Research at McNary Dam to Improve Fish Guiding Efficiency of Yearling and Subyearling Chinook Salmon, 1987

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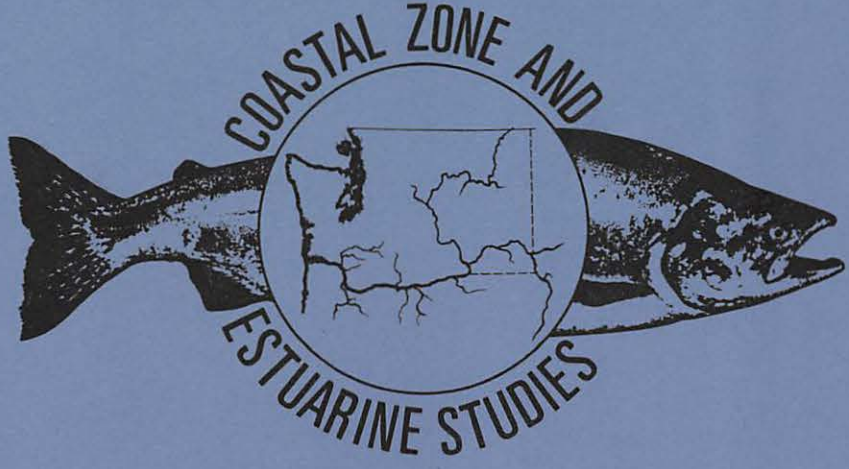
July 1988



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Final Report

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CONTENTS

INTRODUCTION

McNary Dam on the Columbia River was completed in 1954 with no specific provisions for juvenile fish passage (Fig. 1). All downstream migrants either passed through the turbines or over the spillway. Research in ensuing years found that turbine passage and migration through reservoirs were detrimental to salmon survival in the Snake and Columbia rivers (Raymond 1979). Upon development of a means to intercept fish passing through turbines, the U. S. Army Corps of Engineers (COE) constructed a juvenile collection system with submersible traveling screens (STS) at McNary Dam to collect fish and transport them to a release site below Bonneville Dam (Basham et al. 1981). Past evaluations of the STSs during the spring migration found fish guiding efficiencies (FGE) for yearling spring chinook salmon (Oncorhynchus tshawytscha), coho salmon (O. kisutch), and steelhead (Salmo gairdneri) greater than 70% (Krcma et al. 1980, 1983). Studies of subyearling chinook salmon during the summers of 1982 and 1984 yielded FGEs of 33 to 60% (Krcma et al. 1983, 1985).

In 1986, additional research was conducted to test varying strategies to improve FGE for subyearling chinook salmon. The approach involved lowering an STS 0.83 m (33 inches) to intercept a greater proportion of the deeper traveling subyearlings, raising the operating gate to increase the flow up into the gatewells to minimize deflection of fish under the STS, and using a trashrack deflector (TRD) to guide deeper traveling subyearlings into the influence of the STS (Swan and Norman 1987). These tests showed the TRD provided substantial increases in FGE. The FGE was increased from 39% with a standard STS and stored operating gate to 61% with a lowered STS, raised operating gate, and TRD. An increase in FGE, from 22 to 35%, was measured with the same test conditions but with a stored instead of a raised operating

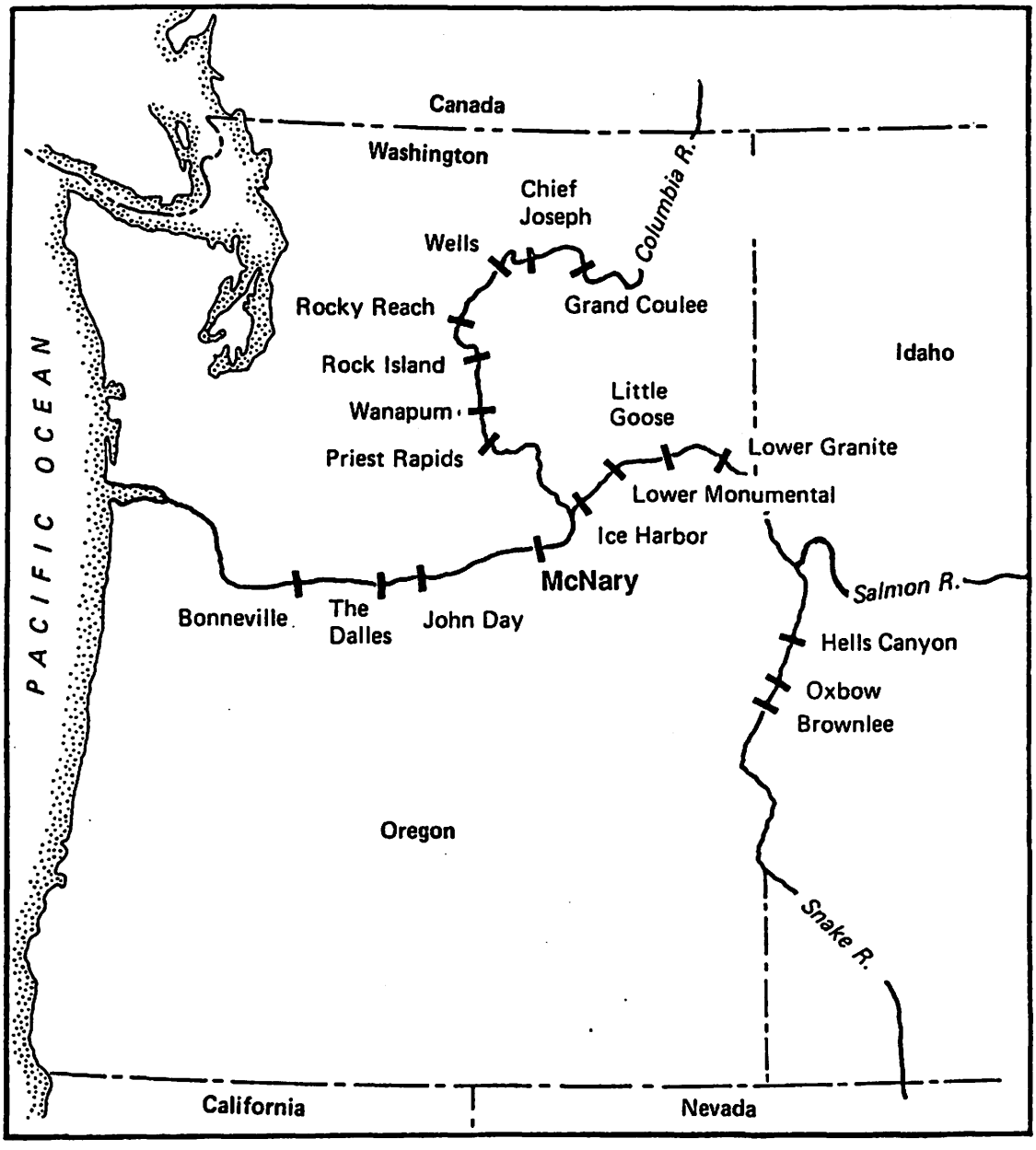

Figure 1. Site location of McNary Dam.

gate. Tests without the TRD, evaluating only the lowered STS or raised operating gate, resulted in no major increases in FGE.

In 1987, the National Marine Fisheries Service (NMFS) continued research at McNary Dam to assess increases in FGE from a lowered STS, raised operating gate, and TRD with yearling spring chinook salmon and subyearling fall chinook salmon.

OBJECTIVES

The 1987 tests during the yearling and subyearling chinook salmon migrations had the following objectives:

1A) Determine bias between Slots 5A and 5B.

1B) Determine the benefits/impacts of the TRD on FGE of yearling chinook salmon.

2A) Determine the benefits of a TRD with and without a lowered STS and raised operating gate on FGE of subyearling chinook salmon.

2B) Determine the benefits of a raised operating gate on FGE of subyearling chinook salmon.

3) Measure diurnal FGE in conjunction with nocturnal FGE to provide an estimate of diel FGE and overall STS effectiveness.

MATERIALS AND METHODS

Experimental Equipment

The following equipment was used to conduct the research:

1) Two standard STSs equipped with frames for suspending two gap, two closure, and five fyke nets (Fig. 2)(Ossiander[1]).

2) Two lowered STSs [modified to intercept fish 0.83 m (33 inches) deeper in the intake than a standard STS] equipped with frames for suspending two gap, two closure, and five fyke nets.

3) One fyke net frame equipped with eight fyke nets for determining vertical distribution of salmonids passing through the turbine intake (Fig. 3).

4) Balanced flow vertical barrier screens in all test gatewells.

5) One trashrack deflector in Slot 5B.

6) One gatewell dip basket net (Swan et al. 1979).

7) Six fish handling carts for holding and on-deck transport of live fish dipped from the gatewells.

8) Fish examining facilities.

9) One mobile crane.

The COE provided the following equipment and services:

1) Gantry cranes for preparation and conduct of vertical distribution and FGE tests.

2) Assistance in positioning STS fyke net frames, field buildings, fish handling facilities, and the trashrack deflector.

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[1] Memo, 10 March 1986, F. Ossiander to T. Barila, COE. "Comparisons of center and side net catches from FGE and vertical distribution tests", justifies why a single column of fyke nets is considered adequate to sample the area under the STS.

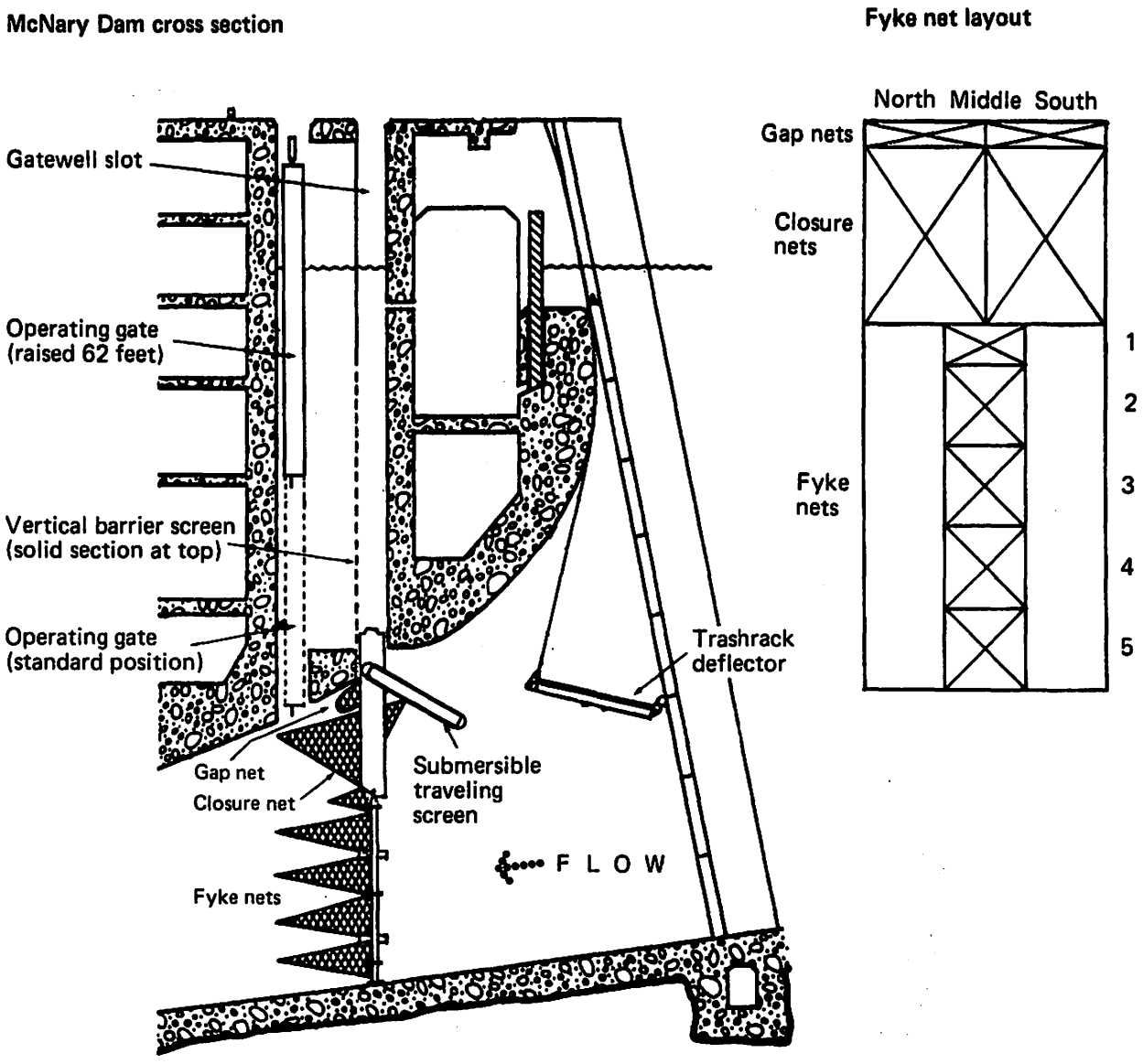

Figure 2. Cross section of turbine intakes at McNary Dam showing STS, trashrack deflector, fyke nets, and varying positions of operating gates for FGE testing in 1987.

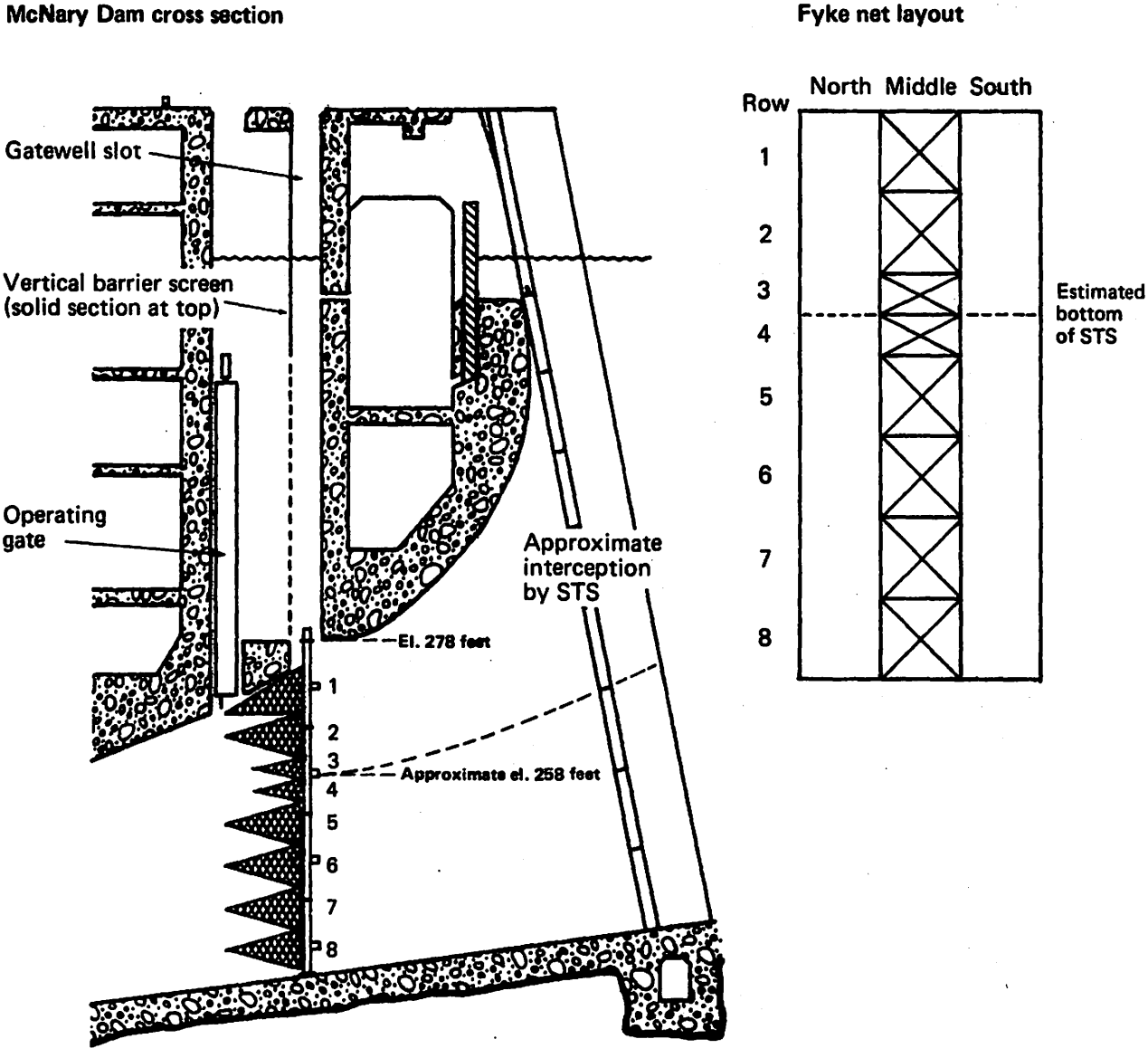

Figure 3. Fyke net frame, nets, and layout at McNary Dam for measurement of vertical distribution of subyearling fall chinook salmon entering a turbine intake in 1987.

Measurements and Procedures

Vertical distribution measurements and FGE tests were conducted at McNary Dam between mid-May and the end of July 1987. Vertical distribution measurements were taken in Slot 5C, and FGE tests were conducted in Slots 5A and 5B. Slot 8B was monitored for diel passage by hourly gatewell dipnetting.

A typical fish guiding efficiency test sequence was as follows:

1) All fish were removed from the gateslot using a dipbasket.
2) The STS with attached fyke net frames was lowered into position with the gantry crane (turbine off).
3) Unit 5 was brought to full power/generating capacity (80 MW). The STSs were operated in the standard cycling mode of 4 minutes on alternated with 24 minutes off.
4) The number of fish entering the gatewell of the test unit was monitored by periodic dipnetting.
5) The test was terminated when an estimated 250 fish (total) were collected.
6) The turbine was shut down, and the remaining gatewell fish were removed.
7) The STS with attached frame and nets was brought to the intake deck, and fish were removed from the nets for identification and enumeration.

The methods for determining FGE were similar to those used in previous FGE tests (Swan et al. 1983). Gatewell dipnet catches provided the number of guided fish; catches from the gap, closure, and fyke nets provided data for estimating the number of unguided fish. FGE was calculated as gatewell catch divided by the total number of fish passing through the intake during the test period:

$$\text{FGE \%} = \frac{\text{gatewell catch}}{\text{gatewell catch + adjusted total net catch}} \text{ X } 100$$

where: adjusted total net catch = gap net catch + closure net catch + center row fyke net catch X 3.

Vertical distribution measurements were taken to verify the depth that fish enter the turbine unit and to determine theoretical fish guiding efficiency (TFGE). A large net frame with eight fyke nets attached was lowered into the bulkhead slot prior to the evaluation (Fig. 3). Fyke nets in Levels 1,2,5,6,7, and 8 were the standard 2.0 m square while those in Levels 3 and 4 were 1.0 by 2.0 m. Only the center one-third of the turbine intake was fished as in the FGE tests. During the measurement period, fish entering the gatewell were periodically dipnetted, identified, and enumerated. At the conclusion of the measurement period, the net frame was removed from the gate slot, and the fish were removed from each net, identified, and enumerated.

Theoretical fish guiding efficiency (TFGE) was calculated as follows:

$$\text{TFGE\%} = \frac{\text{gatewell catch + adjusted fyke net catches in 1,2, and 3}}{\text{gatewell catch + adjusted total net catch}} \text{ X } 100$$

where: adjusted total net catch = center row fyke net catch X 3.

The FGE and TFGE were used to calculate STS effectiveness. The STS effectiveness was derived by dividing FGE by TFGE. For example: if FGE = 50% and TFGE = 60% then STS effectiveness equals 83.3%. The STS effectiveness

provided a means to compare different test conditions when the vertical distribution (TFGE) varied through time.

Descaling of fish in the gatewells was monitored as a measure of fish condition for each FGE and vertical distribution test. Descaling was determined by dividing each side of the fish into five equal areas, and if any two areas on a side were 40% or more descaled, the fish was classified as descaled.

RESULTS

TRD Benefits/Impacts to Yearling Chinook Salmon (Objective 1)

Prior to the trashrack deflector (TRD) tests, FGEs for yearling chinook salmon were measured in Slots 5A and 5B to determine if any slot bias existed (Objective 1A). This was necessary because only one trashrack deflector was available, and it could not be moved between slots to permit a cross-over test design.

There was no statistically significant difference between FGEs for yearling chinook salmon in Slots 5A and 5B during the initial 4-day trial (18 to 21 May) for slot bias (Table 1). Non-target species had similar FGE values in both slots, although the numbers of coho salmon, steelhead, and subyearling chinook salmon captured in the tests were lower than the target estimate (250 fish) during the May period. However, errors in measurements of FGE due to low numbers were considered minimal because the values were comparable to what we would expect and have seen in the past.

The planned 5-day FGE test series to compare the TRD in Slot 5B to a standard condition in Slot 5A with yearling chinook salmon (Objective 1B) was not completed due to large numbers of sockeye salmon in the test intakes beginning the second day (25 May). To minimize sockeye salmon mortality, this

Table 1.--Mean FGE and TFGE for yearling chinook salmon and associated salmonid catch during slot bias tests at McNary Dam, 18-21 May 1987.

Species	Slot 5A FGE[a] (%)	Slot 5B FGE[a] (%)	Slot 5C TFGE[b] (%)	STS effect.[c] (%)
Yr. chinook	86	83	91	87
Steelhead	83	83	89**	98**
Sockeye	73	71	69	94
Coho	86**	86**	72**	131**
Subyr. chinook	20**	25**	48**	69**

[a] Test conditions in Slots 5A and 5B were STS lowered 0.83 m (33 in) and raised operating gate dogged off at deck level. Pooled average of four tests.

[b] Results of a single vertical distribution test on 20 May.

[c] STS effectiveness = FGE/TFGE
Calculation made on day of TFGE test.

** Small sample size (<250 fish).

series was terminated. Observation from the 2 days of tests (22 and 25 July) gave no indication of an adverse or beneficial impact on FGE in the test slot with the TRD for any species.

Vertical distribution was tested in Slot 5C on 1 day only (20 May) as a measure of TFGE for Objective 1. The STS effectiveness (FGE/TFGE) for the different species was calculated using FGE measured in either Slot 5A or 5B depending on which slot contained the most fish of a given species on that day. The high STS effectiveness values, with the exception of subyearling chinook salmon, indicated that nearly all salmonids assumed to be guidable (based on vertical distribution measurements) were intercepted by the STS and guided into the gatewells. The value obtained for coho salmon was likely due to low numbers of fish in the test, and it could not exceed 100%.

TRD Benefits to Subyearling Chinook Salmon (Objective 2)

The FGE tests from 27 June to 10 July (no testing on 3 and 4 July) involved only subyearling chinook salmon. Adequate numbers for this species were present for all FGE tests. No significant differences were detected between FGEs measured with any of the test condition comparisons ($P > 0.05$)(Table 2) (Objective 2A). Mean FGE values were not meaningful because of the large variation in FGEs (range 7 to 78%) during this test series (Fig. 4). No significant differences occurred between the standard STS compared to the standard STS with TRD and the lowered STS compared to the lowered STS with TRD when tests were run on the same days, whereas in 1986, the TRD showed a substantial increase of 13 to 22% in FGE (Swan and Norman 1987). There was also no benefit shown with the lowered STS compared to the standard STS when consecutive days tests were paired.

Table 2.--Comparison of FGE test conditions at McNary Dam, 27 June - 10 July 1987.

Comparison[a]	Slot 5A		Slot 5B		Prob.[d]	Sign.[e]
	SSTS[b] range (%)	LSTS[c] range (%)	SSTS w/TRD range (%)	LSTS w/TRD range (%)		
1[f]	18-73	7-72	---	---	>0.10	NS
2[f]	---	---	18-78	22-65	>0.10	NS
3[g]	---	7-72	---	23-65	>0.10	NS
4[g]	18-73	---	18-78	---	>0.10	NS

[a] Test conditions in both slots were with raised operating gates and balanced flow vertical barrier screens.

[b] Standard STS

[c] Lowered STS

[d] Probability of obtaining such a difference between treatments using a Wilcoxon distribution-free signed rank test (Hollander and Wolfe 1973).

[e] NS indicates no significant difference between treatments.

[f] Consecutive day pairings of FGE in the same slot.

[g] Same day pairings of FGE in Slots 5A and 5B.

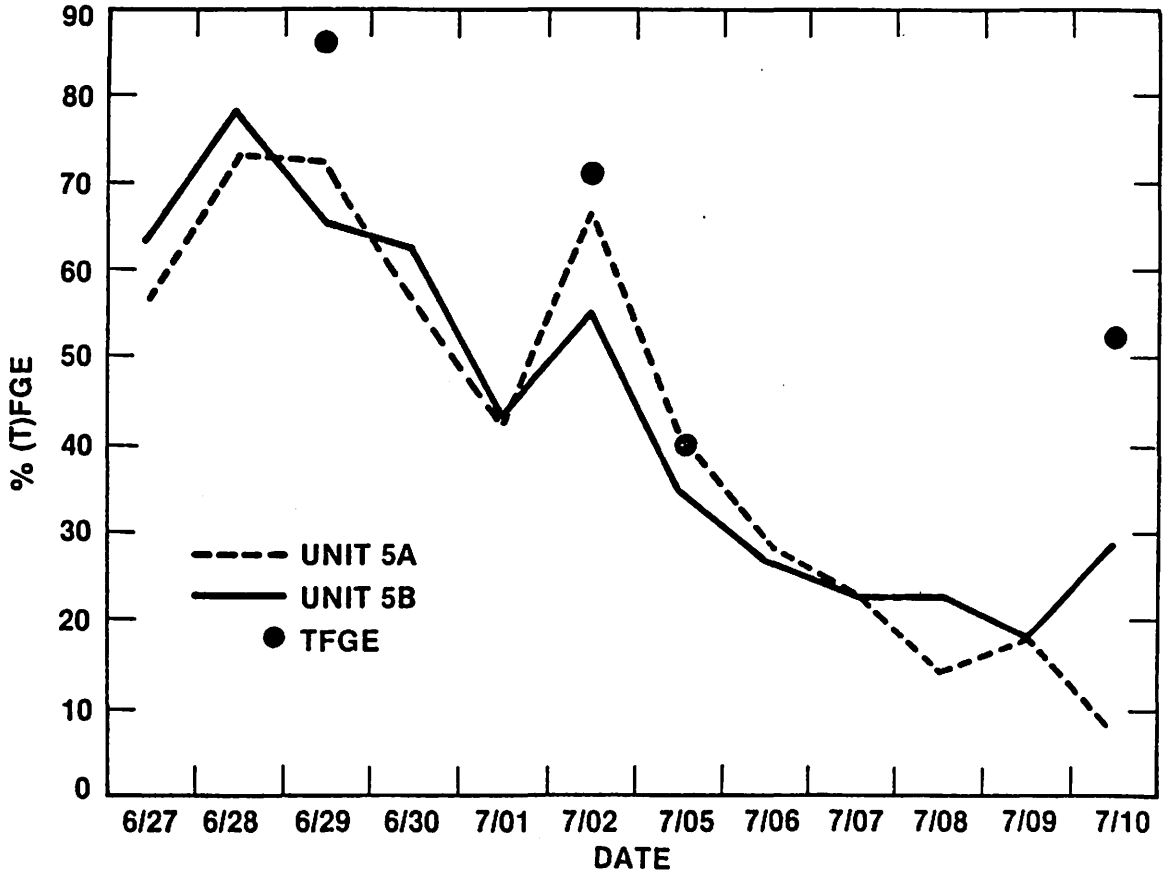

Figure 4. Fish guiding efficiency (FGE) and theoretical FGE at McNary Dam, 1987.

Vertical distribution was measured simultaneously with FGE tests conducted on 29 June and 2, 5, and 10 July. Measurements were taken in Slot 5C with a stored operating gate during the first three tests and in Slot 6B during the last test. The mean TFGE was 63% compared to 47% FGE measured in Slot 5A (w/o TRD) on these same days. The STS effectiveness was 75%, indicating that 25% of the subyearling chinook salmon available for guiding were deflected around or under the STS.

On the 3 days when vertical distribution was measured in Slot 5C, FGEs measured concurrently in Slot 5B with the TRD were less than FGEs in Slot 5A without the TRD. This was opposite the results obtained when FGE tests in Slots 5A and 5B were conducted with a standard STS in Slot 5C rather than a vertical distribution net frame (Fig. 4). Removing the STS from Slot 5C and replacing it with a fyke net frame apparently influenced fish in the adjacent Slot 5B to move to Slot 5C. Although there was no significant difference in results when these 3 days were deleted from the analysis, we nonetheless suggest that TFGE tests be measured in a unit separate from the FGE test unit.

Tests (Objective 2B) to determine guidance levels with a stored operating gate, lowered STS, and TRD were scheduled to begin in mid-July, but were postponed due to increased mortality of downstream migrants arriving at the project. The mortality was hypothesized to be related to thermal shock resulting from sudden changes in water temperature within the juvenile collection system. Standard turbine operations at the dam for this time of year involved operation of a block of turbine units on the north end of the powerhouse near the center of the river (Eby[2]). When sporadic operation of

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[2] Brad Eby, U. S. Army Corps of Engineers, McNary Dam Project, P. O. Box 1441, Umatilla, OR 97882, pers. commun.

additional turbine units occurred, as during FGE testing, there was an infusion of warm water into the collection system. Before this problem could be solved, the numbers of subyearling chinook salmon decreased below levels needed to obtain adequate tests . When adequate fish numbers were again present, about 21 July, a decision was made to proceed with diel testing, as the migration was nearing completion.

Diel FGE Studies (Objective 3)

Four replicates of diurnal and nocturnal FGEs were conducted in Slot 5B equipped with a lowered STS, raised operating gate, and TRD on 21, 22, 29, and 30 July (dates of night tests). Nocturnal FGE averaged 46% (Appendix A6), and the diurnal FGE was 85% for the one test with adequate numbers of fish. The diurnal tests with too few fish (< 30) also indicated a higher daylight FGE (22 July, 58% and 31 July, 85%).

Diel vertical distribution of total fish passage into the turbine intake was not determined but instead, the diel entrance into Gatewell Slot 8B was monitored every hour during three of the four FGE tests (Fig. 5). Approximately 87% of the diel movement of subyearling chinook salmon into the turbine intake occurred at night (2100 to 0500 hours). Data were not obtained on 29 July because Unit 8 was inadvertently shut down by the project for several hours and therefore we were unable to get complete diel measurements.

An approximation of diel FGE (under the conditions tested) was calculated using a nocturnal FGE of 46% (average of three replicates) and a diurnal FGE of 85% (only one replicate). Assuming approximately 85% of subyearling chinook salmon entered the turbine intakes during the night, diel FGE was calculated to be about 52% [(46% x 85%) + (85% x 15%) = 52%]. Similar differences in day and

DIEL GATEWELL CATCH, McNARY DAM, 1987

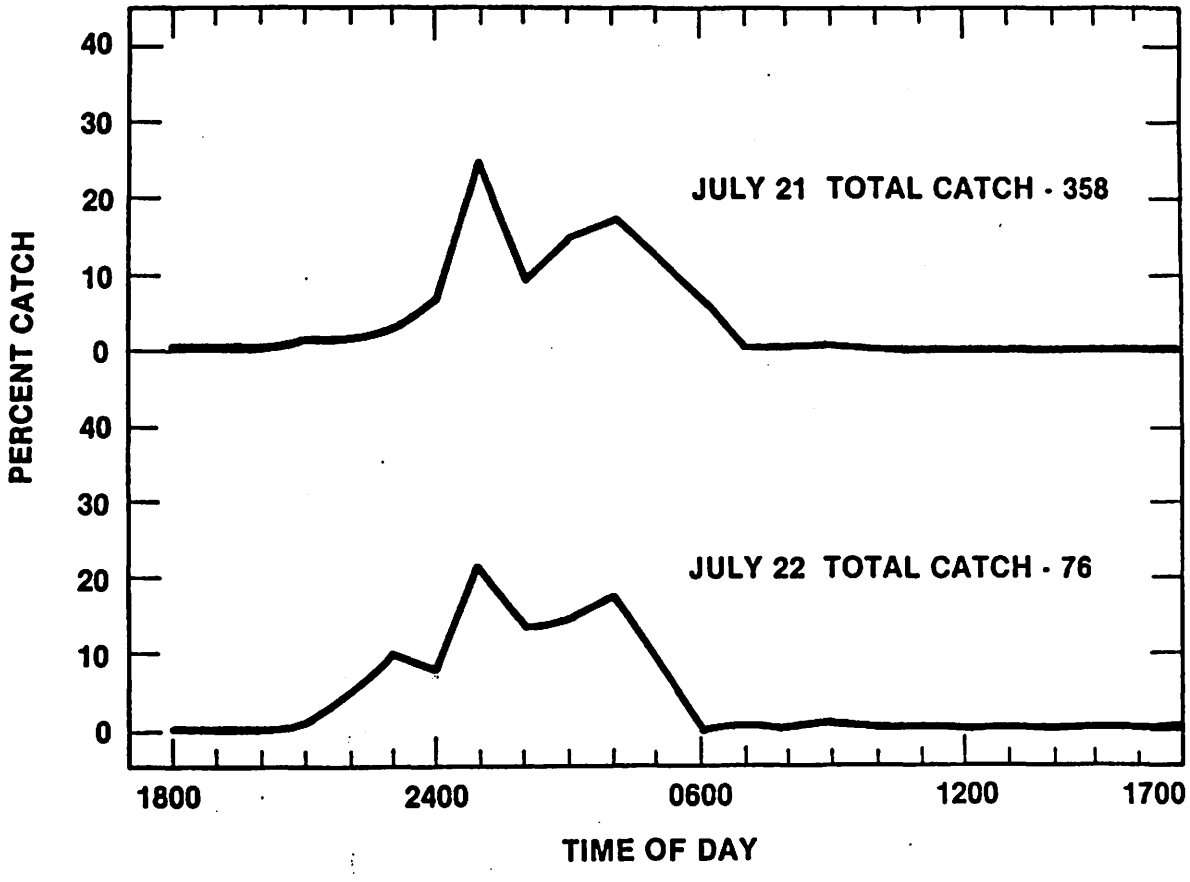

Figure 5. Hourly gatewell dipnet catch, Unit 8B, McNary Dam, 1987.

night FGE were found in 1986 by Swan and Norman (1987), although the FGE values were lower, 69 and 26%, respectively.

Fish Quality

Fish condition was good throughout the subyearling test sequence. Subyearling descaling averaged 5.0% for FGE tests without a trashrack deflector (TRD) and 4.5% for FGE tests with a TRD.

DISCUSSION

In 1986, the TRD significantly improved FGE for subyearling chinook salmon when tested in gateslots with nearly identical conditions. During the period 21 to 25 July, FGE averaged 35% (range 29 to 42%, n=5) in Slot 5B with a TRD and lowered STS versus 21.5% (range 15 to 28%) in Slot 5A with a standard STS and no TRD (Swan and Norman 1987). However in 1987, no benefit was gained from the TRD for either yearling or subyearling salmonids. River flow during the test season in 1987 was the lowest since 1977 (a record drought year) (Fig. 6) whereas river flow during the 1986 season was near average. River flow may have been a factor in the 1987 FGE results. With the lower flow in 1987 there were lower turbidities and higher water temperatures, which may have caused the subyearling chinook salmon to migrate deeper in the water column, below the level at which the TRD was capable of deflecting flows and fish into the influence of the STS. Although low flows at McNary Dam during 1987 may have been a factor, the true cause and effect of the dissimilar FGE results between years are unknown.

Vertical distribution measurements and derived TFGEs for subyearling chinook salmon in 1987 were not improved from those found during previous research at McNary Dam (Krcma et al. 1983, 1985). The maximum FGE for these fish appears to be approximately 65% if 100% of TFGE was realized. However,

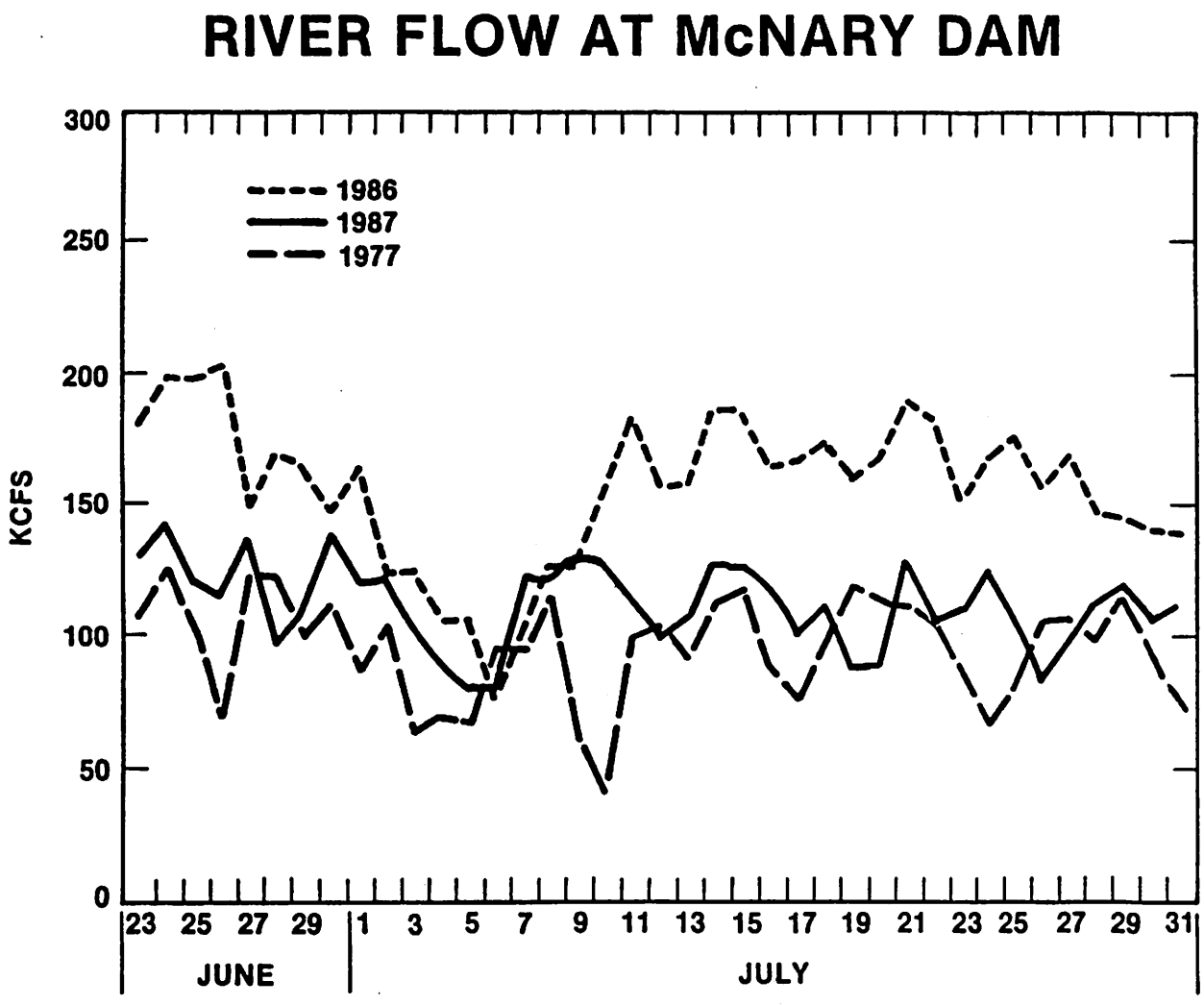

Figure 6. River flow at McNary Dam, 1977, 1986, and 1987.

under our best conditions, we have not guided more than 75% (STS effectiveness) of what is assumed to be the TFGE. These results are not unique to McNary Dam. At John Day and Bonneville dams (Second Powerhouse), it was found that TFGEs were 40 and 43%, respectively, and STS effectivenesses were 53 and 52%, respectively (Krcma et al. 1986, Gessel et al. 1987).

The equipment we tested in 1987 included an 18.8-m (62-foot) raised operating gate, 0.83-m (33-inch) lowered STS, and a TRD. The TRD and lowered STS did not improve FGE. We did not test the raised operating gate against a standard gate, however, FGEs obtained on yearling fish with a raised operating gate were nearly the same as those found in 1982 when a raised gate was tested (Krcma et al. 1983). Raised operating gates have also significantly increased FGEs at other Snake River projects. Based on research to date, we do not recommend lowered STSs or TRD but do recommend raising the operating gates. An approximation of obtainable FGEs with raised operating gates are 86% for spring chinook salmon, 83% for steelhead, and between 25 and 50% for subyearling chinook salmon. A range is given for subyearling chinook salmon because test results have been extremely variable within and between years (FGE range of 7 to 78%).

CONCLUSIONS

1) The trashrack deflector and lowered STS provided no statistically significant increase in FGEs during the 1987 tests.
2) During daylight hours, FGE (under the conditions tested) was higher than during hours of darkness. This was consistent with findings in 1986. However, in general, only about 15% of the fish pass the project during the day.

3) The FGE rises and falls with TFGE. Under normal conditions, with the equipment configurations we tested, average FGEs of 86% for spring chinook salmon, 83% for steelhead, and 25-50% for subyearling chinook salmon are obtainable.

4) Future FGE and vertical distribution studies should be done in separate units. Vertical distribution studies would ideally be done with no STSs in adjacent slots.

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APPENDIX

Data Tables

Appendix Table A1.--Catch data and fish guiding efficiency (FGE) from submersible traveling screen evaluation studies in turbine Unit 5, Slot A, McNary Dam, 18-25 May 1987.

Date[a/]	Time Start (h)	Time End (h)	Spp.[b/]	Nets[c/] LG	RG	LC	RC	M1	M2	M3	M4	M5	Adj. tot.[d/]	Gatewell catch	FGE[e/] (%)
5/18	2000	2143	5	4	2	3	5	5	4	1	0	0	44	378	89.6
			6	0	0	1	1	3	1	0	0	0	14	138	90.8
			1	6	5	15	7	2	7	2	0	0	66	286	81.3
			4	1	0	1	0	0	1	0	0	0	5	98	95.1
			9	11	0	0	1	0	1	3	0	0	24	6	----
5/19	2000	2215	5	2	0	3	2	2	2	0	2	0	25	301	92.3
			6	1	0	2	0	1	3	0	1	1	21	113	84.3
			1	0	0	5	1	5	2	3	0	0	36	129	78.2
			4	0	0	0	0	0	0	0	0	0	0	46	----
			9	0	0	0	1	1	2	2	0	0	16	4	----
5/20	2000	2400	5	0	0	5	5	6	5	2	0	0	49	193	79.8
			6	0	0	1	2	0	7	3	0	0	33	109	76.8
			1	1	0	14	11	1	19	10	0	0	116	203	63.8
			4	0	0	1	1	1	0	3	0	0	14	64	82.1
			9	1	0	0	4	2	11	5	11	0	92	46	33.3
5/21	2000	2400	5	4	1	6	3	18	7	0	1	0	92	425	82.2
			6	0	0	3	1	3	2	1	0	0	22	80	78.4
			1	0	1	12	9	3	19	5	0	0	103	239	69.9
			4	0	0	3	0	2	4	1	0	0	24	62	72.1
			9	2	1	4	4	10	64	19	4	0	302	23	7.1
5/22	2020	0020	5	2	3	3	7	1	12	0	0	0	54	450	89.3
			6	0	0	2	0	1	4	0	0	0	17	122	87.8
			1	0	0	13	6	6	30	10	2	1	166	345	67.5
			4	0	0	1	0	0	0	1	0	0	4	104	96.3
			9	15	6	8	10	10	47	16	9	0	285	44	13.4
5/25	2007	0020	5	0	0	6	4	2	3	2	0	0	31	67	68.4
			6	0	0	1	0	1	1	0	0	0	7	91	92.9
			1	11	8	269	222	239	1,086	810	343	12	7,980	1,190	13.0
			4	0	0	6	0	8	3	8	1	0	66	94	58.8
			9	2	5	8	4	11	27	29	9	0	247	49	16.6

a/ Month/day
b/ Species codes: 1=sockeye salmon, 4=coho salmon, 5=yearling chinook salmon, 6=steelhead, 9=subyearling chinook salmon
c/ Net codes: 1st character, L=left, M=middle, R=right
2nd character, G=gap, C=closure
1-5=fyke net level (Fig. 2)
d/ Adjusted total = RG+LG+RC+LC+3(M1+M2+M3+M4+M5)
e/ FGE = Gatewell catch/(Gatewell catch + Adjusted Total) X 100
---- denotes insufficient sample size.

Appendix Table A2.-- Catch data and fish guiding efficiency (FGE) from submersible traveling screen evaluation studies in Turbine Unit 5, Slot B, McNary Dam, 18-25 May 1987.

Date[a/]	Time		Spp.[b/]	Nets[c/]									Adj. tot.[d/]	Gate-well catch	FGE[e/] (%)
	Start (h)	End (h)		LG	RG	LC	RC	M1	M2	M3	M4	M5			
5/18	2000	2143	5	0	3	1	4	0	1	0	0	1	14	236	94.4
			6	0	0	2	0	2	4	0	0	2	26	72	73.5
			1	4	6	4	4	0	2	5	0	1	42	266	86.4
			4	0	0	0	0	0	0	0	0	0	0	54	----
			9	2	3	3	1	0	0	1	1	0	15	5	----
5/19	2000	2215	5	9	9	1	9	2	6	1	0	0	55	310	84.9
			6	2	0	0	1	1	2	2	0	0	18	122	87.1
			1	3	10	12	3	2	6	2	0	0	58	177	75.3
			4	0	2	0	0	4	1	0	0	0	17	51	75.0
			9	9	6	0	0	4	2	2	0	0	39	3	----
5/20	2000	2400	5	7	6	8	6	9	3	2	0	0	69	260	79.0
			6	3	3	1	0	2	6	1	0	0	34	217	86.5
			1	7	6	18	15	4	24	1	1	0	136	253	65.0
			4	0	4	0	0	0	0	0	0	0	4	75	94.9
			9	9	14	1	0	3	10	1	3	1	78	36	31.6
5/21	2000	2400	5	5	10	4	6	10	4	1	2	0	76	220	74.3
			6	2	1	0	0	4	4	0	1	1	33	130	79.8
			1	9	16	10	9	4	23	3	1	0	137	185	57.5
			4	2	1	1	0	0	3	2	1	0	22	82	78.8
			9	50	39	14	4	28	45	11	16	3	416	96	18.8
5/22[f/]	2020	0020	5	1	6	4	9	2	3	1	0	0	38	236	86.1
			6	1	0	1	2	0	4	1	1	0	22	163	88.1
			1	6	11	5	14	2	24	14	0	0	156	362	69.9
			4	1	2	0	0	2	4	1	0	0	24	156	86.7
			9	47	51	4	2	14	29	24	4	1	320	56	14.9
5/25[f/]	2007	0020	5	3	3	3	1	1	0	0	0	0	13	74	85.1
			6	1	0	0	3	2	2	0	0	0	16	96	85.7
			1	112	113	195	187	152	698	751	586	29	7,255	1471	16.9
			4	0	1	0	3	1	3	1	0	0	19	80	80.8
			9	43	48	2	2	15	28	21	12	2	329	72	18.0

Appendix Table A2.--Continued.

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a/ Month/day
b/ Species codes: 1=sockeye salmon, 4=coho salmon, 5=yearling chinook salmon, 6=steelhead, 9=subyearling chinook salmon
c/ Net codes: 1st character, L=left, M=middle, R=right
2nd character, G=gap, C=closure
1-5=fyke net level (Fig. 2)
d/ Adjusted total = RG+LG+RC+LC+3(M1+M2+M3+M4+M5)
e/ FGE = Gatewell catch/(Gatewell catch + Adjusted Total) X 100
---- denotes insufficient sample size.
f/ TRD at 35-degree angle.

Appendix Table A3.--Catch data and fish guiding efficiency (FGE) from submersible traveling screen evaluation studies in Turbine Unit 5, Slot A, McNary Dam, 27 June - 10 July 1987.

Date[a] Cond.	Time Start (h)	Time End (h)	Spp.[b]	Nets[c] LG	RG	LC	RC	M1	M2	M3	M4	M5	Adj. Tot.[d]	Gate-well catch	FGEe (%)
6/27	2000	2122	5	0	0	0	0	1	0	0	0	0	3	9	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	0	0	66	70	40	100	29	10	0	673	859	56.1
6/28	2000	2054	5	0	0	2	1	1	2	0	1	0	15	26	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	5	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	27	26	42	31	22	37	3	1	0	315	843	72.8
6/29	2000	2035	5	0	0	1	0	0	1	0	1	0	7	25	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	4	----
			1	0	0	0	0	0	1	0	0	0	3	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	1	0	91	105	68	91	18	1	0	731	1,864	71.8
6/30	2000	2034	5	0	0	1	1	0	0	0	1	0	5	10	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	3	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	1	----
			9	43	61	95	132	76	161	50	12	0	1,228	1,514	55.2
7/1	2000	2035	5	0	0	0	1	1	0	2	0	0	10	11	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	1	0	0	3	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	1	0	146	133	77	173	35	6	0	1,153	833	41.9
7/2	2000	2100	5	0	0	0	0	0	1	0	0	0	3	12	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	5	6	38	17	11	34	10	1	1	237	457	65.9
7/5	2000	2335	5	0	0	1	0	0	3	0	0	0	10	4	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	2	0	0	6	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	7	5	67	58	32	100	34	5	1	653	464	41.5

Appendix Table A3.--continued

7/6	2000	2305	5	0	0	2	7	4	7	4	0	0	54	16	22.9
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	0	0	63	71	36	131	53	10	0	824	332	28.7
7/7	2030	2320	5	0	0	4	1	1	10	5	3	0	62	23	27.1
SSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	3	2	62	47	28	145	87	19	1	954	285	23.0
7/8	2010	2335	5	0	0	2	2	0	6	1	1	0	28	6	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	0	0	35	39	20	117	81	15	0	773	128	14.2
7/9	2000	2300	5	0	0	0	1	2	2	2	0	0	19	8	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	1	6	63	65	25	204	176	6	1	1,371	301	18.0
7/10	2035	2240	5	0	0	0	0	0	6	3	7	2	54	7	11.5
LSTS			6	0	0	0	0	0	0	0	0	0	0	3	----
			1	0	0	0	1	0	0	0	0	0	1	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	3	4	244	194	137	555	642	512	70	6,193	486	7.3

a/ Month/day
Test condition codes: SSTS=standard length STS
LSTS=33 inch lowered STS

b/ Species codes: 1=sockeye salmon, 4=coho salmon, 5=yearling chinook salmon, 6=steelhead, 9=subyearling chinook salmon

c/ Net codes: 1st character, L=left, M=middle, R=right
2nd character, G=gap, C=closure
1-5=fyke net level (Fig. 2)

d/ Adjusted total = RG+LG+RC+LC+3(M1+M2+M3+M4+M5)

e/ FGE = Gatewell catch/(Gatewell catch + Adjusted Total) X 100

---- denotes insufficient sample size.

Appendix Table A4.-- Catch data and fish guiding efficiency (FGE) from submersible traveling screen evaluation studies in Turbine Unit 5, Slot B, McNary Dam, 27 June - 10 July 1987. (Trashrack deflector set at 35° angle).

Date/[a] Cond.	Time Start (h)	Time End (h)	Spp.[b]	Nets[c] LG	RG	LC	RC	M1	M2	M3	M4	M5	Adj. tot.[d]	Gate-well catch	FGE[e] (%)
6/27	2000	2122	5	0	0	0	0	0	0	0	0	0	0	6	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	9	14	30	43	22	58	14	6	1	399	690	63.4
6/28	2000	2054	5	0	0	0	0	0	1	0	0	0	3	18	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	3	----
			1	0	0	0	0	0	0	0	0	0	0	1	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	16	23	18	25	14	10	5	0	0	169	602	78.1
6/29	2000	2035	5	0	0	0	0	1	2	0	0	0	9	9	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	1	----
			4	1	0	0	0	0	0	0	0	0	1	0	----
			9	53	58	52	49	28	38	13	1	0	452	850	65.3
6/30	2000	2034	5	1	0	0	0	0	0	0	0	0	1	7	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	19	27	46	53	33	64	17	7	1	511	835	62.0
7/1	2000	2035	5	0	0	1	0	0	0	0	0	0	1	10	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	25	28	49	77	37	94	30	3	0	671	512	43.3
7/2	2000	2100	5	1	0	0	0	1	0	0	0	0	4	10	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	2	5	23	23	14	35	12	4	0	248	304	55.1
7/5	2000	2335	5	0	0	2	2	1	0	2	0	0	13	7	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	8	2	28	28	24	74	59	11	0	570	306	34.9

Appendix Table A4.--continued.

7/6	2000	2305	5	1	1	6	1	2	5	3	1	0	42	20	32.3
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	1	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	9	5	39	41	29	104	42	9	1	649	230	26.2
7/7	2030	2320	5	0	0	2	4	2	4	7	1	1	51	23	31.1
SSTS			6	0	0	0	1	0	0	0	0	0	1	0	----
			1	0	0	0	0	0	0	0	0	0	0	1	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	0	1	18	32	18	144	112	37	4	996	283	22.1
7/8	2010	2335	5	0	0	2	2	1	8	4	0	0	43	22	33.8
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	1	0	3	1	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	0	2	59	40	33	111	71	21	0	809	237	22.7
7/9	2000	2300	5	0	0	1	0	0	0	0	2	0	7	8	----
SSTS			6	0	0	0	0	0	0	0	0	0	0	3	----
			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	1	----
			9	1	1	38	35	16	161	143	56	3	1,212	264	17.9
7/10	2035	2240	5	0	0	1	1	0	4	3	2	0	29	13	31.0
LSTS			6	0	0	0	0	0	0	0	0	0	0	1	----
			1	0	0	0	0	0	0	0	0	0	0	4	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	21	13	104	108	40	183	128	78	14	1,575	632	28.6

a/ Month/day
Test condition codes: SSTS=standard length STS
LSTS=33 inch lowered STS

b/ Species codes: 1=sockeye salmon, 4=coho salmon, 5=yearling chinook salmon, 6=steelhead, 9=subyearling chinook salmon

c/ Net codes: 1st character, L=left, M=middle, R=right
2nd character, G=gap, C=closure
1-5=fyke net level (Fig. 2)

d/ Adjusted total = RG+LG+RC+LC+3(M1+M2+M3+M4+M5)

e/ FGE = Gatewell catch/(Gatewell catch + Adjusted Total) X 100

---- denotes insufficient sample size.

Appendix Table A5.-- Catch data and theoretical fish guiding efficiency (TFGE) from vertical distribution studies in Turbine Unit 5, Slot C, McNary Dam, 29 June - 10 July 1987.

Date[a/]	Time Start (h)	Time End (h)	Spp.[b/]	Nets[c/] M1	M2	M3	M4	M5	M6	M7	M8	Tot.[d/]	Gate-well catch	TFGE[e/] (%)
6/29	2000	2035	5	0	0	0	0	0	0	0	0	0	2	----
			6	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	----
			9	44	45	18	12	6	2	1	0	384	72	86.2
7/2	2000	2100	5	0	0	0	0	0	0	0	0	0	0	----
			6	1	0	0	0	0	0	0	0	3	1	----
			1	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	----
			9	19	29	13	8	13	8	1	0	273	35	70.8
7/5	2000	2335	5	0	0	0	0	1	0	0	0	3	1	----
			6	0	0	0	0	0	0	0	0	0	0	----
			1	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	----
			9	20	48	25	35	48	52	15	6	747	29	39.7
7/10	2035	2240	5	4	2	1	1	1	2	0	0	33	4	----
			6	0	0	0	0	0	0	0	0	0	1	----
			1	1	0	0	0	0	0	0	0	3	0	----
			4	0	0	0	0	0	0	0	0	0	1	----
			9	121	168	88	118	194	61	12	4	2,298	185	53.0**

a/ Month/day
b/ Species codes: 1=sockeye salmon, 4=coho salmon, 5=yearling chinook salmon, 6=steelhead, 9=subyearling chinook salmon
c/ Net codes: 1st character, L=left, M=middle, R=right
1-5=fyke net level (Fig. 3)
d/ Adjusted total = 3(M1+M2+M3+M4+M5+M6+M7+M8)
e/ TFGE = Gatewell catch/(Gatewell catch + Adj. Total) X 100
---- denotes insufficient sample size.
** this data from Slot 6B.

Appendix Table A6.-- Catch data and fish guiding efficiency (FGE) from diel submersible traveling screen evaluation studies in Turbine Unit 5, Slot B, McNary Dam, 21 July - 31 July 1987. (Slot had TRD set at 35 deg. angle)

Date[a] / Cond.	Time Start (h)	Time End (h)	Spp.[b]	Nets[c] LG	RG	LC	RC	M1	M2	M3	M4	M5	Adj. Tot.[d]	Gate-well catch	FGE[e] (%)
7/21	2200	2400	5	0	1	0	4	0	4	1	0	0	20	13	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
Night			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	1	8	33	37	10	31	22	0	0	268	286	51.6
7/22	0600	1200	5	0	0	2	0	0	1	0	0	0	2	3	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
Day			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	0	2	1	2	0	2	1	0	0	14	19	----
7/22	2215	0115	5	1	0	2	0	0	5	0	1	0	21	21	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
Night			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	3	3	8	4	8	14	7	1	0	108	68	38.6
7/29	2330	0100	5	0	0	2	0	1	2	0	0	0	11	4	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
Night			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	1	0	22	39	13	32	11	1	0	233	310	57.1
7/30	0615	0845	5	1	0	0	1	0	1	0	0	0	5	30	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
Day			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	4	2	9	6	4	6	0	0	0	51	292	85.1
7/30	2200	0110	5	0	0	0	1	0	1	3	0	0	13	8	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
Night			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	1	1	36	35	18	48	19	6	0	346	205	37.2
7/31	0615	1310	5	0	0	0	0	0	0	0	0	0	0	0	----
LSTS			6	0	0	0	0	0	0	0	0	0	0	0	----
Day			1	0	0	0	0	0	0	0	0	0	0	0	----
			4	0	0	0	0	0	0	0	0	0	0	0	----
			9	0	0	1	0	1	0	0	0	0	4	22	----

Appendix Table A6.--Continued.

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a/ Month/day
Test condition codes: SSTS=standard length STS
LSTS=33 inch lowered STS

b/ Species codes: 1=sockeye salmon, 4=coho salmon, 5=yearling chinook salmon, 6=steelhead, 9=subyearling chinook salmon

c/ Net codes: 1st character, L=left, M=middle, R=right
2nd character, G=gap, C=closure
1-5=fyke net level (Fig. 2)

d/ Adjusted total = RG+LG+RC+LC+3(M1+M2+M3+M4+M5)

e/ FGE = Gatewell catch/(Gatewell catch + Adj. Total) X 100

---- denotes insufficient sample size.

Appendix Table A7.-- Hourly catch data from gatewell dipnetting, subyearling chinook salmon, Turbine Unit 8, Slot B, McNary Dam, 21-23 July 1987.

Date/time (h)		Hourly catch	% of total	Date/time (h)		Hourly catch	% of total
21	1800	---	---	22	1800	0	0.0
Jul	1900	---	---	Jul	1900	0	0.0
	2000	START	---		2000	0	0.0
	2100	3	.8		2100	1	1.3
	2200	17	4.7		2200	1	1.3
	2300	35	9.8		2300	2	2.6
	2400	28	7.8		2400	5	6.6
22	0100	75	21.0	23	0100	18	23.7
Jul	0200	48	13.4	Jul	0200	7	9.2
	0300	51	14.3		0300	11	14.5
	0400	61	17.1		0400	13	17.1
	0500	32	9.0		0500	9	11.8
	0600	0	0.0		0600	5	6.6
	0700	1	0.3		0700	0	0.0
	0800	ND	0.4		0800	1	1.3
	0900	3	0.4		0900	2	2.6
	1000	ND	0.1		1000	1	1.3
	1100	1	0.1		1100	END	
	1200	ND	0.1				
	1300	1	0.1				
	1400	ND	0.1				
	1500	1	0.1				
	1600	ND	0.1				
	1700	1	0.1			---	---
TOTAL		358	99.8			76	99.9

Start=Beginning of hourly gatewell dipping (preceded by cleanout dipping).
End=Conclusion of hourly gatewell dipping.
ND=No dip made during this time period. Next dip includes catch for this time period.
--- denotes no data for this time period.