, and to limit handling of these fish, which are listed as threatened under the ESA, the tests were terminated. The OPE in 11 of 12 tests for yearling chinook salmon ranged from 75 to 96% (Table 5).

In past orifice passage efficiency studies, OPE of approximately 70% has been used as an indicator of acceptable passage (Krcma et al. 1983). At Lower Monumental Dam in 1992, OPE

Table 5.--Yearling chinook salmon collected in Gatewells A, B, and C, orifice passage efficiency (OPE), and ratio of fish collected in different gatewells, Turbine Unit 4, Lower Monumental Dam, 1992.

Date	Open orifice	Gatewell A	Gatewell B	Gatewell C	OPE (%)	Ratio A to B or C[a]
11 May	B south	331	126	525	76	0.63
12 May	C south	295	564	22	96	0.52
13 May	B north	151	178	706	75	0.21
14 May	C north	257	847	128	85	0.30
22 May	B south	365	81	567	86	0.64
23 May	C south	67	198	11	94	0.34
24 May	B north	169	101	521	81	0.32
25 May	C north	38	128	6	95	0.30
26 May[b]	B north	319	213	416	49	0.77
27 May	C north	257	602	35	94	0.43
28 May	B north	40	8	176	95	0.23
29 May	C south	71	266	22	92	0.27

[a]Ratio of fish collected in Gatewell A (closed orifices) to fish collected in other gatewell with both orifices closed (either Gatewell B or C depending on test conditions).
[b]Statistical outlier, not used in the analysis.

for yearling chinook salmon averaged 88% (95% CI = 83-94). The OPE was 83 and 93% in Gatewells B and C, respectively. This difference was significant ($t = -2.65$, $df = 9$, $P = 0.0266$). This may imply gatewell bias (due to differential numbers of fish collected in Gatewells B and C) in the daily OPE estimates. However, a nearly equal number of Gatewell B (negative bias) and Gatewell C (positive bias) OPEs were included in the overall OPE estimate which should minimize any gatewell bias. The OPE averaged 89 and 88% for the south and north orifices, respectively, which was not a significant difference ($t = 0.24$, $df = 9$, $P = 0.8129$). Fish numbers in Gatewell A averaged 41 and 36% of the numbers in Gatewells B and C, respectively (when B or C had both orifices closed). This difference was not significant ($t = 0.50$, $df = 9$, $P = 0.6267$).

The OPE in 11 of 12 tests for juvenile steelhead ranged from 57 to 85% (Table 6). The OPE for steelhead averaged 66% (95% CI = 60-72) and was 67 and 65% in Gatewells B and C, respectively. This difference was not significant ($t = 0.35$, $df = 9$, $P = 0.7369$) and suggests there was no gatewell bias for Gatewells B and C in the daily OPE estimates. The OPE averaged 63 and 69% for the south and north orifices, respectively, and was not significantly different ($t = -0.97$, $df = 9$, $P = 0.3591$). Steelhead numbers in Gatewell A averaged 52 and 43% of the numbers in Gatewells B and C, respectively (when B or C had both orifices closed). This difference was not significant ($t = 1.66$, $df = 9$, $P = 0.1319$).

A statistical outlier in the OPE data occurred on 26 May. The yearling chinook salmon OPE estimate was almost half the "typical" OPE estimate (49 versus 88%) and the steelhead estimate was the lowest observed during the season (47 versus a range of 57-85%).

Table 6.--Steelhead collected in Gatewells A, B, and C, orifice passage efficiency (OPE), and ratio of fish collected in different gatewells, Turbine Unit 4, Lower Monumental Dam, 1992.

Date	Open orifice	Gatewell A	Gatewell B	Gatewell C	OPE (%)	Ratio A to B or C[a]
11 May	B south	332	249	574	57	0.58
12 May	C south	615	1,061	236	78	0.58
13 May	B north	363	234	636	63	0.57
14 May	C north	383	791	311	61	0.48
22 May	B south	372	278	668	58	0.56
23 May	C south	174	409	170	58	0.43
24 May	B north	246	134	496	73	0.50
25 May	C north	92	302	108	64	0.30
26 May[b]	B north	180	99	186	47	0.97
27 May	C north	297	848	294	65	0.35
28 May	B north	83	30	206	85	0.40
29 May	C south	120	265	91	66	0.45

[a]Ratio of fish collected in Gatewell A (closed orifices) to fish collected in other gatewell with both orifices closed (either Gatewell B or C depending on test conditions).
[b]Statistical outlier, not used in the analysis.

Concurrently, the proportion of fish in Gatewell A relative to the closed Gatewell C was much higher than for all other test days for either species (0.77 versus a range of 0.21-0.64 for yearling chinook salmon and 0.97 versus a range of 0.31-0.58 for steelhead). These observations were an indication something unusual had occurred on that day. Since our objective was to quantify typical OPE, the data from 26 May were not used in the analyses.

CONCLUSIONS

1) Fish guidance efficiency of a 0.8-m (30-in) lowered STS, set at a 55° operating angle and combined with a raised operating gate, was nearly 70% for yearling chinook salmon.

2) During FGE tests, descaling for yearling chinook salmon and steelhead averaged 7.0 and 6.4%, respectively.

3) Orifice passage efficiency over 24-hour intervals during the period 11-29 May, averaged 88 and 66% for yearling chinook salmon and steelhead, respectively. Orifice passage efficiency was not significantly different between the north and south orifices during these tests.

4) Additional orifice passage efficiency tests may be required to verify OPE throughout the juvenile salmonid outmigration.

ACKNOWLEDGMENTS

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Appendix Table 1.--Numbers of fish collected in the individual replicates of FGE tests, and FGE results for yearling chinook salmon and steelhead (n ≥ 50) at Lower Monumental Dam, 1992 (SC = subyearling chinook, YC = yearling chinook, and ST = steelhead).

Date (test slot-test number)

	27 April (3B-1)			28 April (3B-2)			29 April (3B-3)		
Location	SC	YC	ST	SC	YC	ST	SC	YC	ST
Gatewell	0	258	16	1	184	18	0	318	50
Gap Net	0	0	0	0	0	0	0	0	0
Closure	0	33	0	0	29	0	0	43	7
First	0	33	3	0	15	3	0	30	0
Second	0	39	9	0	66	3	3	102	6
Third	0	32	2	0	11	2	0	36	3
Fourth	0	6	0	0	0	0	0	0	0
Fifth	0	0	0	0	0	0	0	0	0
Totals	**0**	**401**	**30**	**1**	**305**	**26**	**3**	**529**	**66**
FGE (%)		**64**			**60**			**60**	**76**

	30 April (3B-4)			1 May (3B-5)			4 May (3B-6)		
Location	SC	YC	ST	SC	YC	ST	SC	YC	ST
Gatewell	0	498	36	0	203	24	0	366	252
Gap Net	0	2	0	0	1	0	0	0	0
Closure	0	84	4	1	14	1	0	28	0
First	0	75	3	0	9	0	0	42	3
Second	0	138	3	0	24	0	0	45	9
Third	0	61	3	0	3	0	0	9	1
Fourth	0	3	0	0	0	0	0	3	0
Fifth	0	0	0	0	0	0	0	0	0
Totals	**0**	**861**	**49**	**1**	**254**	**25**	**0**	**493**	**265**
FGE (%)		**58**			**80**			**74**	**95**

	5 May (3B-7)			6 May (3B-8)			7 May (3B-9)		
Location	SC	YC	ST	SC	YC	ST	SC	YC	ST
Gatewell	0	157	119	0	127	76	1	139	65
Gap Net	0	0	0	0	1	0	0	0	0
Closure	0	16	4	0	13	4	0	30	1
First	0	12	6	0	6	0	0	24	9
Second	0	24	3	0	12	6	0	63	0
Third	0	6	1	0	3	0	0	8	1
Fourth	0	0	0	0	0	0	0	3	0
Fifth	0	0	0	0	0	0	0	0	0
Totals	**0**	**215**	**133**	**0**	**162**	**86**	**1**	**267**	**76**
FGE (%)		**73**	**89**		**78**	**88**		**52**	**85**

Appendix Table 1.--Continued.

	Date (test slot-test number)								
	8 May (3B-10)			18 May (3B-11)			19 May (3B-12)		
Location	SC	YC	ST	SC	YC	ST	SC	YC	ST
Gatewell	2	149	30	1	126	18	0	137	37
Gap Net	0	0	0	0	0	0	0	0	0
Closure	0	20	2	0	12	0	0	13	1
First	3	21	0	0	12	0	0	9	0
Second	0	30	3	0	15	0	0	24	0
Third	1	17	0	0	4	0	0	3	0
Fourth	0	3	0	0	0	0	0	0	0
Fifth	0	0	0	0	0	0	0	0	0
Totals	**6**	**240**	**35**	**1**	**169**	**18**	**0**	**186**	**38**
FGE (%)		**62**			**75**			**74**	

	20 May (3B-13)			21 May (3B-14)			22 May (3B-15)		
Location	SC	YC	ST	SC	YC	ST	SC	YC	ST
Gatewell	0	366	32	0	102	55	2	110	35
Gap Net	0	0	0	0	0	0	0	0	0
Closure	0	28	1	0	12	1	0	11	1
First	0	27	3	0	9	3	0	3	0
Second	0	51	3	0	27	6	0	6	0
Third	0	10	0	0	3	2	0	2	0
Fourth	0	3	0	0	0	0	0	0	0
Fifth	0	0	0	0	0	3	0	0	0
Totals	**0**	**485**	**39**	**0**	**153**	**70**	**2**	**132**	**36**
FGE (%)		**75**			**66**	**79**		**83**	

Appendix Table 2.--Gill Na^{+}-K^{+} ATPase ($\mu mol\ P_i \cdot mg\ Prot^{-1} \cdot h^{-1}$) data for yearling chinook salmon from FGE tests at Lower Monumental Dam, 1992.

Date	Statistic	Gatewell	Fyke nets
28 Apr	Mean	23.7	30.1
	SD	7.0	7.6
	n	20	20
29 Apr	Mean	27.3	28.9
	SD	9.1	9.0
	n	19	20
7 May	Mean	31.8	34.7
	SD	7.1	9.7
	n	20	20
8 May	Mean	35.9	35.3
	SD	6.7	6.1
	n	20	20