Research to Improve Subyearling Chinook Salmon Fish Guiding Efficiency at McNary Dam—1986

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INTRODUCTION

During 1986, personnel of the National Marine Fisheries Service (NMFS), under contract to the Corps of Engineers (COE), conducted research at McNary Dam on the Columbia River (Fig. 1) to develop methods for improving fish guiding efficiency (FGE) of subyearling fall chinook salmon, *Oncorhynchus tshawytscha*, at low-head dams. FGE is an estimate of the percentage of fingerling salmon that are diverted from turbine intakes by submersible traveling screens (STS); once diverted, smolts can be bypassed around hydroelectric dams. The configuration of McNary Dam should allow application of this research to other similar low-head dams located on the Columbia and Snake rivers with poor subyearling FGE (Swan et al. 1982).

Past research by the NMFS has shown FGE for subyearling chinook salmon to be unacceptably low. During FGE testing at McNary Dam in 1982, it was estimated that the FGE for subyearlings migrating in July was 50% compared to 88% for yearling chinook salmon migrating in May (Krcma et al. 1983). During 14 July to 9 August 1984, FGE of subyearlings averaged only 38% (Krcma et al. 1985). Even more alarming, at John Day and The Dalles Dams in July 1985, subyearling FGE ranged from 8 to 20% (Krcma et al. 1986; Monk et al. 1986).

Measures of vertical distribution of fingerlings provide an estimate of theoretical FGE (TFGE). Data collected during the earlier part of the season (16 July) in 1984 at McNary Dam indicated that about 77% of the subyearlings were theoretically available for guiding by the STS (Krcma et al. 1985). However, toward the latter part of the study (2 August), it had dropped to about 59%. It would appear that as the season progressed and water temperatures increased (temperatures were 65° F on 16 July and 70° F on 2 August), the fish entered the intakes more deeply. The deeper distribution

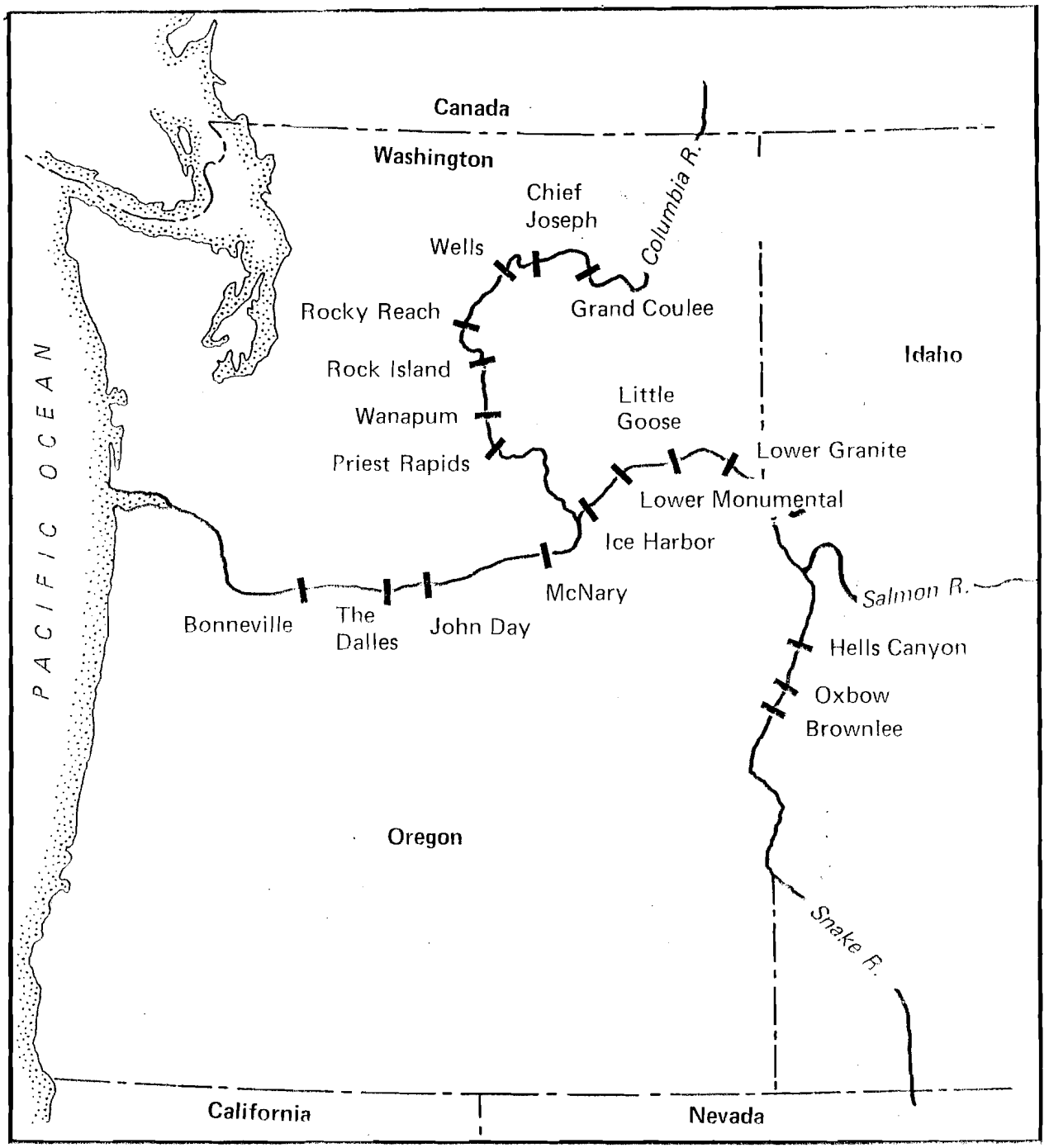

Figure 1.--Main stem dams in the Columbia River Basin.

was even more pronounced in late July of 1985 at John Day Dam when water temperatures were 74° F. Vertical distribution data indicated that only 33% of the subyearlings were high enough in the intake to be intercepted by an STS.

Raising the operating gate to increase flows into the gatewells and minimize deflection of fish under the STS have significantly increased FGE of yearling chinook salmon (Swan et al. 1984), but not subyearling chinook salmon (Krcma et al. 1983). A raised operating gate might provide an increase in FGE of subyearlings when used in combination with other devices or modifications, such as a lowered STS or trashrack deflector, that intercept more of the deeper running subyearlings. Krcma et al. (1979) used a trashrack deflector in addition to a bar screen to intercept more flow and consequently more yearling fish. Gessel et al. (1986) also showed that FGE can be significantly increased by lowering a standard STS 27 inches deeper in the intake unit at Bonneville Dam.

In 1986, we tested various combinations of a lowered STS (33 inches), raised operating gate, and a trashrack deflector at McNary Dam (Fig. 2). Specific objectives were to enhance FGE of subyearlings, measure vertical distribution to provide measures of depth distribution and TFGE, and compare FGE during daylight and nighttime hours near the end of the test season. Descaling of fish was also monitored as a measure of fish condition throughout the testing.

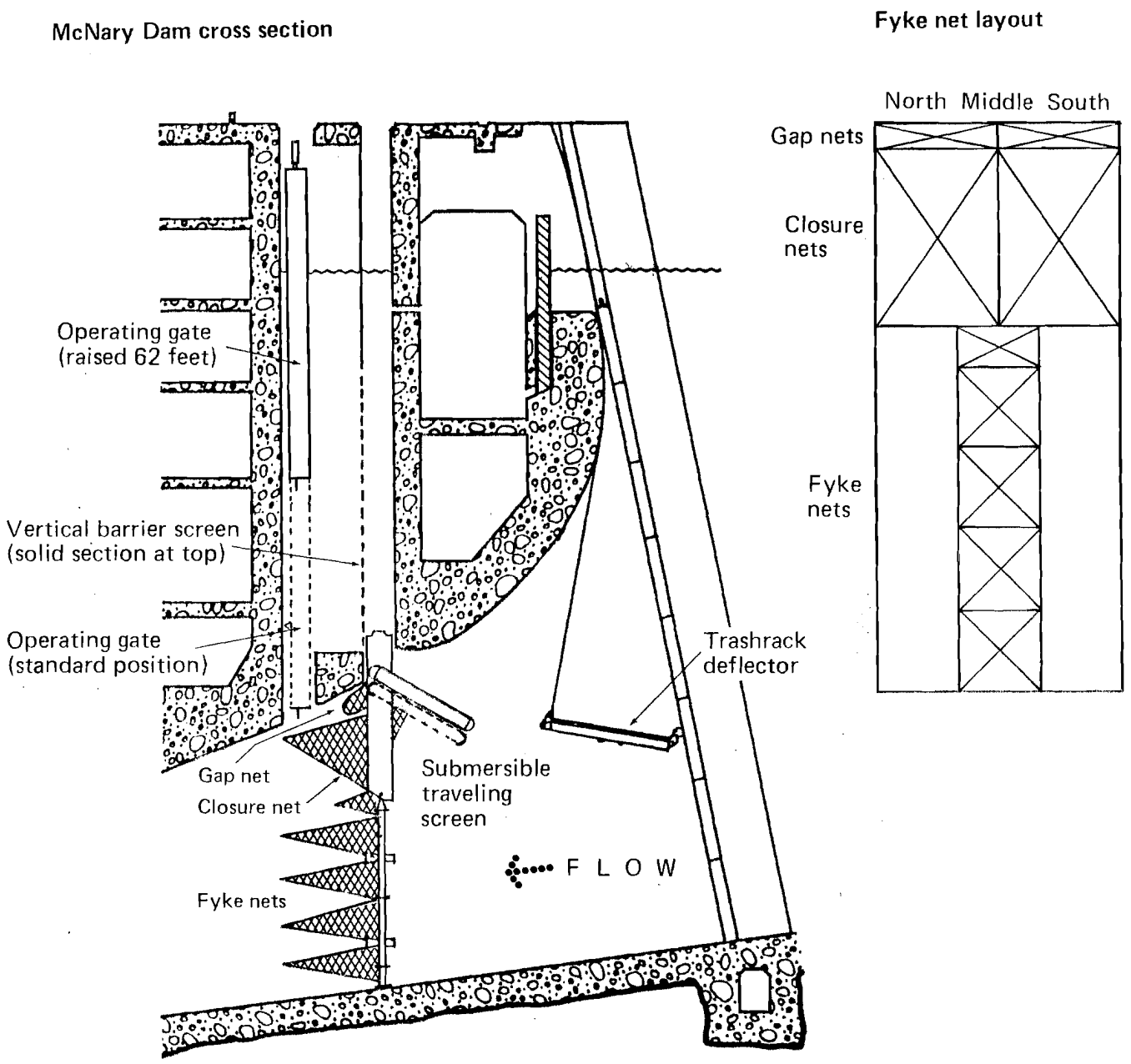

Figure 2.--Cross section of turbine intakes at McNary Dam showing STS, trashrack deflector, fyke nets, and varying positions of operating gates for FGE testing.

METHODS AND MATERIALS

Experimental Equipment

The following equipment was used to conduct the research:

1. One standard STS equipped with frames for suspending two gap, two closure, and five fyke nets.
2. One lowered STS (modified to intercept fish 33 inches deeper in the intake than a standard STS) equipped with frames for suspending two gap, two closure, and five fyke nets.
3. Two fyke net frames, each equipped with seven fyke nets for determining vertical distribution of salmonids passing through the turbine intake.
4. Three balanced flow vertical barrier screens (BFVBS) in Slots 5A, 5B, and 5C.
5. One trashrack deflector.
6. One gatewell dip net (Swan et al. 1979).
7. Six fish 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 services:

1. Gantry cranes for preparation and performance of vertical distribution and STS FGE tests.
2. Assistance in cleaning and positioning the BFVBS and logistics involving positioning of STS fyke net frames, field buildings, fish handling facilities, and the trashrack deflector.

Measurements and Procedures

Vertical distribution and FGE tests were conducted at McNary Dam between late June and early August 1986. Slots 5A, 5B, and 5C were equipped with BFVBSs. Orifices were closed during test conditions in all three slots.

During the test season, Unit 5 was only in service for the duration of each day's test. Testing began at dusk when the turbine was put into service and brought to peak efficiency (80 MW--the turbine load for all tests conducted) Tests continued until adequate numbers of subyearlings for statistical purposes had passed through the testing unit (determined by periodic gatewell dipping)[1/]. Test duration ranged from 1 to 4 hours. A total of six test series were conducted. Each test series contained five replicates with the exception of the diel testing which contained four replicates.

Vertical Distribution

Vertical distribution tests were conducted to verify the depth that fish enter the turbine unit and to determine TFGE. At McNary Dam, this included all fish located in the upper 13 feet of the intake--down to the bottom of the second fyke net (Fig. 3).

Standard methods of determining vertical distribution were utilized (Krcma et al. 1983). The vertical distribution fyke net frame was capable of suspending seven rows and three columns of nets (each approximately 6.5 feet square at the mouth) to cover the entire area of an intake unit (Fig. 3). However, to minimize the sacrifice of fingerlings, only the center column

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[1/] Criterion of 200 to 250 fish per replicate (depending on net coverage) for vertical distribution and FGE tests was extablished at the 11 April 1986 meeting between COE and NMFS biologists and statisticians.

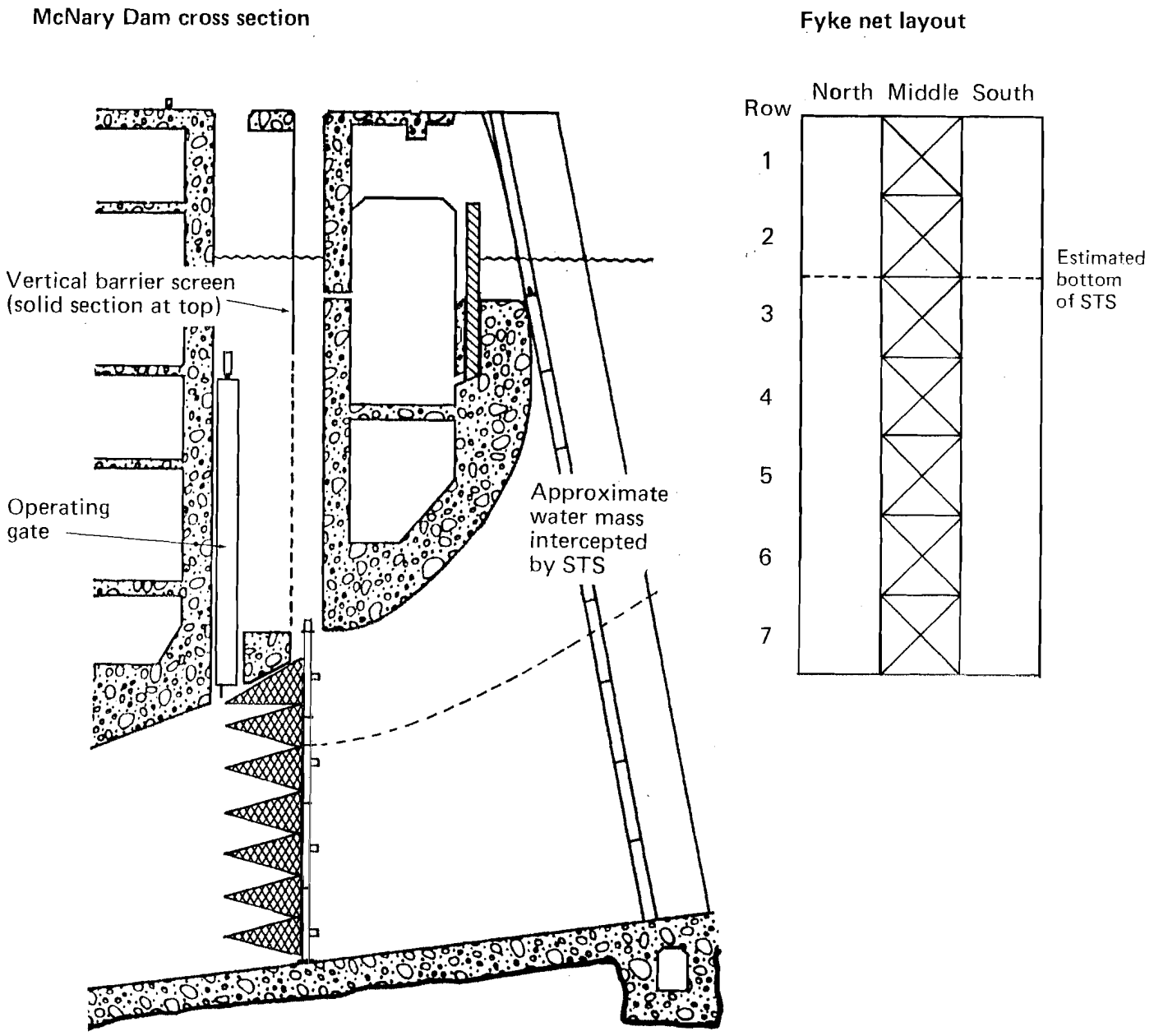

Figure 3.--Fyke net frame and nets at McNary Dam to study the vertical distribution of subyearling fall chinook salmon entering a turbine intake; a view showing the layout of fyke nets in 1986 also shown.

of the fyke net frame was equipped with nets to capture fish. An analysis by Ossiander of over 200 replicates of previous FGE and vertical distribution tests at several dams demonstrated that the center row of nets caught about the expected 33% of the total catch.[2/] Since the center column of fyke nets fished one-third of the intake, catches in each net were expanded by a factor of three for the estimate of depth distribution in the turbine intake and TFGE. A dipbasket was used to collect fish that volitionally entered the gatewell (Swan et al. 1979). Totals from the gatewell plus the expanded individual net catches provided the estimate of total number of fish passing into the intake during the test period.

The first test series was to determine bias, if any, between slots. This was estimated by 5 days of simultaneous testing of TFGE in Slots 5A and 5C. Subsequent tests conducted in Slot 5C provided vertical distribution and TFGE throughout the rest of the FGE testing. A vertical distribution test was conducted on each FGE test day as shown in Table 1. Measures of TFGE over time provide an indication of differences in depth distribution for the different components of subyearling migrating to sea in June and July.

Fish Guiding Efficiency Tests

The STSs were equipped with a composite of nets to recover unguided fish that would normally pass through the turbine (Fig. 2). The following net configuration was used during tests: two gap nets fished near the top of the

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2/ Memo 10 March 1986, Frank Ossiander, NMFS, to Teri Barila, COE. "Comparisons of center and side net catches from FGE and vertical distribution tests."

Table 1.--FGE and vertical distribution test sequence at McNary Dam, 1986.

Test series	Test day	Slots		
		5A	5B	5C
1	1,2,3,4,5	Vertical distribution	(No FGE) Standard STS	Vertical distribution
2	6,7,8,9,10	FGE Standard STS	FGE Lowered STS	Vertical distribution
3	11,12,13,14, 15	FGE Standard STS	FGE Lowered STS with raised operating gate	Vertical distribution
4	16,17,18,19, 20	FGE Standard STS	FGE Lowered STS with trashrack deflector and raised operating gate	Vertical distribution
5	21,22,23,24, 25	FGE Standard STS	FGE Lowered STS with trashrack deflector	Vertical distribution
6	26,27,28,29	FGE Diel tests with standard STS	(No FGE) Standard STS	(No FGE) Standard STS

STS to capture the fish passing through the space between the top of the STS and the ceiling of the intake; two closure ntes attached to the downstream side of (behind) the STS that fished approximately two-thirds of that area to capture unguided fish escaping under and to the back side of the STS; and five rows of fyke nets supported by a net frame suspended below the STS.

Net arrangement was identical for the standard and lowered STS but some dimensions (or throat openings) differed. Gap net dimensions for the standard and lowered STS were 2.8 by 17.5 feet, and 6.8 by 17.5 feet, respectively. Closure nets were identical between STSs. The uppermost fyke net suspended below both STSs was approximately 2.3 by 6.5 feet. The remaining four nets below the standard STS were approximately 6.5 feet square as were the second through the fourth fyke nets below the lowered STS. However, the bottom fyke net under the lowered STS had dimensions of only 2.3 by 6.5 feet.

The methods for calculating FGE were similar to those used in previous experiments of this type (Krcma et al. 1983 and Swan et al. 1983). A dip net was used to recover guided fish from the gatewell. Gatewell dip net catches provided the number of guided fish and determined the actual length of a test. Catches from the gap, closure, and fyke nets attached to the STS provided the estimate of unguided fish.

The STSs were operated in the standard screen cycling mode of 4 min on and 24 min off (consistent with the project's normal STS operations). A standard STS was used in Slot 5A with the operating gate in the standard stored condition. Slot 5B was equipped with a lowered STS and was modified to allow dogging off the operating gate at deck level, raising a trashrack deflector to the test fishing condition of a 35° angle to the intake flow, or lowering the deflector for cleaning.

As shown in Table 1 (Test Series 2 through 5), the varying conditions in Slot 5B tested against standard conditions in Slot 5A were: a lowered STS

with standard gate condition, a lowered STS with raised gate condition, a lowered STS with raised gate condition and trashrack deflector set at the 35° angle, and a lowered STS with standard gate condition and trashrack deflector set at the 35° angle. Each test was about 1 to 4 h long, starting between 2100 and 2200 h and terminating between 2200 and 2400 h.

Test Series 6 was a diel comparison of FGE conducted in Slot 5A. During this series, no testing was conducted in Slots 5B and 5C. Existing conditions were utilized in the diel test, i.e., a standard STS and standard gate condition. Daylight tests began at 0600 h and had a duration of about 2 to 3 h. Night tests began at 2200 h and had a duration of about 1 to 3 h.

Data Analyses

TFGE was calculated as gatewell catch plus numbers of fish in the first two rows of fyke nets divided by the total number of fish passing into the intake during the test period. Confidence intervals for each net catch at the 95% level were defined using the expression:

$$P + t \left(\frac{s}{\sqrt{K}}\right) \left(1 - \frac{\alpha}{2} K - 1\right)$$

Where: K = number of replicates

s = standard deviation among replicates

alpha = probability of Type I error

FGE was calculated as gatewell catch divided by an estimate of the total number of fish passing through the intake during the test period:

$$FGE = \frac{GW}{GW+GN+FN+CN} \times 100$$

GW = gatewell catch

GN = gap net catch

FN = fyke net catch (multiplied by 3 when fishing only the center one-third of the intake)

CN = closure net catch

For each test condition, the experimental design required about 200 to 250 fish per replicate and a minimum of three replicates to be able to identify a difference of 10% or greater in FGE at an $\alpha = 0.05$ level of significance with a power of test of $1 - \beta = 0.80$. In the repeated trials, the number of replicates was determined using the formulas in Appendix A and the FGE standard error of 0.0314 obtained from previous FGE studies.

The paired comparison _t_ test (two-tailed) provided the level of significance associated with any biasing of test results that may occur from conducting tests in different units (Sokal and Rohlf 1981). Evaluation of this potential source of bias was accomplished in Test Series 1 by comparing results of five replicates of simultaneous vertical distribution tests in Slots 5A and 5C.

The level of significance that the treatment effects had in increasing FGE during Test Series 2 thru 5 was also defined by the paired comparison _t_ test. A _t_ value designating a probability level greater than 0.05 defined the conditions a significant difference occurs between treatment effects. The level of significance for diel changes in FGE (Test Series 6) was also defined by the paired comparison _t_ test.

Significance tests for Test Series 1 through 6 proposed 3 sets of hypotheses:

Test Series 1	Null hypothesis (HO);	Slot 5A = Slot 5C
	Alternative hypothesis (H_A);	Slot 5A ≠ Slot 5C
Test Series 2-5	H_0;	Treatment 1 = Treatment 2
	HA;	Treatment 1 ≠ Treatment 2

Treatment 1 remained constant with a standard STS and standard gate level. Treatment 2 used a lowered STS while varying conditions with or without a raised gate and/or trashrack deflector.

Test Series 6	H_0;	Daylight FGE = Night FGE
	H_A;	Daylight FGE $\neq$ Night FGE

Fish Condition

Descaling of fish from the gatewells was monitored as a measure of fish condition throughout the FGE and vertical distribution testing. Standard descaling procedures were followed. Descaling was determined by visually dividing each side of the scaled portion of the fish into five equal areas. If any two areas on a side were 50% or more descaled, the fish was classified as descaled.

RESULTS

Testing began at McNary Dam on 23 June and ended on 1 August. A total of 24 FGE tests and 25 vertical distribution tests were conducted during this period.

Vertical Distribution Tests

Measures of the vertical distribution for subyearlings in Turbine Unit 5C was obtained from 23 June to 25 July. The seasonal cumulative percent of catch by net level with the 95% confidence interval about the mean for each net level is shown in Figure 4. Average TFGE for the test season was 61%

Prior to beginning FGE tests, no slot bias was detected from TFGE tests in Slots 5A and 5C. TFGEs were nearly identical, 64.6% in Slot 5A and 64.8% in Slot 5C. Therefore there is no evidence for rejecting the null hypotheses (P=0.96, df=4). Since there was no slot bias, subsequent vertical distribution tests were conducted in Slot 5C.

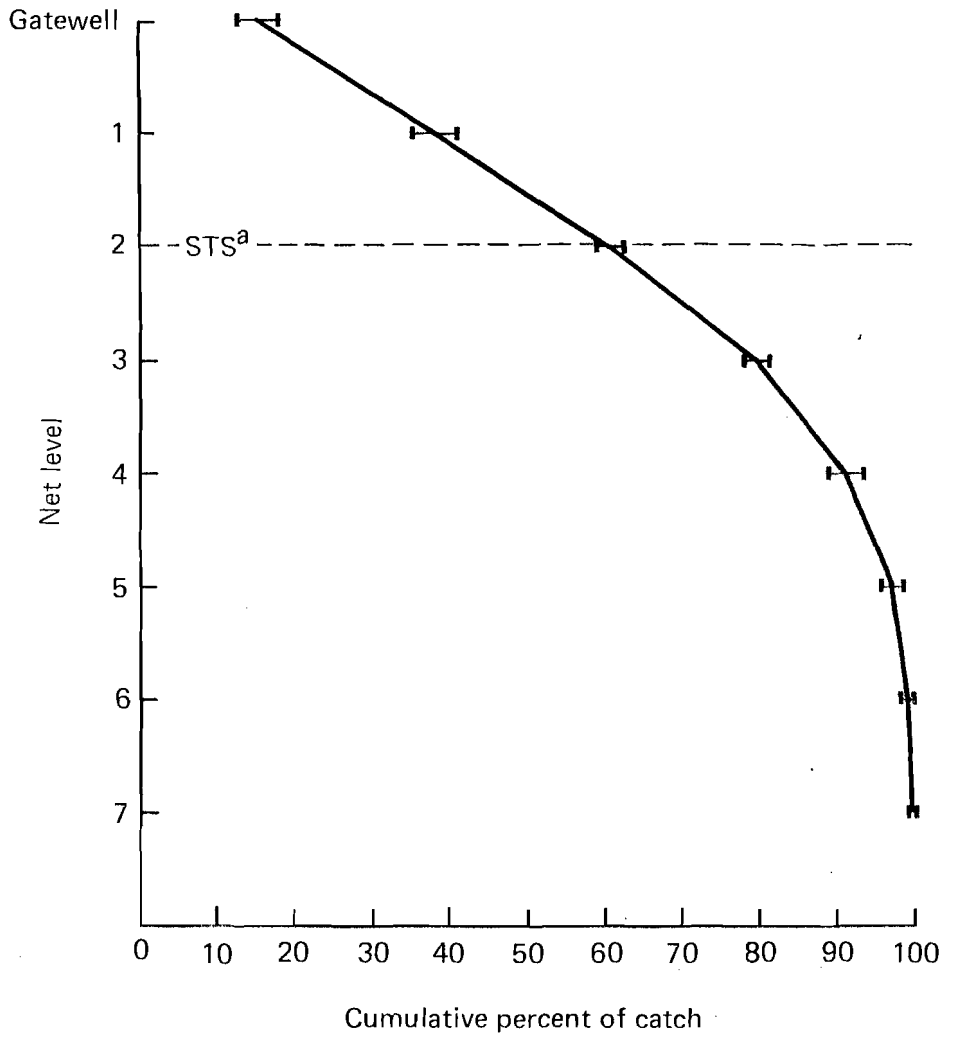

Figure 4.--Vertical distribution curve derived from 25 days of TFGE testing in Slot 5C for subyearling fall chinook salmon at McNary Dam, 1986. The capped lines represent upper and lower 95% confidence limits about the individual points on the curve.

Fish Guiding Efficiency Tests

Table 2 lists the FGE averages for each test series and the level of importance that the treatment effect had in improving FGE in Slot 5B over the control condition in Slot 5A. Differences in Test Series 2 and 3 (no trashrack deflector) were not significant. There was an increase in FGE from about 27 to 37% with a lowered STS without a raised operating gate. However, when the operating gate, was raised there was less benefit from a lowered STS (21 vs 24%, respectively).

Test Series 4 compared existing conditions with a combination of lowered STS, raised gate, and trashrack deflector. The result was a highly significant (P=0.0001, df =4) increase in FGE from 39.2 to 61.2%. Test Series 5 was the same except the operating gate was not raised. Again there was a highly significant difference between these treatments (P=0.002, df=4). While FGE was lower than in Test Series 4 (34.8 vs 61.2%, respectively) the proportionate gain from 21.5% in the control slot to 34.8% in the test slot was a comparable 62%. This suggests that comparable FGE benefits resulted from the trashrack deflector in Tests 4 and 5 whether the operating gate was raised or not. The decline in FGE in Test 5 was because fish were deeper in the intake (TFGE 74% in Test 4 vs 51% in Test 5).

Diel testing was conducted in Slot 5A (existing McNary condition) during the late part of the subyearling migration, 29 July to 1 August. Results showed that FGE was significantly higher (P = 0.007, df = 3) during daylight hours (68.9%) than at night (26.1%). A similar difference in diel FGE was shown to have occurred for yearling chinook salmon at McNary Dam during testing of a bar screen in 1978 (Krcma et al. 1979). The majority of fingerling salmonids pass the dams during twilight and the hours of darkness when FGE is lowest. However, there are nearly 16 h of daylight in June and

Table 2.--FGE and TFGE results by test series for all tests at McNary Dam in 1986.

Test Series	Date	Slots 5A[a/] (%)	Slots 5B[b/] (%)	Slots 5C (%)	Probability[c/]	Significance [d/]
1	23-27 June	TFGE 64.6	No test	TFGE 64.8	0.96	NS
2	28 June-2 July	FGE 27.5	FGE 37.0	TFGE 63.6	0.11	NS
3	6-10 July	FGE 21.1	FGE (RG[e/]) 23.8	TFGE 50.4	0.54	NS
4	14-18 July	FGE 39.2	FGE (RG, TD[f/]) 61.2	TFGE 73.6	0.0001	*
5	21-25 July	FGE 21.5	FGE (TD) 34.8	TFGE 50.7	0.002	*
6	29 July-1 August	FGE 68.9 (day) 26.1 (night)	No test	No test	0.007	*

a/ Test conditions in Slot 5A were existing McNary conditions, i.e., standard gate level and standard STS.

b/ Test conditions in Slot 5B varied, but a lowered STS remained in this slot throughout the test season.

c/ Significance level is designated by the probability of obtaining such a difference between treatments.

d/ Significant and no significant difference between treatments is noted with * and NS, respectively.

e/ A raised gate (RG) with a lowered STS was tested in Slot 5B.

f/ A trashrack deflector (TD), raised gate and lowered STS was tested in Slot 5B.

July and overall daytime passage may be significant, but is presently unknown Measures of day-night FGE over time in conjunction with measures of diel passage would provide an estimate of potential collection efficiency at McNary Dam.

Fish Condition

Fish condition remained high throughout the testing sequence. Descaling of gatewell caught subyearlings was monitored for all test conditions and averaged 2.0% for TFGE tests, 1.9% for FGE tests without a trashrack deflector, and 1.5% for FGE tests with a trashrack deflector.

DISCUSSION

Differences in catches of fish between gateslots can arise as a source of experimental error due to a number of effects, especially, the differences in flow rates between the A and C Slots of a turbine intake. These varying flow rates are caused by the scroll and rotation of the propeller blades of a turbine. Since there were no differences detected between the slots with major differences in flow (A and C) (P=0.96, df=4) (Table 2), it seems logical to assume no gatewell bias between the A and B Slots with comparable flow rates.

Because there was no measure of potential slot effect (Slot 5A vs 5B) the apparent significant benefit of the trashrack deflector cannot be stated but only implied at this time. However, no slot bias existed between Slots 5A and 5C, and there was no significant differences between Slots 5A and 5B in Test Series 2 and 3 prior to operation of the deflector. Based on this evidence and the fact that we have never found significant bias between slots in prior testing at this and other dams, it would appear most likely that the deflector has significantly enhanced FGE for subyearlings at McNary Dam.

Variability in FGE and TFGE throughout the test season and among test series was typical. (Fig. 5) Even with the fluctuations shown, it is obvious that a relation exists between TFGE and FGE, e.g., as TFGE rises and falls so does FGE. The widely fluctuating measures of FGE (10.7 to 53.6%) for the standard (control) condition and the TFGE (34.5 to 85.0%) observed between June and August provide an indication of the high variability in depth distribution between various components of the subyearling migration. Similar results were obtained at John Day Dam in 1986 (Brege et al. 1987) Because of this and the generally low FGEs measured even with a deflector during certain periods, it will probably be difficult to obtain high levels of FGEs for all segments of the subyearling migration at most dams on the Columbia River.

CONCLUSIONS

1. A lowered STS did not provide a significant increase in FGE for subyearling chinook salmon when there was no trashrack deflector.

2. When a trashrack deflector was added, the FGE was significantly increased by about 60% whether the operating gate was in a raised or in a normal stored position.

3. FGE was observed to be significantly higher during daylight hours than during the hours of darkness (68.9 vs 26.1%).

4. TFGE averaged 60.9% with a range of 34.5 to 85.0% whereas FGE for the existing McNary condition averaged 28.4% with a range of 10.7 to 53.6%. As observed at other dams, when TFGE rises and falls so does FGE.

5. Because of widely fluctuating measures of TFGE and low FGEs measured during certain periods (even with a deflector), it will probably be difficult to obtain high levels of FGEs for all segments of the subyearling chinook salmon migration.

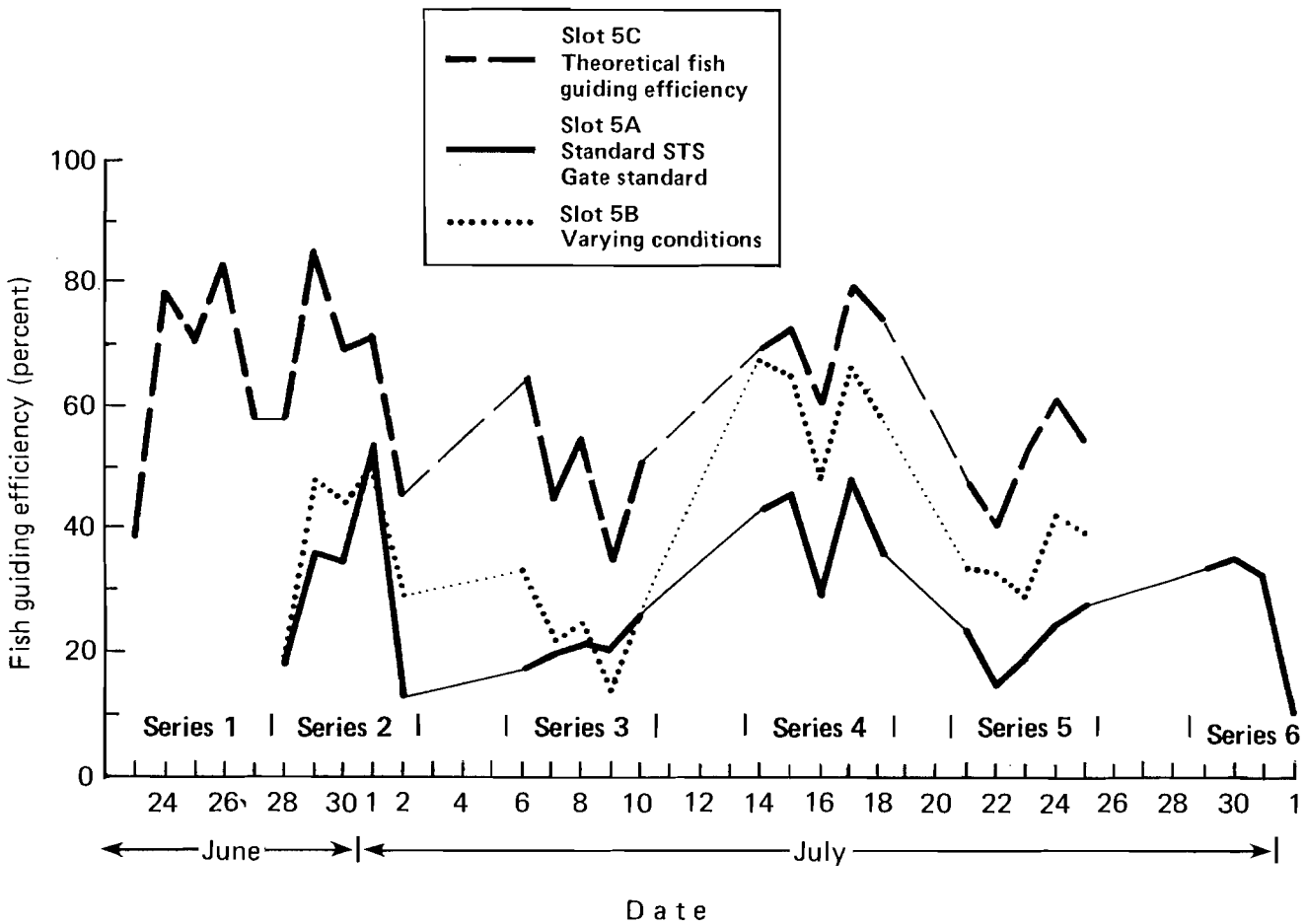

Figure 5.--Comparison of TFGE and FGE over time for subyearling fall chinook salmon at McNary Dam, 1986.

6. Fish condition remained high throughout the testing sequence. Descaling of subyearling chinook salmon was less than 2% for all test conditions.

ACKNOWLEDGMENTS

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APPENDIX A

Sample Sizes Needed for Comparative Trials

In these experiments we are mainly concerned with comparing different treatment groups to determine the best condition. In some cases a comparison is made against a standard value or an estimate of an average value is desired. In the design of these studies, it is necessary to determine the sample sizes required to assure acceptable results.

Typically, the information needed to determine sample sizes and number of replicates required is the experimental error variance, s^2; the size of the effect to be detected, δ; the number of means being compared, k; and the α and β levels (the probability of a Type I error, α, and the probability of a Type II error, β) desired from the statistical test. It is usual to specify α, β, and δ to satisfy research objectives. For the studies considered here we use $\alpha = 0.05$, $\beta = 0.20$, and $\delta = 0.10$. We estimate a value for the standard error, s, based on compilation of data from past fish guidance efficiency (FGE) studies. From these data we obtained a value of 0.0314 for chinook salmon and a value of 0.0272 for steelhead. Limited data from other species show slightly lower standard errors. We have used the value obtained from chinook salmon in our sample size computations.

The data are collected in the form of fish counts and will often be used directly in contingency table analysis. For this analysis, sample size formulas will be used which apply to categorical data. In some tests, the FGE is expressed as a percentage and an average value is also estimated. Standard randomized block procedures apply to these situations.

In these studies we are dealing with research on fish in their natural environment. It is not anticipated that our experiments will contain the uniformity of laboratory studies. When conditions provide the opportunity, we plan additional repeated measurements as assurance against the lack of uniformity in field conditions. These may not be stipulated by a formal

experimental design. They have several uses in subsequent data analysis. Replicated measurements should steadily decrease the error associated with the comparisons among treatment groups, and they can also be used to make an assessment of measurement accuracy, e.g., the closeness among comparable measurements (Tsao and Wright 1983). This assessment is especially useful to identify problem areas in the data collection system which may require special investigation. For a more lucid and comprehensive discussion see Cochran and Cox (1957) and Mosteller and Tukey (1977).

In these experiments, we compare experimental units by means of a test of significance. We will be attempting to establish that one procedure is superior or different than another by at least some stated amount. Consequently, the experiments must be large enough to reasonably ensure that if the true difference is equal to or greater than the specified amount, we have a high probability of detecting it, or obtaining a statistically significant result. The procedures used as follows provide an approximation that is adequate for design purposes. The notation for the formulas is given below.

1. Two group comparison case: This case is concerned with determining whether one condition is better than another condition (a one-way comparison), or with determining whether two conditions differ (a two-way comparison). The formula used is:

$$NT = (ZA + ZB)^2 \ / \ 2 \ (\arcsin \sqrt{P1} - \arcsin \sqrt{P2})^2.$$

This formula is given by Paulson and Wallis (1947), it is also used by Cochran and Cox (1957), sample size graphs calculated by Feigl (1978) and Lemeshow et al. (1981) showed that it provided the closest approximation to an exact method when the underlying proportions are small. This formula may be

expressed in different forms, depending on the definition of ZA and ZB. We follow the form used by Feigl. The formula applies to categorical data.

2. More than two groups or multinomial case: The procedures used for obtaining confidence intervals and sample sizes follow methods given by Angers (1984), Bailey (1980), Goodman (1965), and Miller (1966). The formula used is:

$$NM = [(B)\ (P_i\ (1-P_i)]\ /\ D^2.$$

3. For determining the number of replicates, the procedures follow those given in Steel and Torrie (1960), Cochran and Cox (1957), and Diamond (1981).

The formula used is:

$$R \geq 2\ (T_1 + T_2)^2\ (S^2)\ /\ D^2.$$

This formula is an approximation which depends on how well S^2 estimates the experimental error. Successive approximations must be used since the number of degrees of freedom associated with T_1 and T_2 depends upon R.

The following notation is used in the samples size formulas:

NT - sample size in the two group comparison.

ZA - standardized normal deviate exceeded with probability A. Where A is $1 - \alpha/2$ for the two-sided case and A is $1 - \alpha$ for the one-sided case.

ZB - standardized normal deviate exceeded with probability B. Where B is $1 - \beta$, for the one-sided case. This corresponds to the probability of obtaining a significant result. Note that ZB - -ZB' where B' equals β. Hence, (ZA + ZB) could be written as (ZA - ZB') without altering the value of NT.

P1 - proportion in the control group.

P2 - proportion in the test group.

NM - smallest sample size such that the statistical precision levels for the multinomial parameters, P_i are simultaneously satisfied.

B - tabular value for the upper percentile of the chi-squared distribution at the $1-\alpha/k$ statistical precision level with one degree of freedom. Where k is the number of proportions being compared.

P_i - expected proportion in each multinomial category, i=1, 2, ..., k.

D - level of difference it is desirable to be able to detect, this can be different for each treatment (or multinomial) category.

R - the number of replicates per treatment.

T_1 - t-distribution value associated with type I error, α.

T_2 - t-distribution value associated with type II error; T_2 is the tabulated t for probability $2(1-Q)$ where Q is the power of the test, $1-\beta$.

S_2 - estimated experimental error, this is usually obtained from previous experiments.

The degrees of freedom for T_1 and T_2 are the product (L-1) (R-1), where L is the number of treatment groups, and R the number of replicates. Successive approximations are involved in the calculations for parts (2) and (3) since the number of degrees of freedom assoicated with tabulated probability distribution values depends on sample size.

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APPENDIX B

Catch Data[1/]

1/ Only catches of subyearling chinook salmon are given. Less than 0.5% of the total catch was composed of yearling fish.

Appendix Table B1.--Catches of subyearling chinook salmon during Test Series 1 (vertical distribution testing for unit bias). Tests conducted at an 80 MW turbine load at McNary Dam in 1986.

	Unit 5A TFGE							Unit 5C TFGE						
Sample level[a/]	June 23	June 24	June 25	June 26	June 27	Total	Cumulative percent	June 23	June 24	June 25	June 26	June 27	Total	Cumulative percent
Gatewell	81	51	78	160	314	684	10.5	56	108	65	161	152	542	13.1
1	273	189	204	687	744	2097	42.6	150	312	138	363	255	1218	42.5
2[b/]	249	165	183	273	567	1437	64.6	111	234	156	201	222	924	64.8
3	318	120	99	111	387	1035	80.5	174	135	84	96	192	681	81.2
4	273	66	69	45	216	669	90.8	147	24	51	33	129	384	90.5
5	243	54	18	21	105	441	97.5	120	18	12	9	90	249	96.5
6	93	18	9	6	21	147	99.7	45	3	6	9	36	99	98.9
7	9	3	0	0	3	15	100.0	30	3	3	0	12	48	100.0
Total	1539	666	660	1303	2357	6525		833	837	515	872	1088	4145	

a/ Sample level refers to the level of the water column in which fish were captured. Gatewell was the upper portion of the water column and Level 7 was the portion just above the bottom of the intake. The gatewell Level was the actual numbers of fish caught whereas Levels 1 thru 7 were expanded by a factor of three to provide an estimate.

b/ Fish theoretically available for guiding with a standard STS was determined to be all fish in Levels Gatewell through 2.

Appendix Table B2.--Catches of subyearling chinook salmon during vertical distribution tests in Unit 5C at an 80 MW turbine load at McNary Dam, 1986.

	Test Series 2[a]							Test Series 3						
Sample level[b]	June 28	June 29	June 30	July 1	July 2	Total	Cumulative percent	July 6	July 7	July 8	July 9	July 10	Total	Cumulative percent
Gatewell	205	115	483	175	101	1079	15.7	134	171	346	68	97	816	10.3
1	423	180	594	180	195	1572	38.7	246	366	639	141	114	1506	29.4
2[c]	459	129	807	138	174	1707	63.6	210	393	672	174	207	1656	50.4
3	393	51	495	111	219	1269	82.1	141	417	564	249	177	1548	70.0
4	270	9	228	54	174	735	92.8	96	378	510	249	123	1356	87.2
5	99	12	81	24	132	348	97.9	54	195	213	141	69	672	95.7
6	18	3	39	3	39	102	99.4	18	111	51	63	42	285	99.3
7	9	0	9	6	18	42	100.0	3	24	6	21	6	60	100.0
Total	1876	499	2736	691	1052	6854		902	2055	3001	1106	835	7899	

Appendix Table B2.--Continued.

Sample level[b/]	Test Series 4 July 14	July 15	July 16	July 17	July 18	Total	Cumulative percent	Test Series 5 July 21	July 22	July 23	July 24	July 25	Total	Cumulative percent
Gatewell	115	249	129	571	730	1794	22.5	130	84	100	133	127	574	11.3
1	117	288	168	498	984	2055	48.2	216	123	168	219	153	879	28.6
2[c/]	174	273	171	495	915	2028	73.6	330	204	174	213	198	1119	50.7
3	117	189	144	270	522	1242	89.1	342	276	210	204	225	1257	75.5
4	36	69	72	75	279	531	95.7	204	195	129	90	126	744	90.2
5	24	33	66	45	90	258	98.9	144	108	51	42	42	387	97.8
6	6	3	24	0	36	69	99.8	39	27	3	15	12	96	99.7
7	0	0	0	0	12	12	100.0	6	12	0	0	0	18	100.0
Total	589	1104	774	1954	3568	7989		1411	1029	835	916	883	5074	

a/ Vertical distribution Test Series 2 thru 5 were conducted simultaneously with FGE Test Series 2 thru 5.

b/ Sample level refers to the level of the water column in which fish were captured. Gatewell was the upper portion of the water column and Level 7 was the portion just above the bottom of the intake. The gatewell Level was the actual numbers of fish caught whereas Levels 1 thru 7 were expanded by a factor of three to provide an estimate.

c/ Fish theoretically available for guiding with a standard STS was determined to be all fish in Levels Gatewell thru 2.

Appendix Table B3.--Catches of subyearling chinook salmon during fish guiding efficiency tests conducted at an 80 MW turbine load at McNary Dam in 1986.

Test Series	Date	Unit 5A FGE[a/] Gatewell number	Unit 5A FGE[a/] Unguided (est.)	Unit 5A FGE[a/] Total	Unit 5A FGE[a/] FGE (%)	Unit 5B FGE[b/] Gate level (ft) (ft)	Unit 5B FGE[b/] Gatewell number	Unit 5B FGE[b/] Unguided (est.)	Unit 5B FGE[b/] Total	Unit 5B FGE[b/] FGE (%)
2	6/28	299	1388	1687	17.7	0	333	1358	1691	19.7
	6/29	206	365	571	36.1	0	242	267	509	47.5
	6/30	1098	2104	3202	34.3	0	1366	1753	3119	43.8
	7/01	392	339	731	53.6	0	385	383	768	50.1
	7/02	242	1692	1934	12.5	0	239	611	850	28.1
Test series average[c/]					27.5					37.0
3	7/06	248	1148	1396	17.8	62	455	880	1335	34.1
	7/07	455	1788	2243	20.3	62	501	1803	2304	21.7
	7/08	797	2920	3717	21.4	62	871	2644	3515	24.8
	7/09	287	1113	1400	20.5	62	177	1128	1305	13.6
	7/10	284	793	1077	26.4	62	210	630	840	25.0
Test series average					21.1					23.8
4[d/]	7/14	401	527	928	43.2	62	469	225	694	67.6
	7/15	522	613	1135	46.0	62	683	370	1053	64.9
	7/16	192	465	657	29.2	62	290	316	606	47.9
	7/17	846	906	1752	48.3	62	1334	648	1982	67.3
	7/18	2471	4354	6825	36.2	62	2499	1783	4282	58.4
Test series average					39.2					61.2
5[d/]	7/21	330	1100	1430	23.1	0	409	815	1224	33.4
	7/22	162	922	1084	14.9	0	309	631	940	32.9
	7/23	158	660	818	19.3	0	210	513	723	29.0
	7/24	165	498	663	24.9	0	254	345	599	42.4
	7/25	200	522	722	27.7	0	271	416	687	39.4
Test series average					21.5					34.8

a/ The test condition in Slot 5A was conducted with a standard STS and standard gate level (zero).

b/ The STS in Slot 5B was lowered 33 inches (lowered STS).

c/ Test Series average was calculated by summing the number of subyearlings in the gatewell divided by the sum of estimated unguided subyearlings.

d/ Test Series 4 and 5 were conducted with a trashrack deflector set at a 35° angle to the intake flow.

Appendix Table B4.--Catches of subyearling chinook salmon during Test Series 6 (evaluation of day vs. night FGE). Tests conducted with a standard gate level and standard STS at an 80 MW turbine load at McNary Dam in 1986.

	Slot 5A daylight FGE					Slot 5A night FGE				
Date	Test duration[a/] (h)	Gatewell number	Unguided (est.)	Total	FGE (%)	Test duration (h)	Gatewell number	Unguided (est.)	Total	FGE (%)
7/29	3.42	498	275	773	64.4	1.45 h	476	942	1418	33.6
7/30	2.42	357	245	602	59.3	1.45 h	386	698	1084	35.6
7/31	1.50	1261	301	1562	80.7	1.00 h	264	552	816	32.4
8/01	2.33	320	280	600	53.3	2.77 h	180	1497	1677	10.7
	Test Series average[b/]				68.9					26.1

a/ The daylight FGE tests began at 0600, and the night FGE tests began at 2200 during Test Series 6.

b/ Test series average was calculated by summing the number of subyearlings in the gatewell divided by the sum of estimated unguided subyearlings.