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Is It Affected by Smoltification Levels in Yearling Chinook Salmon?

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COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

Little Goose and Lower Granite Dams are the two dams where juvenile salmonids are collected for transportation from the Snake River (Fig. 1). Submersible traveling screens (STS) that divert smolts from the turbine intakes into gatewells are a vital component of the collection system at these collector dams (Fig. 2). The U.S. Army Corps of Engineers (COE) and the National Marine Fisheries Service (NMFS) are continuing their efforts to improve the efficiency of the STSs and thus fish collection at these dams.

A fish guiding efficiency (FGE) of about 70% has been deemed the maximum necessary for effective collection based on research at other dams. Tests at McNary and Bonneville Dams (First Powerhouse) determined that the measured FGE approached this figure (Krcma et al. 1980, 1982).

The adequacy of fish collection facilities at Little Goose Dam prior to this study has not been measured. Baseline data obtained at Lower Granite Dam in 1982 revealed that FGE for juvenile chinook salmon, *Oncorhynchus tshawytscha*, was only about 50%, considerably below acceptable levels (Swan et al. 1983). Flow patterns from model studies performed in fall 1982 suggested that the problem might be fish diverting under the STS. Raising the operating gate in the model increased the upward flows in the gatewell and reduced the flow deflecting under the STS. Tests at Lower Granite Dam in 1983 demonstrated that with an operating gate raised 20 ft, FGE was increased to about 74% compared to about 55% without a raised gate (Swan et al. 1984).

Initial tests in 1984 and again in 1985 with a raised operating gate produced exceptionally low (33 to 43%) FGE for chinook salmon. FGE with the raised operating gate continued to improve as the season progressed, averaging

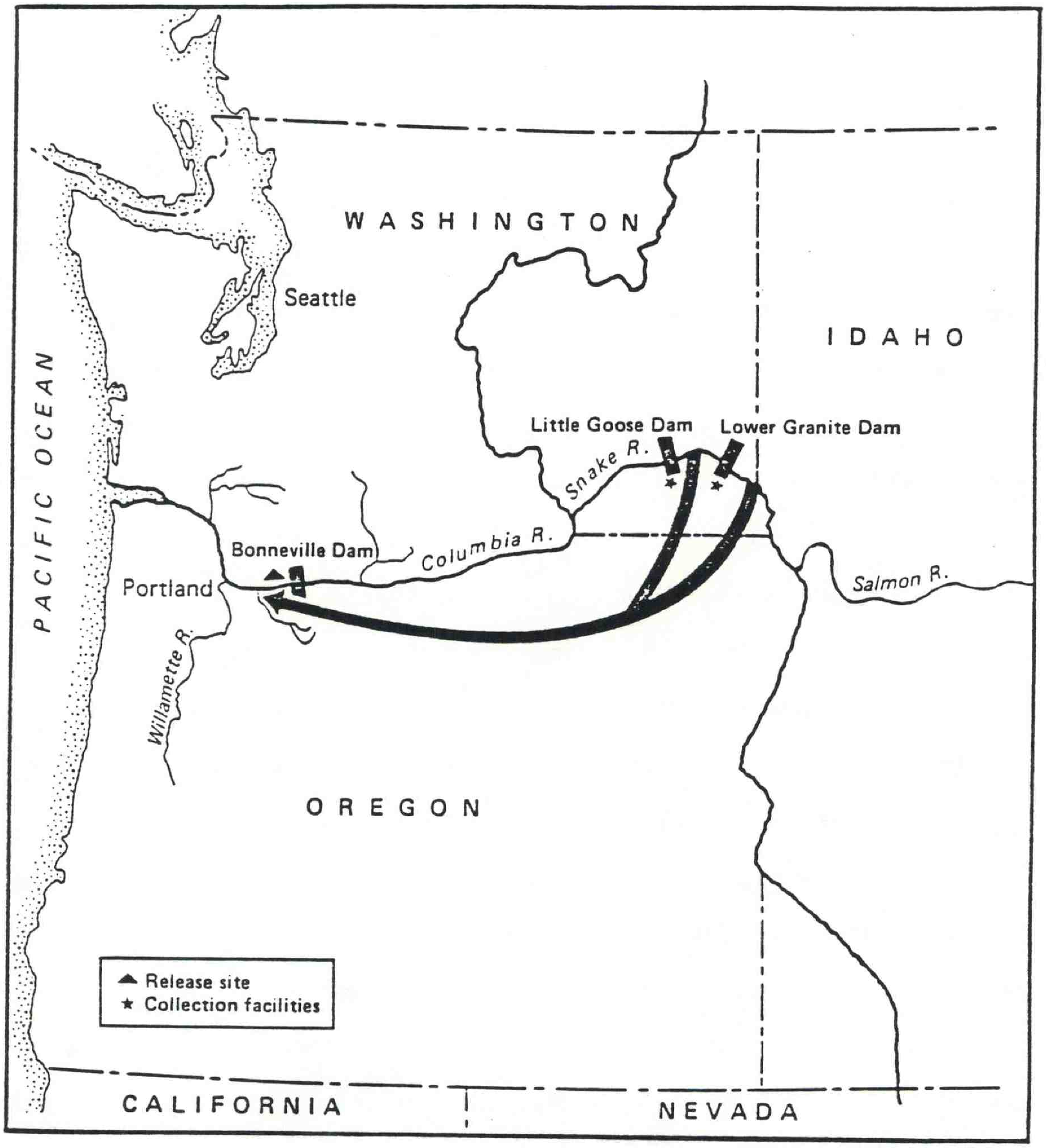

Figure 1.--Locations of fish collection facilities on the Snake River, transportation route, and release site.

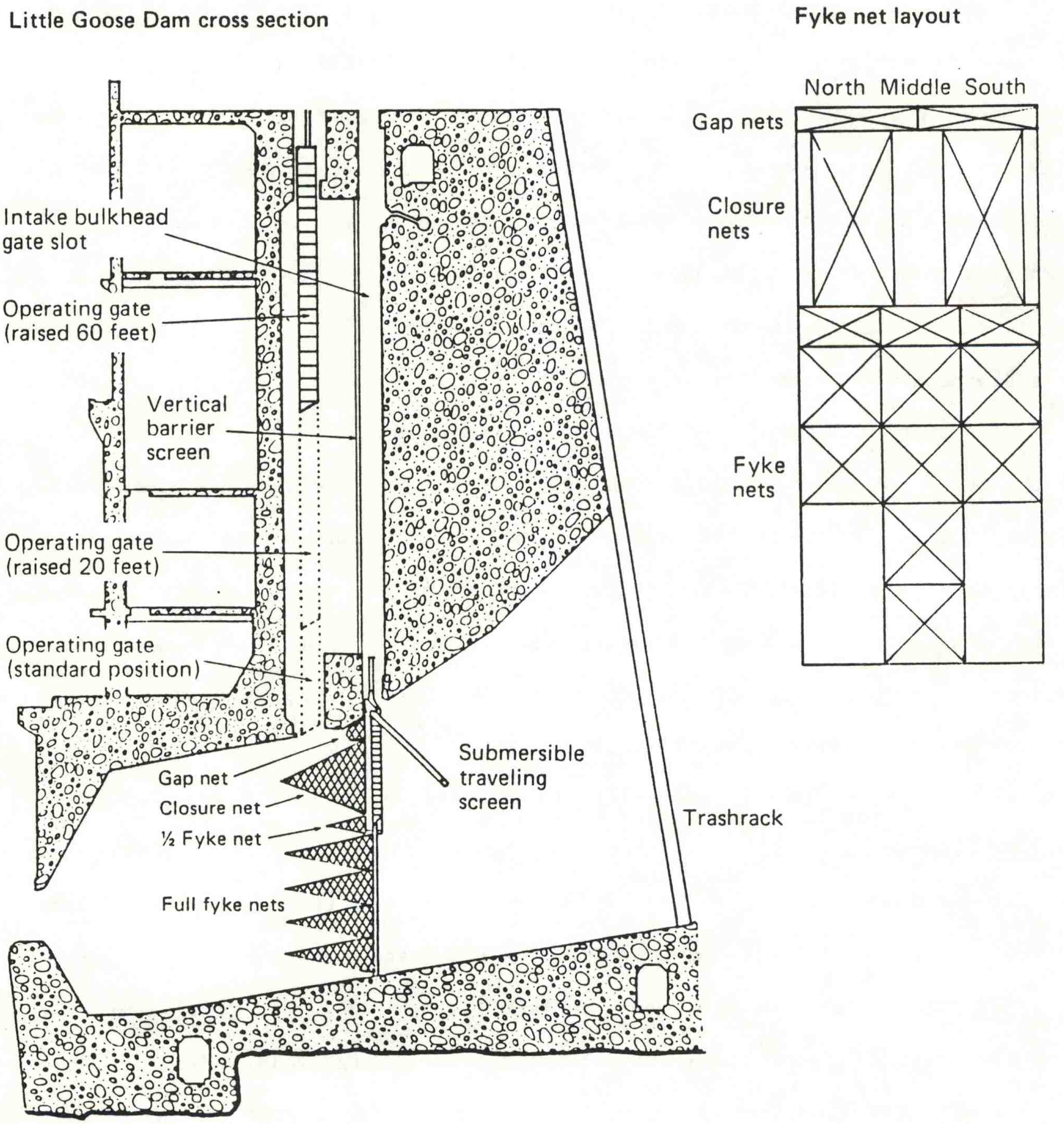

Figure 2.--Cross-section of turbine intakes at Little Goose Dam showing STS, fyke nets, and varying positions of operating gates for FGE testing; a view showing the net layout in 1986 is also shown.

about 70% during the last series of tests in each year. The increasing FGE over time suggests that biological factors rather than mechanical factors may be affecting FGE. A low level of smoltification (based on Na^{+}-K^{+} ATPase activity--a recognized index of the status of smoltification) of hatchery fish early in the migration has been suggested as a potential explanation for low FGE. We also suspect that the degree of smoltification at different periods in the migration would vary considerably from year to year because of differences in hatchery rearing or degree-days. The consistency in 1983, for example, with high FGE throughout the migration may have resulted because a greater proportion of the migration was further along in the parr/smolt transformation than in 1984 or 1985.

It is important to know whether the assumed smoltification phenomenon is peculiar only to Lower Granite Dam or if it is also occuring at other Snake River dams. If it is the latter, major modifications, such as trashrack deflectors, redesigned STSs, or other devices may be needed to move chinook salmon higher in the water column. Such solutions, though, are not easily attained as shown by continuing poor FGE at the Second Powerhouse at Bonneville Dam even with major structural modification.

To determine what will be required for acceptable FGE at Little Goose Dam and if FGE is also affected there by varying levels of smoltification in yearling chinook salmon, specific FGE tests and smoltification studies were conducted at Little Goose Dam in FY86. The FGE tests measured existing FGE of the STS at Little Goose Dam and the benefits to FGE of a raised operating gate, lowered STS, and trashrack deflector. Smoltification studies compared levels of smoltification of chinook salmon at varying depths in the forebay and turbine intake with measures of FGE and vertical distribution during the early, middle, and late periods of their migrations at Little Goose Dam. This report summarizes findings from the research conducted in 1986.

PART I: FGE TESTS

Approach

The objectives of FY86 research were to determine the following:

1. The FGE of the existing STSs at Little Goose Dam.

2. Improvements in FGE with a 20-ft raised operating gate, a lowered STS in the turbine intake, and a trashrack deflector.

3. Theoretical FGE, based on vertical distribution of fish in the intake.

In addition, descaling of gatewell-caught fish was monitored as a measure of fish condition throughout the testing. The study focused on yearling chinook salmon because FGE measured for these fish at Lower Granite Dam has been marginal at best and generally much lower than for steelhead, *Salmo gairdneri*.

Methods and Materials

Experimental Equipment

The following equipment and services were needed to conduct the research:

1. Three STSs equipped with a full complement of fyke and gap nets (Fig. 2).

2. Two gatewell dipnets (Swan et al. 1979).

3. On-deck fish examining facilities.

4. Two mobile cranes.

5. A standard vertical barrier screen (SVBS) in Slots 4A, 4B, and 4C.

6. One vertical distribution net-frame and fyke nets.

7. COE services.

a. Gantry crane service for operation and performance of STS FGE and vertical distribution tests.

b. Special provisions for temporarily raising the operating gate in Slots 4A, 4B, and 4C.

c. Unit outage required for vertical distribution and FGE tests.

Measurements and Procedures

Testing began in mid-April when adequate numbers of yearling chinook salmon began arriving at Little Goose Dam. A standard STS was used in Slots 4A and 4B with testing alternating between the 20-ft raised gate and the standard gate (zero level) in each unit to eliminate potential bias from differences between gatewells. The lowered STS, with a 62-ft raised gate level, was tested in Slot 4C simultaneously with the FGE tests in Slots 4A and 4B. Slots 4A, 4B, and 4C were equipped with standard vertical barrier screens. Bypass orifices in Slots 4A, 4B, and 4C remained closed throughout the testing season. Due to lower river flows during the testing season, there was no spill during the hours of testing. However, on 16, 23, and 24 April there was spill earlier in the day. FGE tests were conducted on the second and third day preceded by a vertical distribution test in Slot 4B on the first day of each 3-d interval.

Fish Guiding Efficiency Tests.--The methods for determining FGE were similar to those used in previous experiments of this type (Swan et al. 1983). Gatewell dipnet catches provided the number of guided fish. Catches from the gap and fyke nets attached to the STS provided the number of unguided fish.

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

$$FGE = \frac{GW}{GW + GN + FN + 1.5\ (CN)} \times 100$$

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; the closure net catch was expanded by 1.5 because the closure nets only fished two-thirds of the area.

Turbine Unit 4 was functioning only when FGE tests were conducted. The STSs were operated in the standard screen cycling mode (4 min out of every 24 min), the same as the rest of the project STSs.

During a test in Slots 4A and 4B, the operating gate in one slot was raised 20 ft, and the gate in the other slot was in the standard stored condition. The gate levels were reversed during the next day's test. Tests in Slot 4C were always conducted with the gate raised 62 ft and the STS lowered 3 ft (opposed to standard STSs in Slots 4A and 4B). A total of 12 FGE test-days were completed (Table 1).

The STSs were equipped with a composite of seven net rows to recover unguided fish that would normally pass through the turbine. A dipnet was used to recover guided fish from the gatewell above the STS. The following net configuration was used during tests (Fig. 2): two gap nets fished near the top of the STS to capture fingerlings passing through the space between the top of the STS and the ceiling of the intake, two closure nets 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

Table 1.--Little Goose Dam FGE and vertical distribution statistically-ranked experimental test plan.

Test day	Slots 4A	4B	4C
1[a],4,7,10,13,16	No STS	Vertical distribution	No STS
2,6,8,12,14,17	FGE with standard STS	FGE with standard STS raised gate	FGE with lowered STS raised gate
3,5,9,11,15,18	FGE with standard STS raised gate	FGE with standard STS	FGE with lowered STS raised gate

a/ Test-day 1--13 April 1986.

STS. The top three rows of the fyke-net frame were equipped with three nets that fished completely across the intake. The lower two rows fished the center column only, providing a one-third sample.

The following sequence of events was typical for conducting an STS FGE test:

1. The STSs in Slots 4A, 4B, and 4C with attached fyke-net frames were lowered into the intake with the gantry crane, and the STSs were extended to the fish guiding angle of 55°.

2. The gatewells were dipped to remove all fish present at that time.

3. The operating gates in Slots 4A and 4B were set for the prescribed test condition.

4. The numbers of fish entering the gatewells were monitored by periodic dipnetting, and the test was terminated when statistically adequate numbers of fish were collected.

5. The turbine was shut down, and final cleanout dips were made.

6. The operating gates in Slots 4A and 4B were returned to their normal or temporary stored position.

7. The STSs were retracted from the 55° angle and brought to the surface. Fish captured in the nets were removed for identification and enumeration.

After the initial test, the following additional steps became routine:

8. The fyke nets were checked for condition; the STSs with attached fyke nets and frames were again lowered into the intake and extended to the guiding angle.

9. Just prior to starting the next FGE test, the operating gates in Slots 4A and 4B were again set at the appropriate levels.

10. To begin the next test (about dusk the next evening), Unit 4 was brought on-line to peak efficiency and the sequence was repeated.

For each test condition the experimental design required approximately 200 to 250 fish per replicate and a minimum of three replicates.[1/] This provided the means to detect a difference of 10% or greater in FGE at an alpha = 0.05 level of significance with a power of test $1 - \beta = 0.80$. In the repeated trials, the number of replicates was determined using the formulas in Appendix A, as based on FGE standard error of 0.0314 obtained from other FGE studies. The paired comparison *t* test (Sokal and Rohlf 1981) and balanced cross-over analysis of variance[2/] were used in the statistical analysis.

Each test started at dusk; approximately 1900 or 2000 h, and had a duration of 1 to 4 h until adequate numbers of guided fish were collected, as determined by gatewell dipnetting.

Vertical Distribution Tests.--Vertical distribution tests provided the means to determine: (1) how deep chinook salmon and steelhead were traveling in the turbine intake and if this figure varied through the migration; (2) numbers of fish in the intake that potentially were in the area that could be intercepted by an STS (Fig. 3); and (3) an estimate, that could be calibrated with concurrent hydroacoustic tests, of total passage through the intake over several hours.

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

2/ Recommended by Dr. Lyle D. Calvin, consulting statistician for the COE.

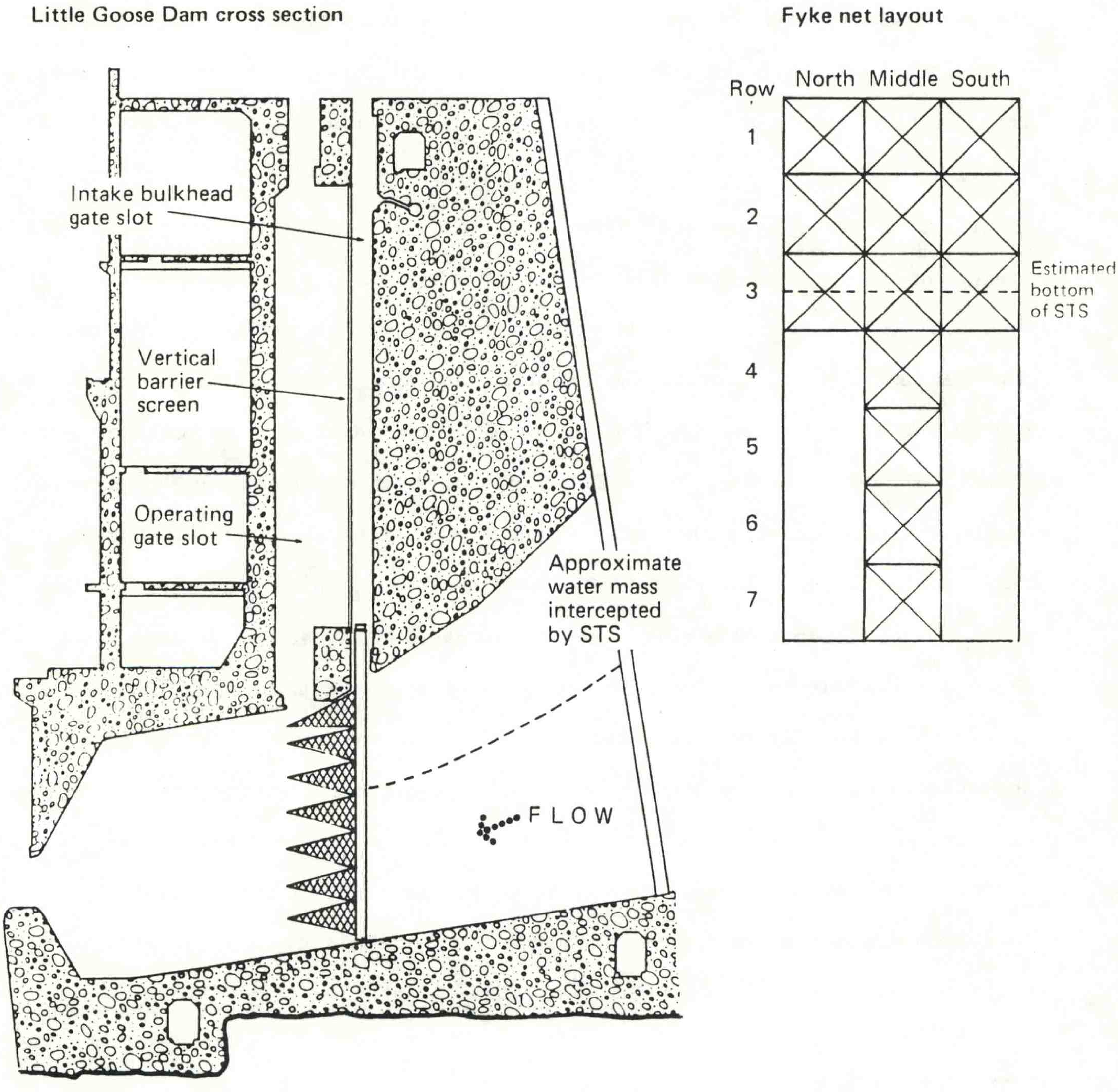

Figure 3.--Fyke-net frame and nets at Little Goose Dam to study the vertical distribution of juvenile salmonids entering a turbine intake; a view showing the layout of fyke nets in 1986 is also shown.

Tests were conducted in Slot 4B on the first day of each 3-d interval. No STSs were in Slots 4A and 4C during these tests. The operating gate in Slot 4B was in the standard stored position. The top three horizontal rows of the vertical distribution net-frame were fully netted in an effort to balance the flows. Due to lower numbers of fish handled during the tests, all nets, from ceiling to floor of the turbine intake, had cod ends attached. An analysis by Ossiander[3/] 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. A standard test for vertical distribution was conducted in a similar manner and length of time as the FGE tests, i.e., closing the orifice, lowering the net frame, dipnetting the gatewell, etc. At the end of each test, individual net catches were identified and enumerated by species. Vertical distribution was based on an estimate of the total number of fish entering the intake. Actual numbers of fish sampled in Fyke Net Rows 1, 2, and 3 were used. Since the center column of fyke nets fished one-third of the intake, each net catch from Rows 4 through 7 was multiplied by a factor of 3 to estimate the number of fish at that net level. The sum of these estimates plus the gatewell catch provided an estimate of the total number of fish and their distribution when entering the intakes. The percentage of fish for each net level (vertical distribution) was determined by dividing the computed net level catch by the total intake estimate. The theoretical fish guiding efficiency (TFGE) estimate was derived by dividing the gatewell catch plus the number of fish

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

caught in the upper two and one-half nets (approximately the water mass intercepted by the STS) by the total intake estimate. Confidence intervals (CI) for each net catch at the 95% level were defined using the expression:

$$P \pm t(\frac{s}{\sqrt{k}})(1 - \frac{\alpha}{2}, K-1)$$

Where: K = number of replicates
s = standard deviation among replicates
α = probability of Type I error

Fish Condition. 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: if any two areas on a side were 50% or more descaled, the fish was classified as descaled. Intermittent observations of mean length frequencies for yearling chinook salmon were recorded for an indication of the fish size during the test season.

Results

Fish Guiding Efficiency Tests

Existing FGE measured for yearling spring chinook salmon with a standard gate setting and STS provided a seasonal average of 61% (range 47-70%) (Table 2). Raising the operating gate 20 ft provided a significant ($P < 0.005$) increase in FGE to a seasonal average of 74% (range 61 to 76%). Raising the operating gate 62 ft and lowering the STS 3 ft provided a nearly identical increase in FGE. This treatment gave a seasonal average of 73% (range 61 to 75%). Results shown for Little Goose Dam in 1986 were very similar to those at Lower Granite Dam 1983, e.g., consistently high FGE

Table 2.--Results of FGE and vertical distribution tests on yearling chinook salmon at Little Goose Dam, 1986.

Test series[a]	Dates	Slot 4B standard STS, standard gate condition % TFGE[b]	Slots 4A & 4B standard STS, standard gate condition % FGE	Slots 4A & 4B standard STS, gate raised 20 ft % FGE	Slot 4C lowered STS, gate raised 62 ft % FGE
1	13-15 Apr	80.2	70.4	75.6	67.2
2	16-18 Apr	60.0	58.1	74.8	74.5
3	19-21 Apr	90.9	60.0	75.1	71.8
4	22-24 Apr	80.3	56.9	71.4	72.5
5	25-27 Apr	92.3	46.7	61.4	60.5
6	28-30 Apr	81.6	54.9	72.2	74.7
	Grand Average	83.4	61.0	73.5	72.8

a/ Each test series consisted of 3 days (one vertical distribution replicate on the first day and two FGE replicates on the second and third day).

b/ Based on results of vertical distribution studies.

throughout the sampling period, as contrasted with low FGE initially at Lower Granite Dam in both 1984 and 1985.

The importance of the treatment effect between the gate raised 20 ft and standard stored gate positions alternating in Slots 4A and 4B was measured using a cross-over design for analysis of variance. This analysis removes the contribution to the variance due to days and to units. The cross-over experimental design is balanced with respect to units, treatments, and pairs of days.

The cross-over design[4/] gives a statistical test (two-tailed t test) of the null hypothesis that there is no treatment effect between the standard stored gate and the gate raised 20 ft. The results showed a significant difference between the mean FGEs of Treatment 1 (standard gate position) and Treatment 2 (gate raised 20 ft) ($P < 0.005$). The alternative hypothesis that the treatments were the same was, therefore, rejected.

Treatment 3 (gate raised 62 ft and STS lowered 3 ft) was not of the cross-over test design because mechanical constraints confined sampling to one turbine unit. Measurement of this treatment effect was compared to the other two treatments by using a paired comparison for the t tests (Sokal and Rohlf 1981). All treatments were run in unison with 12 test days for each gate setting. Treatment 3 was conducted in Slot 4C whereas Treatments 1 and 2 alternated between Slots 4A and 4B. This provided 6 test days with the 20-ft gate setting in Slots 4A and 4B, as well for the standard gate setting.

4/ See Appendix B for calculations.

The two-tailed paired *t* test with Treatment 1 in Slot 4A and Treatment 3 in Slot 4C defines a significant difference between the mean FGEs. Treatment 1 in Slot 4B and Treatment 3 in Slot 4C also exhibit a significant difference ($P < 0.025$). For this set of tests the hypothesis that treatments were the same was again rejected.

The two-tailed paired *t* test with Treatment 2 in Slot 4A and Treatment 3 in Slot 4C shows no significant difference between mean FGEs. The probability value is $P > 0.500$. Treatment 2 in Slot 4B and Treatment 3 in Slot 4C also shows no significant difference with a probability value of $0.400 > P > 0.200$. There is no evidence to reject the null hypothesis, therefore, there is no important difference between FGE measured for yearlings with the gate setting at 20 ft and the gate setting at 62 ft with a lowered STS.

Figure 4 illustrates the data given in Table 2 and depicts the important difference in FGE between the raised gate settings and standard stored gate. Figure 4 also depicts the lack of a meaningful difference between the gates raised 20 and 62 ft with a lowered STS and portrays the consistently high FGEs measured throughout the sampling period.

In conjunction with the target species, FGE was calculated for incidental catches of steelhead (Table 3). Because we did not sample during peak periods of the steelhead migration and steelhead were collected at Lower Granite Dam, adequate numbers of this species were not obtained throughout the test season. Sample size requirements of the experimental design were 200 to 250 fish per sample and three to five replicated days per treatment. Consequently, analysis of the steelhead data could not be carried through for the treatment effect of the gate raised 62 ft with the lowered STS.

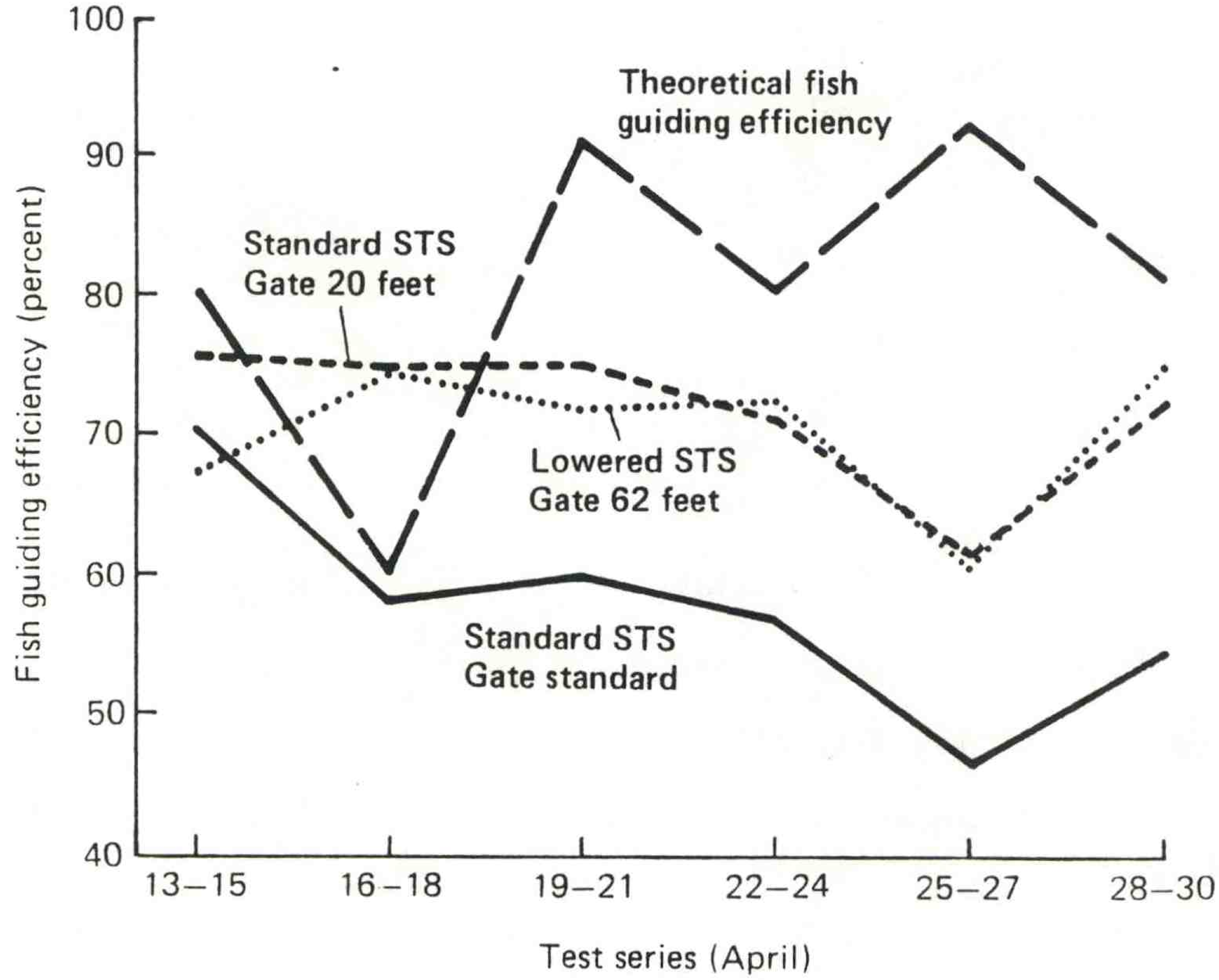

Figure 4.--Comparisons of TFGE and FGE over time for yearling chinook salmon at Little Goose Dam, 1986, under varying test conditions.

Table 3.-- Results of FGE and vertical distribution tests for steelhead at Little Goose Dam, 1986.

Test series[a]	Dates	Slot 4B standard STS, standard gate condition % TFGE[b]	Slots 4A & 4B standard STS, standard gate condition % FGE	Slots 4A & 4B standard STS, gate raised 20 ft % FGE	Slot 4C lowered STS, gate raised 62 ft % FGE
1	13-15 Apr	80.4[c]	87.1[d]	87.7[d]	80.6[d]
2	16-18 Apr	79.2[c]	63.2[c]	76.3[c]	82.9[c]
3	19-21 Apr	85.0[c]	73.0[c]	73.0[c]	78.6[c]
4	22-24 Apr	100.0[c]	63.0[c]	65.2[d]	77.1[c]
5	25-27 Apr	83.3[c]	65.7	68.3	79.3
6	28-30 Apr	85.4	71.0	75.7	78.7
	Grand Average	84.8	69.1	73.0	79.2

a/ Each test series consisted of 3 days (one vertical distribution replicate on the first day and two FGE replicates on the second and third day).

b/ Based on results of vertical distribution studies.

c/ Fewer than 200 steelhead in all replicates.

d/ Fewer than 200 steelhead in one of two replicates.

The cross-over design for analysis of variance was used with steelhead for 4 d of testing Treatments 1 and 2. The mean FGEs were not significantly different between these treatments, with a probability value of $0.400 > P > 0.200$. Therefore, the null hypothesis was not rejected.

Vertical Distribution Tests

The seasonal averaged percent catch by net level for yearling chinook salmon during vertical distribution tests is shown in Figure 5. The cumulative percent of catch shows that for this test season, average TFGE (to Net Level 3T) was greater than 80% with a 95% confidence interval of ± 2.2%. The chinook salmon data collected at Little Goose Dam in 1986 show a sharp contrast to those at Lower Granite Dam for 1984 and 1985 when TFGE gradually increased as the season progressed. Figure 4 shows the general relationship between TFGE and FGE.

Fish Condition

Fish condition remained acceptable throughout the season. Descaling was monitored for all test conditions throughout the test season. Seasonal descaling averages were 2.1% for chinook salmon and 0.7% for steelhead (Table 4). A higher rate of descaling occurred in tests conducted with existing conditions at Little Goose Dam (3.5% for chinook salmon and 0.9% for steelhead). However, no explanation for this higher rate of descaling is evident.

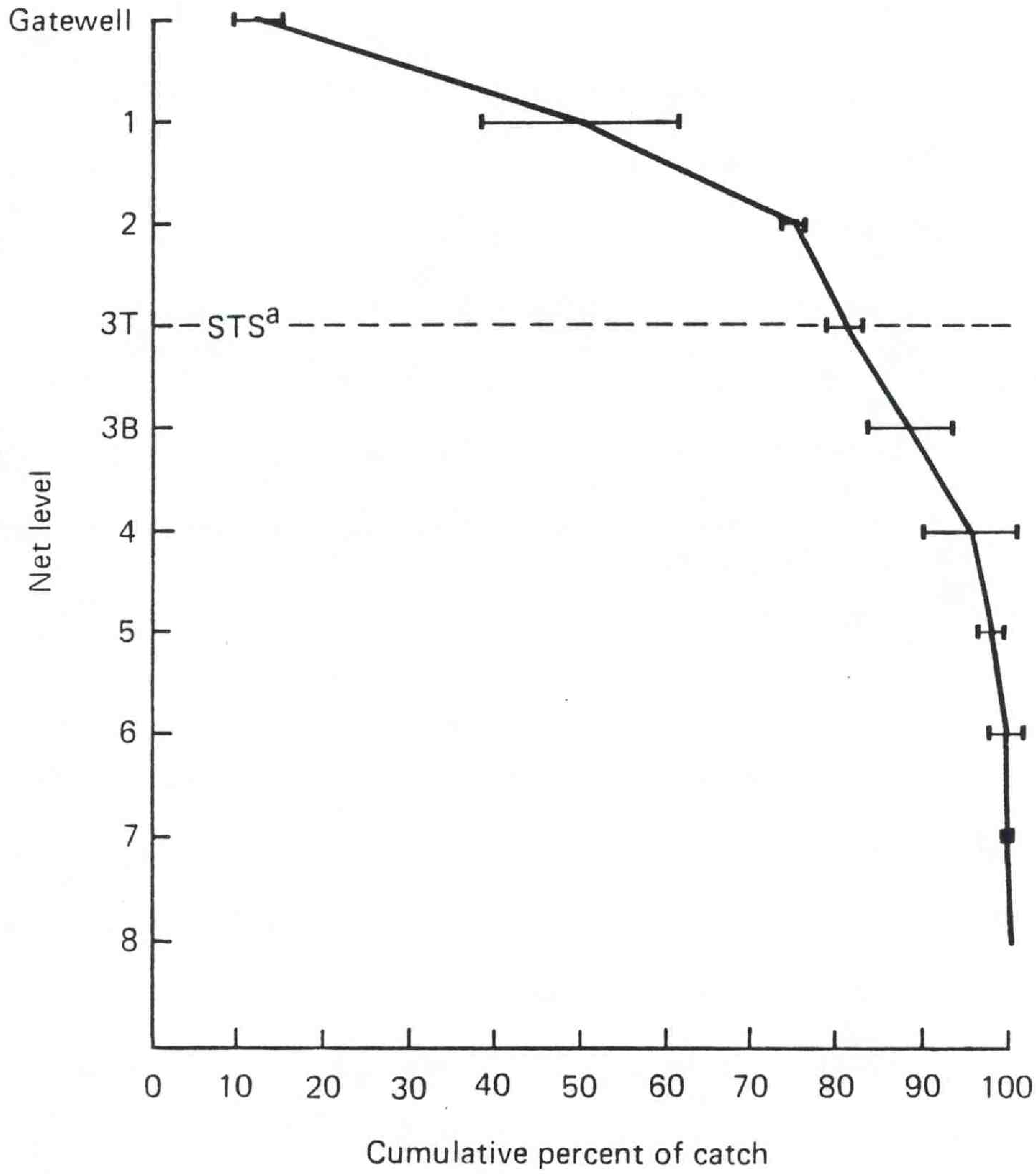

Figure 5.--Vertical distribution curve for yearling chinook salmon at Little Goose Dam, 1986. The capped lines represent upper and lower 95% confidence limits about the individual points on the curve. [(a) is maximum net-level intercepted by a standard STS (TFGE).]

Table 4.--Descaling for yearling chinook salmon and steelhead sampled in FGE and vertical distribution (TFGE) testing at Little Goose Dam, 1986.

Operating gate level (ft)	Fish guiding efficiency tests 20-30 April Slot 4A	Slot 4B	Slot 4C	Grand Avg.	Vertical distribution tests 22-28 April Slot 4B
	Chinook salmon (% descaled)				
0	5.0	2.0	*	3.5	1.4
20	1.8	1.8	*	1.8	*
62	*	*	1.4	1.4	*
FGE and TFGE seasonal average				2.1	
	Steelhead (% descaled)				
0	1.6	0.3	*	0.9	2.8
20	0.0	0.7	*	0.3	*
62	*	*	0.5	0.4	*
FGE and TFGE seasonal average				0.7	

* No tests conducted at gate levels indicated.

PART II: SMOLTIFICATION STUDIES

Background

This research addresses the issue of whether interactions between biological changes associated with the smoltification process and structural configurations at the dam are responsible for the observed fluctuations in FGE observed for yearling chinook salmon.

Of the numerous physiological, anatomical, and behavioral changes which occur during the parr/smolt transformation, several have been documented that are of particular concern with respect to assessing FGE:

1. Salmonid parr tend to be demersally oriented whereas the smolt stages are pelagic and often accumulate near the surface (Folmar and Dickhoff 1980).

2. Atlantic salmon smolts were found to be more positively buoyant than the parr (Pinder and Eales 1969). Presumably, this is a mechanism to facilitate their downstream migration by enabling them to maintain position within the swifter surface waters. Buoyancy is a function of swim-bladder volume (Saunders 1965; Pinder and Eales 1969).

3. Flagg and Smith (1982) demonstrated that coho salmon smolts are less proficient swimmers than parr. Glova and McInerney (1977) observed decreased swimming-proficiency through smoltification. Similar observations have been made for Atlantic salmon (Thorpe and Morgan 1978).

The population of spring chinook salmon passing Lower Granite Dam is comprised of numerous stocks of both wild and hatchery origin. These migrants display significant size disparity, ranging from about 100 to over 200 mm. A heterogeneous population comprised of fish from assorted stocks and of disparate size adds complexity when attempting to identify biological factors that affect FGE. During April and May, the spring chinook salmon parr/smolt transformation accelerates. However, the level of smoltification probably is not uniform throughout the population; e.g., while most wild fish may be smolted, some hatchery fish may not be at time of release and may still not completely smolted by the time they arrive at Lower Granite Dam. Furthermore, the rate of smoltification can be influenced by the fish's size; Johnston and Eales (1970) observed that large Atlantic salmon parr smolted faster than did smaller individuals.

Based on this information and the presumption that the cited biological features apply to yearling chinook salmon, the following scenario could have been occurring at Lower Granite Dam. Over the course of the spring chinook salmon outmigration, the smoltification profile and/or the size composition of the population changes. Early in the migration, a large proportion of the fish are in parr or transitional stages; later, smolts predominate. Concomitantly, the relative buoyancy of the population may become more positive and the fish surface-oriented. Concurrently, the swimming stamina of the overall population may decline as smolts comprise an increasing proportion of the population. Either separately or in concert, changes in these two mechanisms, buoyancy and swimming ability, may directly affect a fish's susceptibility to interception and diversion by a STS.

Preliminary data collected in 1985 suggest that such a scenario is reasonable (Giorgi et al. 1987, in press). On 17 May 1985, during an FGE test, fish sampled from the gatewell and fyke nets were assayed for Na^+-K^+ ATPase activity (a recognized index of the status of smoltification). Approximately 12 fish were sampled from each of three fyke nets, the closure net, and the gatewell. We tested the null hypothesis that guided fish displayed the same Na^+-K^+ ATPase activity as unguided fish using a Mann-Whitney test at $\alpha = 0.05$. We rejected the null hypothesis and concluded that guided fish displayed higher Na^+-K^+ ATPase activity. Thus, the data suggested that fish displaying elevated Na^+-K^+ ATPase activity may be more susceptible to STS; however, more data are needed, and the relation between fish size and guidance needs to be examined. Therefore, our research in 1986 had the following objectives:

1. Define changes in buoyancy and/or swimming stamina which may influence fingerling susceptibility to interception and diversion by the STS.

2. Determine if the smoltification status of the population passing Little Goose Dam changes over the course of the outmigration and assess its relation to FGE.

Methods and Materials

Swimming Stamina

Changes in swimming stamina (U-critical) through time were documented at the chosen hatcheries. Swimming stamina (U-critical) was calculated, using the swimming speed at fatigue and the time of fatigue, by the methods described in Beamish (1978):

$$\text{U-critical} = Ui + (t_i/t_{ii} \times U_{ii})$$

Where: U-critical = Critical swimming speed (BL/s)

U_i = Highest velocity maintained for the prescribed period (BL/s)

U_{ii} = Velocity increment in each test (BL/s)

t_i = Time (minutes) that the fish swam at the fatigue velocity

t_{ii} = Prescribed period of swimming (minutes)

Because the index of swimming stamina was designed for fish that could swim for at least one complete swimming trial period and because fish that could not swim for at least one such period probably were too weak or sick for our purpose, U-critical measurements were made for fish that could swim for at least 15 min at 1.5 body lengths/s.

Fish were anesthetized, weighed to the nearest 0.1 g, and measured to the nearest mm (fork length). The fish were placed in numbered test compartments within the swim chamber (Fig. 6) and allowed a 1-h recovery period. The initial water velocity was set at 1.5 body lengths per second (BL/s) and increased 0.5 BL/s every 15 min until the fish reached fatigue (i.e., fish could no longer hold position in the current and remained impinged against the electrified screen).

Buoyancy

Changes in buoyancy which may be associated with smolt development and could potentially affect vertical distribution were documented. Fish buoyancy as influenced by adjustments in swim-bladder volume can be measured indirectly by employing the Cartesian diver principle as described by Pinder and Eales (1969). Basically, individual fish are placed in a closed chamber to which a vacuum is applied. The pressure at which the fish just rises off the bottom of the chamber adjusted to the prevailing atmospheric pressure is an indirect measure of swim-bladder volume. This measure is referred to as the pressure of neutral buoyancy (PNB) (Saunders 1965) and is defined as:

$$PNB \text{ (mm Hg)} = PA - PR$$

where

PA = atmospheric pressure

PR = vacuum required to achieve flotation

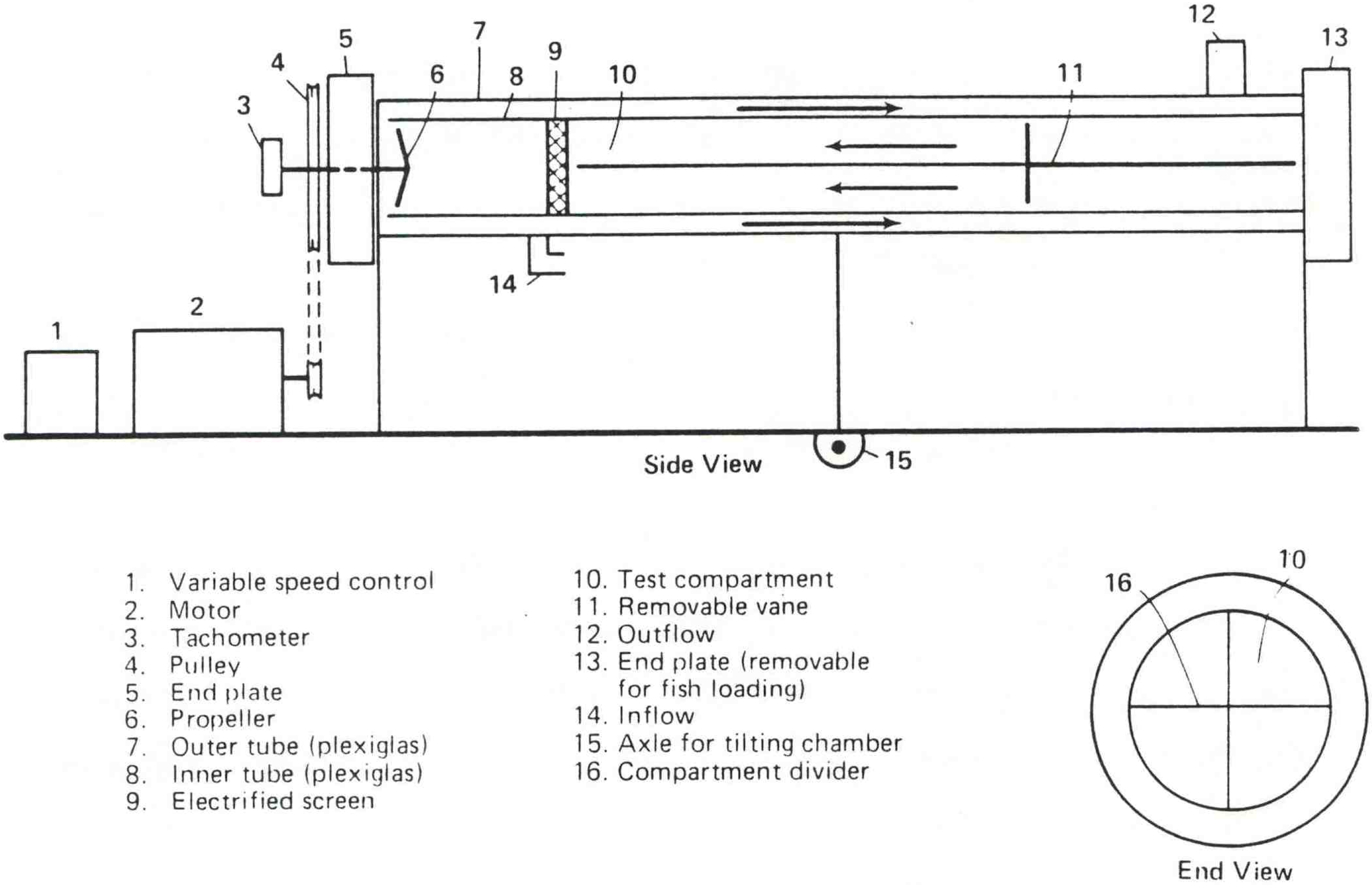

Figure 6.--Schematic diagram of swim chamber used to measure swimming stamina.

In our study, buoyancy measurements were made in a cylindrical Plexiglas[5/] pressure-chamber 30 cm high by 25 cm diameter. The apparatus was 0.8 filled with a 50 ppm MS222 solution. Pressure within the system was controlled with an electric vacuum pump. Pressure readings were made with a vacuum gauge. Atmospheric pressures were measured with an aneroid barometer.

Experiments were conducted January-April 1986. Fish were randomly selected from raceways and housed inside the hatchery building in separate troughs for a period of 24 to 48 h prior to the test. Sufficient water flow was maintained to ensure suitable water quality.

Smoltification Indices

Three physiological indices of smoltification were assayed in these studies: gill Na^+-K^+ ATPase and the thyroid hormones thyroxine (T_4) and triiodothyronine (T_3). Gills were sampled from both fresh-killed fish and dead fish collected in fyke-net sampling. Independent work by Zaugg (pers. commun.) demonstrated that for spring chinook salmon Na^+-K^+ ATPase activity remains stable at ambient river temperature (approximately 45°-55°F) for at least 4 h. Postmortem gill filaments used for the Na^+-K^+ ATPase assay were trimmed from the gill arch and placed into a 1.5 ml microcentrifuge tube filled with sucrose ethylenediamine imidazole (SEI) and immediately frozen on dry ice. Na^+-K^+ ATPase activity was determined according to the method of Zaugg and McLain (1972) with minor modification.

5/ Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Blood samples were also collected but only from freshly killed specimens. Blood was centrifuged, and the plasma was collected and frozen at < -20° C until assayed for T_3 and T_4. Hormones were assayed using a specific radio immunoassay (Dickhoff et al. 1978, 1982).

In addition to these physiological indices, lengths and weights were recorded for all specimens and a condition factor (K) (Lagler et al. 1977) was calculated for all fresh-killed specimens.

Sampling Protocol

The first objective was to define changes in swimming stamina and buoyancy associated with the smoltification process (as indicated by assorted smolt indices). To accomplish this, we sampled two hatchery stocks of spring chinook salmon (from Little White Salmon and Dworshak Hatcheries) once a month from January 1986 through the production release dates later that spring. A freeze-branded segment of the Dworshak River population was later intercepted at Lower Granite Dam where the behavioral and physiological factors were again assessed. Two other freeze-branded hatchery stocks (from Rapid River and Sawtooth Hatcheries) were sampled at the time of the hatchery production release and later at the Lewiston Trap (operated under the Water Budget Measures Program) and Lower Granite Dam. The specific sampling dates are in Table 5.

The second study objective was to determine whether the smoltification status of the population passing Little Goose Dam changes over the course of the outmigration and assess its relation to FGE. To accomplish this, we sampled fish from FGE tests conducted in Slot 4B on three dates (15, 20, and 26 April). Up to 20 fish were sampled from the gatewell and each fyke-net

Table 5.--Sampling dates and sites for hatchery stocks of spring chinook salmon, 1986. Swimming stamina and buoyancy were measured and physiological indices (Na^+-K^+ ATPase, T_3, and T_4) were assayed.

Little White Salmon		Dworshak		Rapid River		Sawtooth	
Date	Site	Date	Site	Date	Site	Date	Site
10-11 Jan	Hatchery	14-15 Jan	Hatchery	-	-	-	-
04-05 Feb	Hatchery	08-09 Feb	Hatchery	-	-	-	-
04-05 Mar	Hatchery	16-17 Mar	Hatchery	08-09 Mar	Hatchery	12-13 May	Hatchery
11 Apr	Hatchery	02-03 Apr	Hatchery	05-09 Apr	Lewiston trap	14 Apr	LGR[a/] & Lewiston trap
-	-	-	-	13 Apr	LGR	-	-
-	-	-	-	23 Apr	LGR	-	-

a/ LGR = Lower Granite Dam.

row. Secondarily, we attempted to determine whether fish distributed themselves vertically in the forebay according to their physiological status in the parr/smolt transformation and whether there were differences between Lower Granite and Little Goose Dams. For this, we sampled in the forebay of both Lower Granite and Little Goose Dams using monofilament gillnets. Each gillnet was 3 m square and was comprised of three 1-meter wide vertical panels, 2.2 cm, 2.9 cm, and 3.5 cm stretch mesh. Nets were suspended from the log boom at Lower Granite Dam and from an anchored vessel at Little Goose Dam. Nets were fished at three different depths: surface, midwater, and just off the bottom.

We also collected scales from fish sampled during FGE testing to determine if the FGE for spring chinook salmon varied between wild and hatchery stocks. The criterion to differentiate between wild and hatchery stocks was the presence or absence of a winter check mark (a band of closely spaced circuli). In theory, a hatchery fish scale should have more numerous, uniformly spaced circuli with no apparent winter check because of controlled water temperature and feeding in the hatchery environment. Conversely, a wild fish scale should have widely spaced circuli near the focus becoming more closely spaced near the outer margin (winter check) because of harsh and variable environmental conditions.

Scales were collected from both guided and unguided spring chinook salmon captured in FGE tests during the early (15-16 April), mid (20 April), and late (26 April) outmigration. Scales were placed in a scale envelope and labeled with fish length, weight, marks, net level, and date of capture.

Scales were later sorted in water and mounted on glass slides with cover slips, taped, and viewed under a dissecting microscope. Scale readings were verified by a fisheries biologist experienced in salmonid scale reading (John Loch, Washington Department of Game, Kalama, Wash.).

Results

Swimming Stamina

At Dworshak Hatchery, spring chinook salmon swimming stamina was relatively stable over the sampling period (January to April) with U-critical values ranging from 2.63 to 2.91 BL/s. Similarly, at Little White Salmon Hatchery there was no conclusive evidence that swimming performance was changing while fish were in the hatchery during the period January through release in April. For this stock, U-critical values ranged from 2.73 to 3.10 BL/s (Fig. 7).

Two hatchery stocks were intercepted at riverine sampling sites and swimming stamina was again assessed. Dworshak Hatchery fish were caught at Lower Granite Dam whereas Rapid River fish were caught at the Lewiston Trap. Swimming stamina levels observed at the riverine sampling sites were compared with values measured at the hatchery using a Mann-Whitney U-statistic. For both stocks, riverine fish exhibited stamina levels significantly ($P < 0.05$) higher than hatchery samples. Mean swimming stamina (U-critical) increased from 2.91 BL/s in the hatchery at the time of release (3 April) to 3.62 at Lower Granite Dam on 23 April. Similarly, stamina levels in Rapid River fish increased from 2.82 to 3.41 BL/s at the hatchery and trap, respectively (Table 6). Only a few Sawtooth fish were intercepted, thus swimming stamina was not measured.

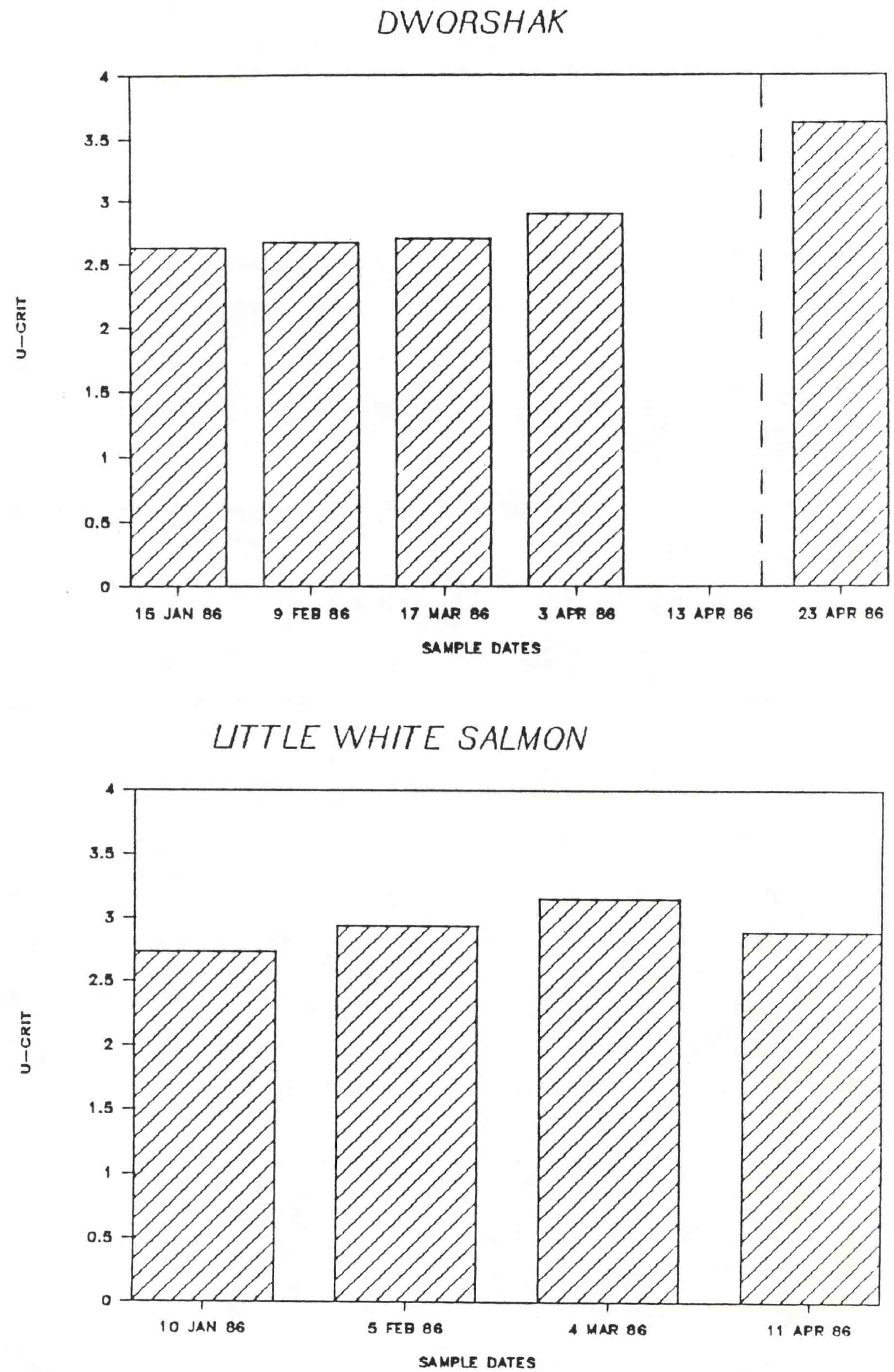

Figure 7.--Mean value (BL/S) of swimming stamina (expressed as U-critical) measured for spring chinook salmon reared at both Little White Salmon and Dworshak hatcheries. Data for Dworshak fish on 23 April were collected at Lower Granite Dam (data to the right of the stippled vertical line).

Table 6.--Swimming stamina (U-critical) data for Dworshak, Little White Salmon, and Rapid River stocks, 1986. Lower Granite Dam (LGR) and the smolt trap at Lewiston, Idaho (LT) were the two in-river interception sites.

Stock	Sample site	Date of sample	Temp. (°C)	U-critical Mean (BL/S)	U-critical St. Dev. (BL/S)	n
Dworshak	Hatchery	14 Jan	4.5	2.63	0.21	12
	Hatchery	09 Feb	3.0	2.70	0.19	12
	Hatchery	17 Mar	4.0	2.79	0.55	10
	Hatchery	03 Apr	4.0	2.91	0.28	12
	LGR	23 Apr	12.0	3.62	0.84	11
Little White Salmon	Hatchery	09 Jan	3.5	2.73	0.14	12
	Hatchery	04 Feb	8.0	2.93	0.29	11
	Hatchery	05 Mar	7.5	3.10	0.21	12
	Hatchery	11 Apr	10.5	2.88	0.49	11
Rapid River	Hatchery	09 Mar	6.0	2.82	0.26	16
	LT	09 Apr	10.0	3.41	0.60	11

Buoyancy

Buoyancy data collected at both Little White Salmon and Dworshak Hatcheries suggested that these stocks of spring chinook salmon exhibit no increase in buoyancy during their hatchery residence. At both hatcheries, values of PNB were stable over the sampling period (January-April) and were high, ranging from 52.1 to 65.5 cm Hg (Table 7). Such values indicate that the fish were quite buoyant at the time of sampling (the maximum achievable PNB for any day would be the prevailing atmospheric pressure).

For three hatchery stocks (Dworshak, Rapid River, and Sawtooth), we were able to measure buoyancy both in the hatchery and later at a downstream interception site, either the migrant trap at Lewiston or Lower Granite Dam. Using the Mann-Whitney U-statistic, we tested for differences between buoyancy levels observed at the hatchery and those measured at the downstream interception site. For the Dworshak stock, buoyancy levels were the same. However, both Rapid River and Sawtooth stocks exhibited significantly lower buoyancy ($P < 0.05$) at the riverine interception sites than in the hatchery (Table 7). The biological significance of this observation is uncertain at this time. The 1987 studies have been designed to better address this issue.

These results are inconsistent with those observed for Atlantic salmon (Pinder and Eales 1969). It is possible that chinook salmon do not exhibit the same responses as Atlantic salmon. However, we suspect that our protocol for processing the fish may have resulted in erroneous data. Pinder and Eales killed their fish with a concentrated lethal dose of MS-222 prior to measuring buoyancy. In our study, fish were not killed, but merely anesthetized, to ensure that we could extract an adequate amount of a blood for the assay of thyroid hormones. When fish were anesthetized, they were observed to swim

Table 7.--Fish buoyancy data (1986) expressed as the pressure of neutral buoyancy (PNB). Data for Dworshak, Little White Salmon, and Rapid River stocks. Lower Granite Dam (LGR) and the smolt trap at Lewiston, Idaho (LT) were the two in-river interception sites.

Stock	Sample site	Date of sample	PNB (cm Hg) Mean	St. Dev.	n
Dworshak	Hatchery	14 Jan	59.4	5.0	18
	Hatchery	08 Feb	65.5	4.1	14
	Hatchery	08 Feb	52.1	9.6	12
	Hatchery	17 Mar	64.3	3.2	12
	Hatchery	03 Apr	57.7	6.1	21
	LGR	15 Apr	61.9	2.2	15
Little White Salmon	Hatchery	09 Jan	59.4	4.7	12
	Hatchery	04 Feb	61.7	7.1	16
	Hatchery	05 Mar	63.3	6.2	17
	Hatchery	11 Apr	60.5	10.1	13
Rapid River	Hatchery	09 Mar	67.6	3.2	16
	LT	09 Mar	56.1	9.5	10
Sawtooth	Hatchery	13 Mar	69.1	3.9	21
	LGR	14 Apr	65.0	3.5	9

nosing at the water's surface. Since salmonids are physostomes, it is possible they were entraining air at this time and the high PNB values we observed were an artifact of this behavior related to the anesthesia. Until we resolve this, conclusions regarding the buoyancy data should not be made. Testing proposed for 1987 should eliminate this uncertainty.

Smoltification Indices

Patterns of the physiological indices observed at Little White Salmon Hatchery from January to April increased steadily from a mean Na^{+}-K^{+} ATPase activity of 6.71 to 15.23 µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$ and a T_3 activity of 0.98 to 1.66 ng $\cdot$ ml^{-1} (Table 8 and Fig. 8). The other thyroid hormone, T_4, exhibited a fluctuating pattern peaking on 5 February and again on 11 April. A physical index of smoltification, K-factor, was also calculated and found to be relatively stable, with mean values ranging from 1.11 x 10^{-5} to 1.18 x 10^{-5} over the sampling period (Fig. 8).

The temperature regime at Little White Salmon Hatchery proved to be unstable. Temperatures ranged from approximately 3.5° to 10.5° C from 9 January to 11 April (Table 6). This is a potentially confounding factor for the interpretation of smolt index data since expression of all the indices may be affected by temperature. Due to this problem, we recommended against using this site in the proposed FY87 studies.

In contrast, the environmental conditions at Dworshak Hatchery were very stable with respect to temperature. From 14 January to 3 April 1986, temperatures ranged from 3.0° to 4.5°C, with the lowest values recorded in February (Table 6). Na^{+}-K^{+} ATPase data from Dworshak Hatchery are incomplete because one set of gill samples collected on 3 April was misplaced. The

Table 8.--Data for physiological indices from Dworshak and Little White Salmon Hatcheries; n=12. Units for Na^{+}-K^{+} ATPase and thyroid hormones are ($\mu mol\ P_i \cdot mg\ Prot^{-1} \cdot h^{-1}$) and ($ng \cdot ml^{-1}$), respectively.

Hatchery	Sample date	Mean	S.D.
		Na^{+}-K^{+} ATPase	
Dworshak	15 Jan	2.15	1.30
	09 Feb	4.16	1.52
	17 Mar	7.92	2.15
Little White Salmon	10 Jan	6.71	2.07
	05 Feb	7.03	1.21
	05 Mar	9.77	1.93
	11 Apr	15.23	5.07
		T_3	
Dworshak	15 Jan	2.15	0.74
	09 Feb	1.48	0.67
	17 Mar	1.12	0.26
	03 Apr	1.86	0.63
Little White Salmon	10 Jan	0.98	0.84
	05 Feb	1.20	0.41
	05 Mar	1.33	0.78
	11 Apr	1.66	0.68
		T_4	
Dworshak	15 Jan	9.29	5.26
	09 Feb	7.77	3.22
	17 Ma	11.73	4.11
	03 Apr	12.52	4.00
Little White Salmon	10 Jan	5.00	2.00
	05 Feb	6.88	3.12
	05 Mar	4.08	5.02
	11 Apr	5.72	3.34

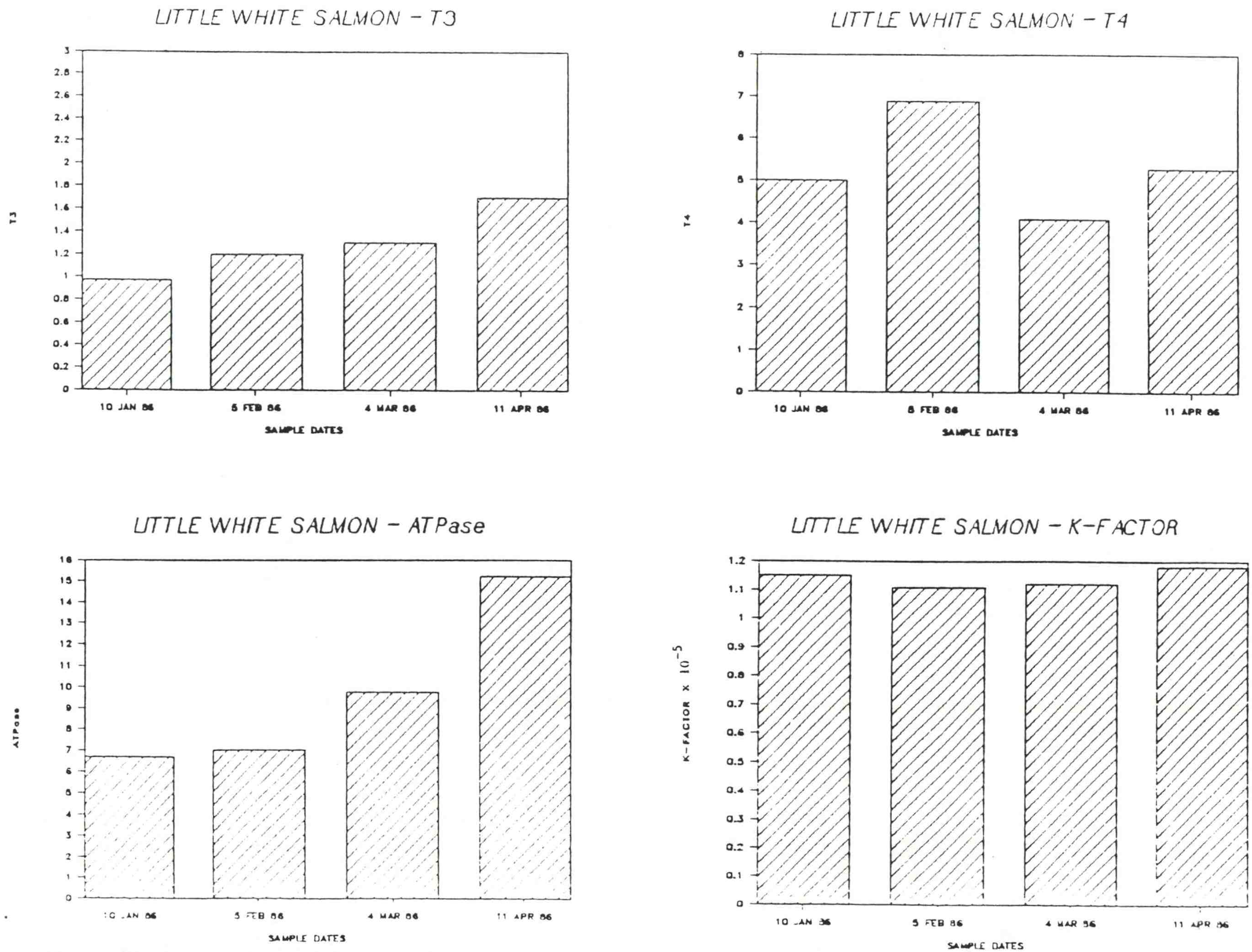

Figure 8.--Mean value of four smolt indices measured for spring chinook salmon at Little White Salmon Hatchery.

enzyme levels (means) for 15 January and 9 February, 2.15 and 4.16 µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$, respectively, are uncharacteristically low (Table 8) (Fig. 9). We suspect there was a storage problem while the samples were held prior to the assay. Both the T_3 and T_4 data displayed fluctuating activity levels over the sampling period. Mean T_3 values ranged from 1.12 to 2.15 ng $\cdot$ ml^{-1}, with the lower values observed in February and March and peaks occurring in both January and April (Table 8). T_4 values ranged from 7.77 to 12.52 ng $\cdot$ ml^{-1}, with values decreasing from January to February then steadily increasing until the last hatchery sample on 3 April. K-factor was also calculated. Mean values were generally stable, ranging from 1.08×10^{-5} to 1.14×10^{-5} (Fig. 9).

All hatchery stocks exhibited significantly higher Na^+-K^+ ATPase activity at the riverine sampling sites (Table 9). However, in the case of the Dworshak Hatchery fish it took some time for Na^+-K^+ ATPase levels to increase once fish were in the river. Dworshak fish collected at Lower Granite Dam on 13 April had been in the river 10 d post-release, yet exhibited nearly the same mean Na^+-K^+ ATPase levels (8.48 µmol $P_i \cdot$ mg $prot^{-1} \cdot h^{-1}$) as those measured in the hatchery (7.92 µmol $P_i \cdot$ mg $prot^{-1} \cdot h^{-1}$) on 17 March 1986. Ten days later, on 23 April at Lower Granite Dam, the mean Na^+-K^+ ATPase activity for the same stock was 21.8 units, significantly higher ($P < 0.01$) than that measured at the same site on 13 April 1986 (Fig. 9). Both the Sawtooth and Rapid River Hatchery stocks exhibited significantly higher Na^+-K^+ ATPase levels at the riverine sampling site than were observed in the hatchery (Table 9). Mean values of Na^+-K^+ ATPase for Sawtooth River fish increased from 9.03 to 20.72 µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$, and Rapid River fish increased from 6.98 to 12.27 µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$.

Table 9.--Gill Na^+-K^+ ATPase and thyroid hormone data for hatchery stocks at the last sampling prior to release and when intercepted at two downstream sites, Lower Granite Dam and the migrant trap at Lewiston, Idaho.

Stock	Sample site	Date	Mean	S.D.	n	Mann-Whitney U	Mann-Whitney P
				Na^+-K^+ ATPase			
Dworshak	Hatchery	17 Mar	7.92	2.15	12		
	Dam	13 Apr	8.48	2.74	12	65.0[a]	0.707
		23 Apr	21.82	4.90	18	2.0[b]	<0.001
Rapid River	Hatchery	09 Mar	6.98	1.65	12		
	Trap	09 Apr	12.27	1.97	10	2.0	<0.001
Sawtooth	Hatchery	13 Mar	9.03	1.46	12		
	Trap	14 Apr	20.72	3.03	9	0[c]	<0.001
	Dam	14 Apr	20.56	6.76	9	4.0[d]	<0.001
				T_3			
Dworshak	Hatchery	03 Apr	1.86	0.63	12		
	Dam	13 Apr	1.63	0.70	12		
	Dam	23 Apr	2.84	1.74	18		
Rapid River	Hatchery	09 Mar	1.26	0.33	12	16.0	<0.01
	Trap	09 Apr	2.63	1.91	10		
Sawtooth	Hatchery	13 Mar	0.77	0.37	12	61.0	<0.05
	Dam & trap	14 Apr	1.50	0.98	18		
				T_4			
Dworshak	Hatchery	03 Apr	12.52	4.05	12		
	Dam	13 Apr	4.77	2.80	12		
	Dam	23 Apr	9.85	3.65	18		
Rapid River	Hatchery	09 Mar	5.75	2.94	11	33.0	0.075
	Trap	09 Apr	9.32	5.03	10		
Sawtooth	Hatchery	13 Mar	3.49	2.63	12		
	Dam & trap	14 Apr	5.68	5.10	18	89.5	0.431

a/ 13 April vs Hatchery.
b/ 23 April vs Hatchery.
c/ Lewiston Trap vs Hatchery.
d/ Lower Granite Dam vs Hatchery.

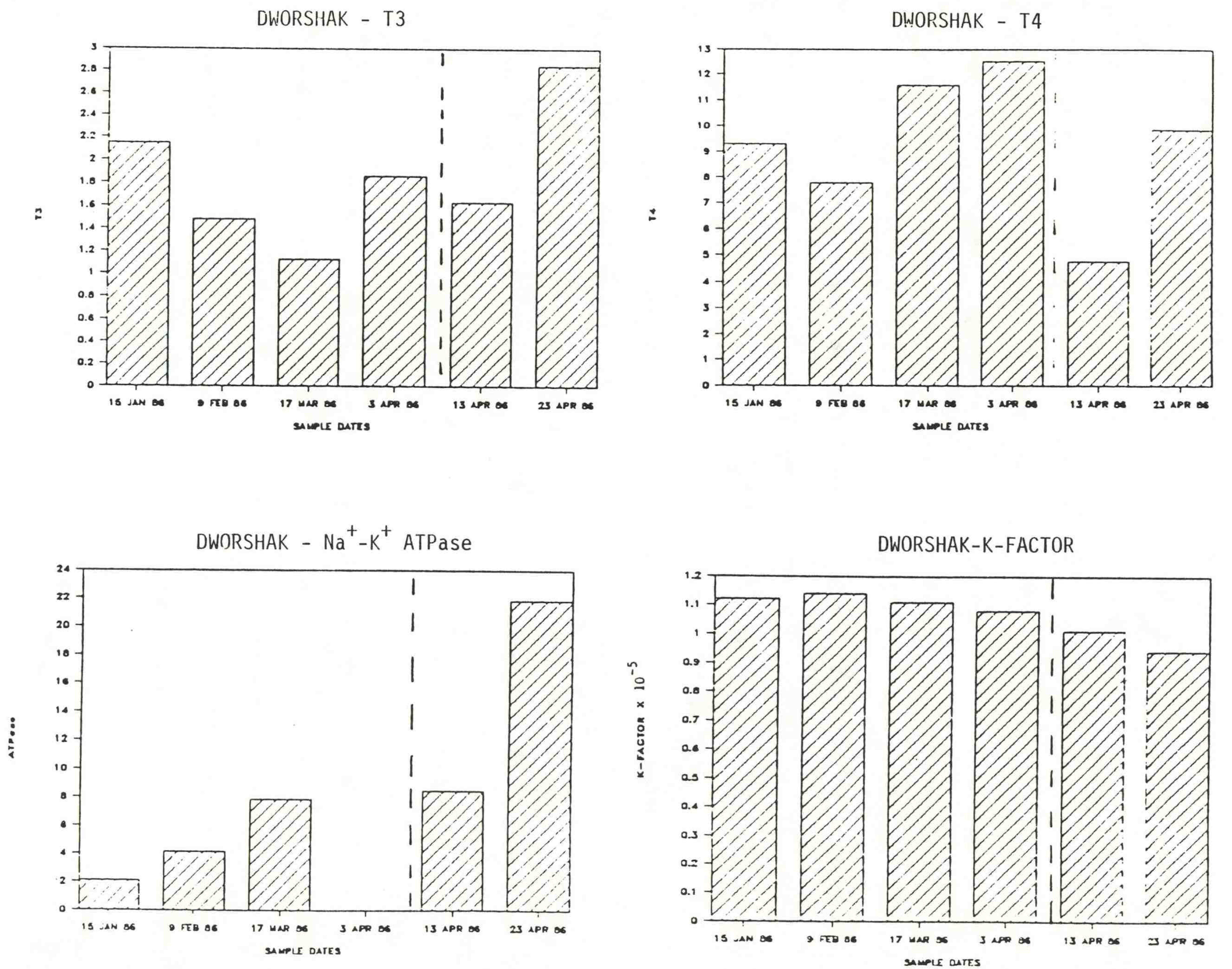

Figure 9.--Mean values of four smolt indices measured for spring chinook salmon at Dworshak Hatchery. Data to the right of the strippled vertical line were collected at riverine sampling sites.

Unlike Na^{+}-K^{+} ATPase which typically increases during smoltification, the patterns exhibited by thyroid hormones are variable and need to be interpreted in conjunction with Na^{+}-K^{+} ATPase. Thyroid hormones were sampled to provide a more complete picture of the smoltification process for the individual stocks. For all three stocks, T_3 levels were higher at the riverine sampling site than at the hatchery (Table 9). Changes in T_4 concentrations from the hatchery to in-river were not consistent. Both Rapid River and Sawtooth hatchery stocks exhibited post-release increases in the mean T_4 concentration for the samples. T_4 values increased from 5.75 to 9.32 ng $\cdot$ ml^{-1} and 3.49 to 5.68 ng $\cdot$ ml^{-1}, respectively. In neither case were these increases statistically significant. However, the mean T_4 levels for the Dworshak stock dropped significantly from 12.52 ng $\cdot$ ml^{-1} at the hatchery on 3 April to 4.77 ng $\cdot$ ml^{-1} on 13 April at Lower Granite Dam.

The K-factor for the Dworshak River stock decreased significantly from 1.08×10^{-5} at time of release to 0.94×10^{-5} on 23 April at Lower Granite Dam (Fig. 9). Similar significant post-release decreases were noted for both the Rapid River and Sawtooth hatchery stocks, from 1.10×10^{-5} to 0.9×10^{-5} and 1.13×10^{-5} to 1.00×10^{-5}, respectively.

FGE and Smoltification

Na^{+}-K^{+} ATPase patterns witnessed at Little Goose Dam on 15 and 20 April 1986 showed a gradient of decreasing Na^{+}-K^{+} ATPase activity with increased depth. The highest values (29.7 μmol P_i $\cdot$ mg $Prot^{-1}$ $\cdot$ h^{-1}) were observed in the gatewells, and the lowest values (9.8 μmol P_i $\cdot$ mg $Prot^{-1}$ $\cdot$ h^{-1}) occurred in the lower nets of the fyke-net frame (Table 10, Fig. 10).

Table 10.--Gill Na^{+}-K^{+} ATPase ($\mu mol\ P_i \cdot mg\ Prot^{-1} \cdot h^{-1}$) data acquired from sampling during FGE tests at Little Goose Dam in 1986. Standard deviations are in parentheses.

Date		Gatewell	Fyke net 1	Fyke net 2	Fyke net 3	Fyke net 4
15 April	$\bar{x}$	29.70 (6.69)	23.00 (6.00)	18.58 (5.27)	21.69 (7.68)	15.03 (9.30)
	n	20	20	20	10	5
20 April	$\bar{x}$	23.58 (6.76)	21.54 (4.60)	17.92 (5.68)	9.80 (4.50)	12.90 (2.36)
	n	20	9	11	7	3
26 April	$\bar{x}$	23.68 (6.76)	33.07 (8.60)	28.45 (4.31)	25.04 (9.68)	39.25*(5.05)
	n	20	9	20	8	2

* = one fish each in Fyke Nets 4 and 5 were averaged (44.3, 34.2) to generate this mean value which was assigned to Fyke Net 4.

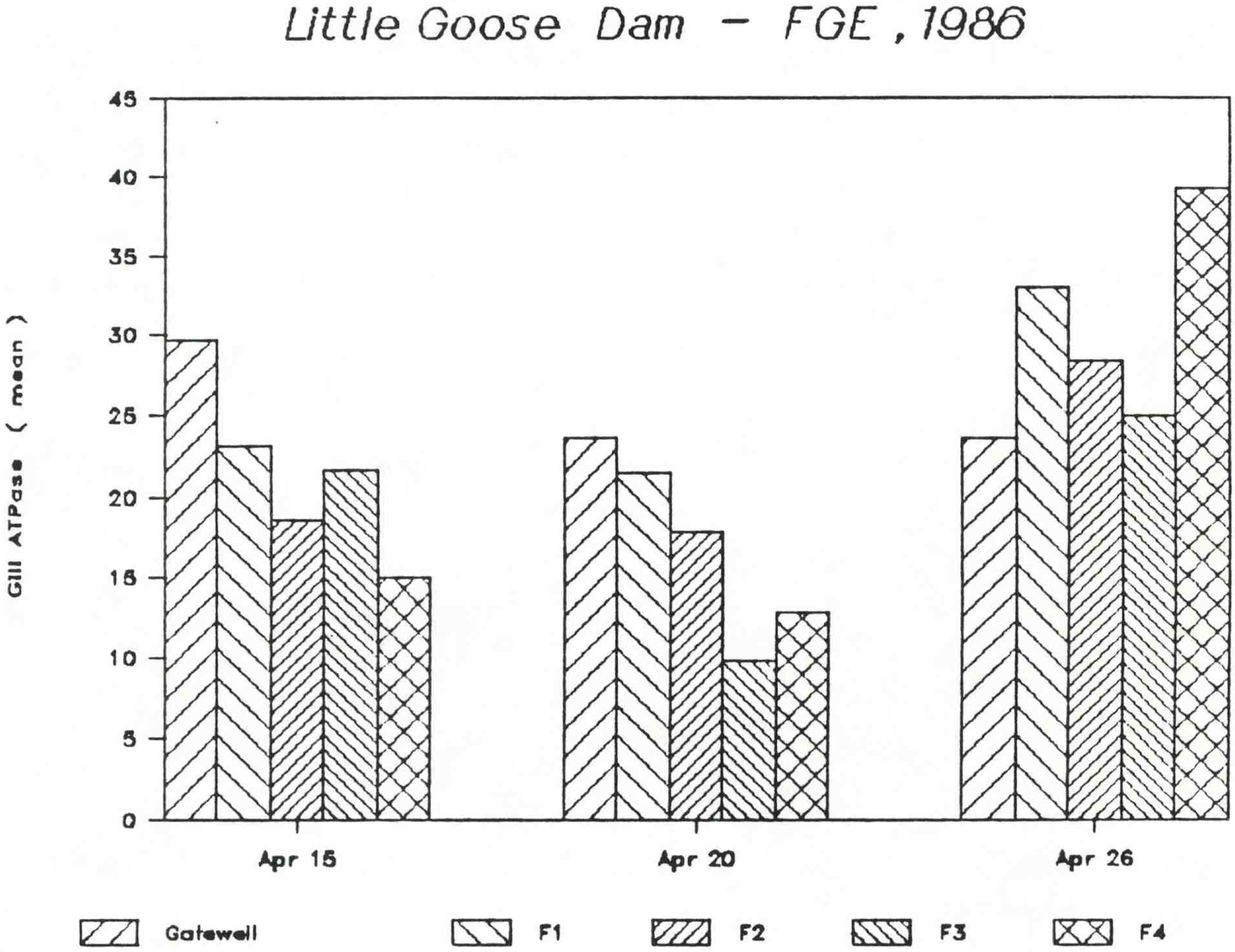

Figure 10.--ATPase data (means, µmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$) collected during FGE tests at Little Goose Dam in 1986.

Na^+-K^+ ATPase patterns observed on 26 April were different from those observed previously. The vertical gradient was no longer apparent, and higher levels were observed in the fyke nets (Table 10, Fig. 10). Furthermore, overall Na^+-K^+ ATPase levels were higher than observed previously.

Secondary data acquired at Lower Granite Dam on 16 May 1985 displayed the same patterns as those observed on 15 and 20 April 1986 at Little Goose Dam. Mean values of Na^+-K^+ ATPase activity generally decreased with increasing depth ranging from 43.4 to 33.0 μmol $P_i \cdot$ mg $Prot^{-1} \cdot h^{-1}$, from the gatewell to Fyke Net Row 4, respectively (Table 11, Fig. 11).

Partitioning the samples into those obtained from gatewell vs fyke and closure nets combined, we tested the hypothesis that guided fish possessed higher gill Na^+-K^+ ATPase levels than unguided fish using a one-tailed Mann-Whitney test. On three of four occasions (16 May 1985 and 15, 20 April 1986) we rejected the null hypothesis concluding that guided fish have significantly higher gill Na^+-K^+ ATPase levels. For data collected on 26 April 1986, we did not reject the null hypothesis (Table 12).

There is no evidence that fish guidance was associated with fish size. Using a Mann-Whitney test, we failed to detect any differences in the mean lengths of guided and unguided fish (Table 12).

Forebay Gillnet Sampling

From 8 to 18 April 1986, a total of 95 net sets were made in the forebay of Lower Granite and Little Goose Dams. Gillnet panels (3 m^2, variable mesh) were fished at various depths from the surface to the bottom (22 m) for a total of 397 h of fishing time. Nets were deployed from 45 to 250 m from the face of the dam. Only three chinook salmon were caught at depths from 10 to

Table 11.--Gill Na^+-K^+ ATPase ($\mu mol\ P_i \cdot mg\ Prot^{-1} \cdot h^{-1}$) data acquired from sampling at Lower Granite Dam on 16 May 1985. The sample size (n) indicates the number of fish assayed from each location.

	Gatewell	Closure net	Fyke net 1	Fyke net 2	Fyke net 3	Fyke net 4
n	14	12	11	11	11	2
$\bar{X}$ Na^+-K^+ ATPase	43.4	41.3	42.3	36.4	33.6	33.0
St. error of $\bar{X}$	2.2	3.8	4.3	2.7	2.9	8.0

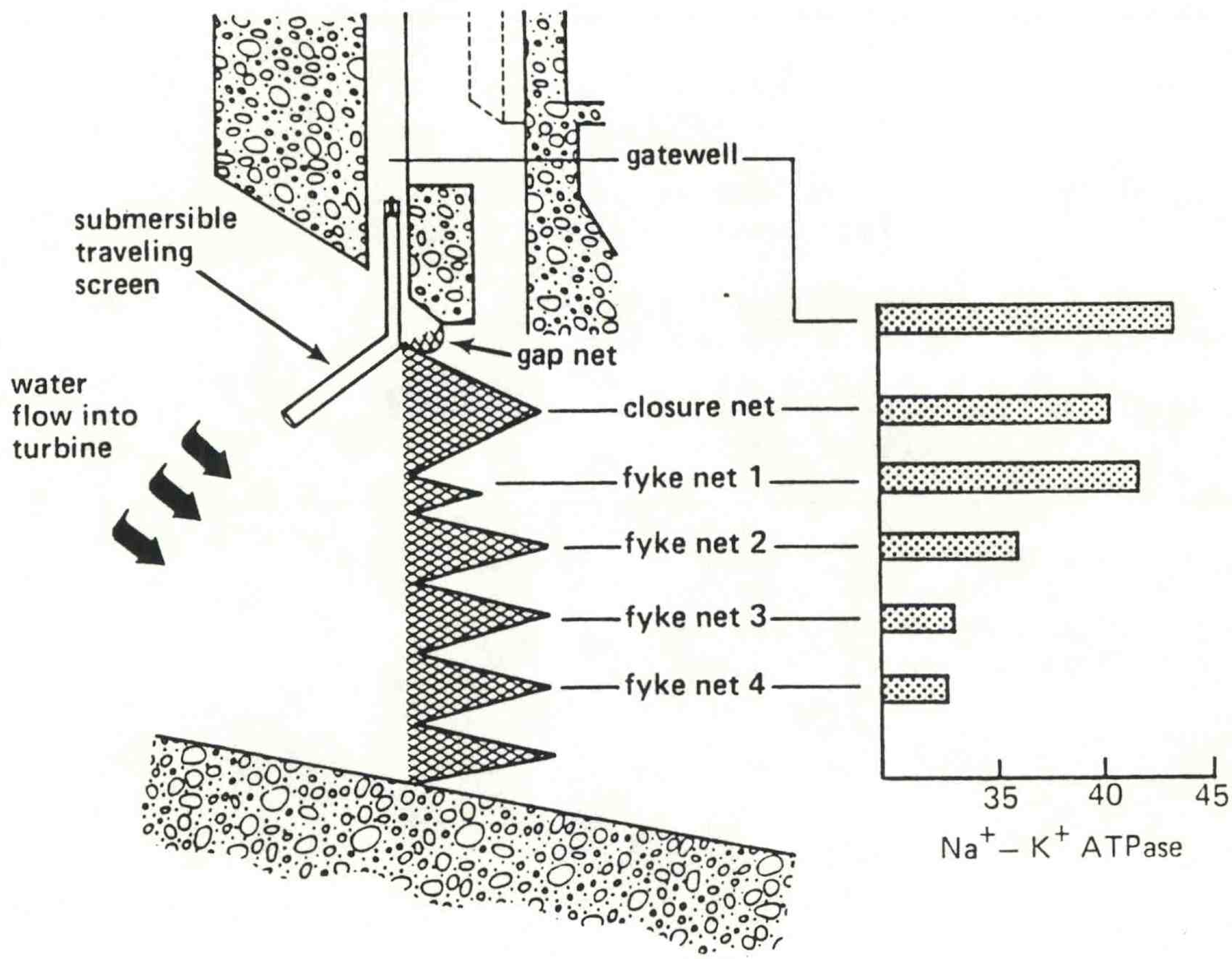

Figure 11.--Na^{+}-K^{+} ATPase data (mean, µmol P_i · mg $Prot^{-1}$ · h^{-1}) collected during an FGE test at Lower Granite Dam on 16 May 1985.

Table 12.--Results of Mann-Whitney tests for Na^+-K^+ ATPase activity and fork length in guided vs unguided fish.

	Factor	Mann-Whitney U	P
16 May 1985	Na^+-K^+ ATPase	226[a/]	<0.05
	Fork length	309[a/]	>0.50
15 April 1986	Na^+-K^+ ATPase	179[b/]	<0.001
	Fork length	621[b/]	0.47
20 April 1986	Na^+-K^+ ATPase	144.5[c/]	<0.01
	Fork length	360.5[c/]	0.23
26 April 1986	Na^+-K^+ ATPase	581[d/]	>0.50
	Fork length	292[d/]	0.07

a/ n = 14 guided and 47 unguided.
b/ n = 20 guided and 56 unguided.
c/ n = 20 guided and 30 unguided.
d/ n = 20 guided and 41 unguided.

18 m. The only other species captured were two chiselmouth, Acrocheilus alutaceus. Since the capture rate of yearling chinook salmon in the forebays was so inadequate, none of the comparisons proposed which required forebay samples was possible.

Guidability--Hatchery vs Wild Fish

A total of 204 scale samples were mounted and analyzed, including 17 branded spring chinook salmon from four different hatcheries. Unfortunately, no branded wild or Sawtooth Hatchery fish were captured for comparison. Sawtooth Hatchery spring chinook salmon differ from the usual hatchery spring chinook salmon in that they reportedly are reared under conditions similar to wild fish and may have scales with wild-like characteristics. Since no wild scales were available for comparison, scales were sorted into "wild-like" and "hatchery-like" categories. Only three "wild-like" scales were identified. All were collected during the 15 April FGE tests; one each in the gap net, Fyke Net 1, and Fyke Net 4.

Discussion

There are a number of possible explanations for the observations that at both Dworshak and Little White Salmon Hatcheries, swimming stamina remained stable, but there were substantial changes in Na^{+}-K^{+} ATPase activity and thyroid hormone levels (Tables 5 and 7) and at riverine sampling sites two stocks (Dworshak and Rapid River) exhibited significant increases in swimming stamina and all stocks exhibited significant increases in Na^{+}-K^{+} ATPase activity over that observed at respective hatcheries. Perhaps fish increase their stamina in response to the more vigorous physical activity they experience after release from the hatchery. Such benefits have been ascribed to coho salmon, O. kisutch, stocks in a series of experiments conducted by Besner (1980). Alternatively, once released from the hatchery, the weaker fish, those exhibiting poor stamina, may die leaving only the hardiest (highest stamina) to survive to the downstream recovery sites. Thirdly, swimming stamina may be linked to the smoltification process. In fact, both stocks showed a significant increase in Na^{+}-K^{+} ATPase activity at a downstream recovery site relative to maximum levels observed in the hatchery (Table 9). However, we have no direct evidence to indicate that this is a causal relationship. Furthermore, river temperatures (10°-11°C) were notably higher than those at either Dworshak or Rapid River Hatcheries at the time of release (4°-6°C). Therefore, possible temperature-related effects may confound the interpretation of swimming stamina data.

The buoyancy data collected in 1986 were inconclusive. We did not observe the increased buoyancy through smoltification observed in Atlantic salmon (Pinder and Eales 1969). However, we suspect our processing protocol may have influenced the PNB measurements and the observed values may be an artifact of our procedures. In 1987, we will modify our procedures.

The thyroid hormones are not in themselves a good measure of the status of a fish within the parr-smolt transformation. However, in conjunction with Na^{+}-K^{+} ATPase data, they provide a more complete picture of the physiological status of the population. More importantly, the thyroid hormones may play an important role in facilitating behavior or locomotory responses which in turn may affect FGE. Recent studies by Youngson et al. (1986) indicated there may be a link between water velocity, exercise, swimming performance, and the endocrine system as mediated by the thyroid hormones. For this reason, we feel it is important to monitor hormone levels and examine their potential association with swimming performance or perhaps some other behavior such as buoyancy adjustment.

For characterizing the status of the population in the parr-smolt transformation, gill Na^{+}-K^{+} ATPase appears to be the most reliable single index. Through smoltification, Na^{+}-K^{+} ATPase increases predictably to some maximal level then stabilizes (Rondorf et al. 1985). This is not the case for the thyroid hormones which can display a variety of patterns through development (Figs. 8 and 9) and must be interpreted in conjunction with Na^{+}-K^{+} ATPase data to be of use for indexing purposes.

Condition factor showed promise as an index of smoltification, particularly at Dworshak Hatchery, where K-factor decreased with smolt development (Fig. 9). At Little White Salmon Hatchery, this pattern was not observed even though Na^{+}-K^{+} ATPase activity increased over the same period. Using K-factor as a measure of smoltification in FGE studies is of questionable value. Since the fish collected in the fyke nets are dead, there is a possibility of passive water absorption by tissues, which in turn affects weight and K-factor. Since we have no data that detail water absorption and weight-gain rates, we do not recommend this index for interpretation of FGE data.

The indices of smoltification at both the Little White Salmon and Dworshak Hatcheries suggest that the smoltification process was underway but not yet complete by the time the fish were released. The values for the physiological indices of smoltification of fish collected on the river were significantly higher than those seen at any sampling date in the hatchery. Both gill Na^{+}-K^{+} ATPase and plasma levels of thyroid hormones in fish collected from the gatewells were elevated several-fold over that found in fish at the hatchery. These data could be interpreted in several ways, not mutually exclusive. One possibility is that the fish may have been released from the hatchery in an incomplete state of smoltification, and smoltification proceeded during downstream migration. Evidence for this possibility is supplied by the studies of Zaugg (1982) who found elevated gill Na^{+}-K^{+} ATPase in fish collected near the Columbia River estuary shortly after the sampled fish had been released from the hatchery. An alternate interpretation is that the fish collected in the gatewells at the downstream sites were the most completely smolted fish in the population that was released (if less smolted fish did not migrate or were not guided through the bypass system at Lower Granite Dam, then only the more completely smolted fish in the population would appear in the gatewell of Little Goose Dam). This second hypothesis is supported by the results of the study on vertical distribution at both Little Goose Dam (1986) and Lower Granite Dam (1985). In the majority of cases, the fish with the highest gill Na^{+}-K^{+} ATPase activities were found in the gatewell or shallower fyke nets (Figs. 10 and 11) which suggest that they would be more likely guided to the gatewells. Both of these mechanisms, the in-river advancement of smoltification and STS selectivity of the most smolted fish, may be acting in concert. A better understanding of which of these two hypotheses is most accurate or how they are interrelated could be obtained by more extensive sampling at the hatchery concurrent with sampling at Lower Granite and Little Goose Dams.

Generally, Na^{+}-K^{+} ATPase data collected during FGE testing showed a vertical gradient in enzyme activity with the highest mean values occurring uppermost in the water column (Figs. 10 and 11). On two of the three sampling dates at Little Goose Dam, 15 and 20 April 1986, guided fish exhibited Na^{+}-K^{+}

ATPase levels significantly higher than the unguided population. These observations are consistent with those at Lower Granite Dam in 1985. On 26 April, though, the enzyme levels of guided fish were lower than the unguided fish even though a gradient in enzyme activity was evident within the fyke-net assay. The apparent anomaly cannot be explained.

We have theorized that the in-season changes in FGE from about 40 to 70% at Lower Granite Dam in 1984 and 1985 (Swan et al. 1985, 1986) may be related to the status of smoltification within the population. Unfortunately, in 1986 we were not sampling at that dam, and at Little Goose Dam, FGE was relatively stable and high at the outset and throughout the migration. The FGE in Slot 4B on 15, 20, and 26 April was 77.0, 79.4 and 68.19%, respectively, with a mean of 74.8% Consequently, we were not able to examine a situation similar to that at Lower Granite Dam. In 1987, we propose to conduct concurrent studies at both dams. If the seasonal FGE patterns at Lower Granite Dam are consistent with those previously observed at that site, we should be better able to examine the relationship between FGE and the prevailing physiological status of the chinook salmon populations.

GENERAL CONCLUSIONS

1. FGE for yearling chinook salmon with the operating gate raised 20 ft averaged 74%, a significant ($P < 0.005$) 13% increase from the 61% measured with the operating gate in the normal stored position.

2. There was no significant difference between FGE when the operating gate was raised 20 or 62 ft.

3. TFGE and FGE for yearling chinook salmon were high initially and remained at high levels, as in 1983 at Lower Granite Dam, throughout the

sampling period. This is in sharp contrast with measurements at Lower Granite Dam in 1984 and 1985 when TFGE and FGE were low initially and gradually increased as the season progressed.

4. Yearling chinook salmon which are further along in the parr/smolt transformation are more susceptible to guidance by an STS. Levels of gill Na^{+}-K^{+} ATPase (a measure of smoltification) were significantly higher on guided than unguided fish at Lower Granite Dam in 1985 and at Little Goose Dam in 1986.

5. There is no relation between fish size and guidance of yearling chinook salmon.

6. Swimming stamina and gill Na^{+}-K^{+} ATPase increased significantly from time of release at the hatchery to arrival at riverine sampling sites.

7. The buoyancy studies were inconclusive. Further examination of this response is proposed for 1987 research.

8. Capture rate of yearling chinook salmon in forebays was inadequate for analysis.

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APPENDIX A

Sample Sizes Needed for Comparative Trials

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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- α/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-β.

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

Calculations for the Cross-over Design Analysis of Variance and Significance Levels Associated with Treatment Effects for Yearling Chinook Salmon at Little Goose Dam, 1986

Appendix Table B1.--Original data collection arrangement assigned to the treatment variables and calculations for the analysis of the cross-over design for test conditions alternating in Slots 4A and 4B at Little Goose Dam, 1986.

Data arrangement

	Slot 4A			Slot 4B		
Date	Gate level (ft)	% FGE	Treatment variable	Gate level (ft)	% FGE	Treatment variable
4/14	0	73.9	y_{1A} [a]	20	75.8	y_{2B} [b]
4/15	20	76.6	y_{2A}	0	69.4	y_{1B}
4/17	20	71.9	y_{2A}	0	57.3	y_{1B}
4/18	0	58.8	y_{1A}	20	81.0	y_{2B}
4/20	0	60.8	y_{1A}	20	79.4	y_{2B}
4/21	20	75.6	y_{2A}	0	62.5	y_{1B}
4/23	20	77.7	y_{2A}	0	70.9	y_{1B}
4/24	0	49.5	y_{1A}	20	65.9	y_{2B}
4/26	0	43.4	y_{1A}	20	68.1	y_{2B}
4/27	20	60.6	y_{2A}	0	54.4	y_{1B}
4/29	20	56.7	y_{2A}	0	54.3	y_{1B}
4/30	0	55.9	y_{1A}	20	79.2	y_{2B}

[a] The treatment variable y_1 identifies treatment 1 (standard gate level with a standard STS). The subscript following this variable identifies Unit A or Unit B.

[b] The treatment variable y_2 identifies treatment 2 (gate raised 20 feet with a standard STS).

Calculations

The difference between treatment effects is measured by the equation:

$$1/2\ (y_{1A} + y_{1B} - y_{2A} - y_{2B}) = T$$

where y_{1A} and y_{1B} = FGE for treatment 1 in Units 4A and 4B, and y_{2A} and y_{2B} = FGE for treatment 2 in Units 4A and 4B.

Paired days	1/2 (y_{1A} +	y_{1B} -	y_{2A} -	y_{2B}) =	T
4/14-15	73.9	69.4	76.6	75.8	-4.55
4/17-18	58.8	57.3	71.9	81.0	-18.40
4/20-21	60.8	62.5	75.6	79.4	-15.85
4/23-24	49.5	70.9	77.7	65.9	-11.60
4/26-27	43.4	54.4	60.6	68.1	-15.45
4/29-30	55.9	54.3	56.7	79.2	-12.85

The mean difference between treatments = $\bar{T} = \Sigma T/n = -13.12$

A statistical test of the null hypothesis that treatment 1 = treatment 2 is given by the t test:

$$t = \bar{T}/s$$

where $s = \sqrt{\frac{s^2}{n}}$ and $s^2 = \frac{\Sigma(T - \bar{T})^2}{n - 1}$

In the calculations, $s^2 = 23.32$, therefore: $t = \frac{-13.12}{\sqrt{\frac{23.32}{6}}} = -6.655$

at 5 degrees of freedom, this t value is significant at the $0.005 < P < 0.001$ probability level. The alternative hypothesis (treatment 1 $\neq$ treatment 2) is accepted.

Appendix Table B2.--Statistical analysis of Little Goose Dam FGE tests for yearling chinook salmon, 1986.

Test condition	Test analysis	*t* statistic	D.f.	Probability level
Treatment 1[(a)] vs Treatment 2[(b)]	Cross-over design	-6.655 *	5	$0.005 > P > 0.001$
Treatment 1 in Slot 4A vs Treatment 3 in Slot 4C[(c)]	Paired comparison *t* test	-4.193 *	5	$0.010 > P > 0.005$
Treatment 1 in Slot 4B vs Treatment 3 in Slot 4C	Paired comparison *t* test	-3.259 *	5	$0.025 > P > 0.010$
Treatment 2 in Slot 4A vs Treatment 3 in Slot 4C	Paired comparison *t* test	-0.363 ns	5	$0.900 > P > 0.500$
Treatment 2 in Slot 4B vs Treatment 3 in Slot 4C	Paired comparison *t* test	1.118 ns	5	$0.400 > P > 0.200$

(a) Treatment 1 was the standard STS with standard gate condition. This treatment alternated between Slots 4A and 4B.

(b) Treatment 2 was the standard STS with gate raised 20 feet condition. This treatment also alternated between Slots 4A and 4B.

(c) Treatment 3 was the lowered STS with gate raised 62 feet condition. This treatment was only tested in Slot 4C.

APPENDIX C

Catch Data for Fish Guiding Efficiency and Vertical Distribution Tests at Little Goose Dam, 1986

Appendix Table C1.--Catches of yearling chinook salmon during fish guiding efficiency tests conducted at a 135 MW turbine load at Little Goose Dam in spring of 1986.

		Slot 4A FGE[a]					Slot 4B FGE[a]					Slot 4C FGE[b]				
Test series[c]	Date	Gate level (ft)	Gatewell number	Unguided (est.)	Total	% FGE	Gate level (ft)	Gatewell number	Unguided (est.)	Total	% FGE	Gate level (ft)	Gatewell number	Unguided (est.)	Total	% FGE
1	4/14	0	1121	395	1516	73.9	20	802	256	1058	75.8	62	427	173	600	71.2
	4/15	20	877	268	1145	76.6	0	631	278	909	69.4	62	310	143	453	68.4
2	4/17	20	274	107	381	71.9	0	181	135	316	57.3	62	190	97	287	66.2
	4/18	0	438	307	745	58.8	20	596	140	736	81.0	62	344	73	417	82.5
3	4/20	0	293	189	482	60.8	20	404	105	509	79.4	62	237	65	302	78.5
	4/21	20	997	322	1319	75.6	0	551	331	882	62.5	62	395	157	552	71.6
4	4/23	20	1100	315	1415	77.7	0	608	249	857	70.9	62	471	103	574	82.1
	4/24	0	620	632	1252	49.5	20	880	455	1335	65.9	62	548	244	792	69.2
5	4/26	0	228	297	525	43.4	20	273	128	401	68.1	62	127	72	199	63.8
	4/27	20	487	317	804	60.6	0	258	216	474	54.4	62	178	103	281	63.3
6	4/29	20	187	143	330	56.7	0	140	118	258	54.3	62	111	34	145	76.6
	4/30	0	588	463	1051	55.9	20	809	213	1022	79.2	62	403	135	538	74.9

(a) The test conditions in Slots 5A and 5B were conducted with standard STS.

(b) The test condition in Slot 5C was conducted with a lowered STS.

(c) A vertical distribution test was conducted prior to the earliest date listed for each test series (i.e. vertical distribution was conducted on 13 April for Test Series 1).

Appendix Table C2.--Catches of steelhead trout during fish guiding efficiency tests conducted at a 135 MW turbine load at Little Goose Dam in spring of 1986.

		Slot 4A FGE(a)					Slot 4B FGE(a)					Slot 4C FGE(b)				
Test series(c)	Date	Gate level (ft)	Gatewell number	Unguided (est.)	Total	% FGE	Gate level (ft)	Gatewell number	Unguided (est.)	Total	% FGE	Gate level (ft)	Gatewell number	Unguided (est.)	Total	% FGE
1	4/14	0	127	23	150	84.7	20	214	24	238	89.9	62	103	25	128	80.5
	4/15	20	35	11	46	76.1	0	56	4	60	93.3	62	38	9	47	80.9
2	4/17	20	90	23	113	79.6	0	49	25	74	66.2	62	58	16	74	78.4
	4/18	0	59	38	97	60.8	20	45	19	64	70.3	62	73	11	84	86.9
3	4/20	0	42	14	56	75.0	20	33	8	41	80.5	62	29	5	34	85.3
	4/21	20	67	29	96	69.8	0	47	19	66	71.2	62	52	17	69	75.4
4	4/23	20	108	63	171	63.2	0	85	50	135	63.0	62	74	17	91	81.3
	4/24	0	70	41	111	63.1	20	74	34	108	68.5	62	74	27	101	73.3
5	4/26	0	254	96	350	72.6	20	183	70	253	72.3	62	132	26	158	83.5
	4/27	20	570	280	850	67.1	0	405	248	653	62.0	62	423	119	542	78.0
6	4/29	20	281	126	407	69.0	0	173	102	275	62.9	62	234	54	288	81.3
	4/30	0	484	166	650	74.5	20	494	123	617	80.1	62	429	125	554	77.4

(a) The test conditions in Slots 5A and 5B were conducted with standard STS.

(b) The test condition in Slot 5C was conducted with a lowered STS.

(c) A vertical distribution test was conducted prior to the earliest date listed for each test series (i.e. vertical distribution was conducted on 13 April for Test Series 1).

Appendix Table C3.--Catches of yearling chinook salmon during vertical distribution tests in Slot 5B at Little Goose Dam, 1986.

	Test Series 1[(a)]		Test Series 2		Test Series 3		Test Series 4		Test Series 5		Test Series 6	
	13 April		16 April		19 April		22 April		25 April		28 April	
Level of sample[(b)]	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent
Gatewell	123	11.2	18	14.4	64	10.5	49	12.0	65	16.6	32	9.6
1	431	50.5	21	31.2	292	58.5	164	52.0	176	61.5	120	45.6
2	269	75.0	29	54.4	155	84.0	104	77.4	102	87.5	90	72.6
3T[(c)]	57	80.2	7	60.0	42	90.9	12	80.3	19	92.3	30	81.6
3B[(d)]	102	89.5	20	76.0	19	94.0	30	87.6	18	96.9	19	87.3
4	51	94.2	21	92.8	18	97.0	36	96.4	12	100.0	21	93.6
5	48	98.6	3	95.2	12	99.0	9	98.6	0	100.0	9	96.3
6	15	100.0	6	100.0	3	99.5	6	100.0	0	100.0	9	99.0
7	0	100.0	0	100.0	0	99.5	0	100.0	0	100.0	3	100.0
8	0	100.0	0	100.0	3	100.0	0	100.0	0	100.0	0	100.0
Totals	1096		125		608		410		392		333	

(a) Each vertical distribution test series was followed by 2 days of FGE testing.

(b) Level of sample refers to the level of the water column that fish were captured. Gatewell was the upper portion of the water column and Level 8 was the portion just above the bottom of the intake. Levels Gatewell thru 3B are actual numbers of fish caught whereas Levels 4 thru 8 have been 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 captured in Levels Gatewell thru 3T (top net in the halved net level 3).

(d) Net level 3B (bottom) is the upper most level of theortically unguided fish.

Appendix Table C4.--Catches of steelhead trout during vertical distribution tests in Slot 5B at Little Goose Dam, 1986.

	Test Series 1[a]		Test Series 2		Test Series 3		Test Series 4		Test Series 5		Test Series 6	
	13 April		16 April		19 April		22 April		25 April		28 April	
Level of sample[b]	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent	Number sampled	Cumulative percent
Gatewell	17	18.5	10	20.8	11	27.5	13	32.5	30	25.0	110	30.3
1	40	62.0	18	58.3	17	70.0	14	67.5	40	58.3	114	61.7
2	10	72.9	6	70.8	6	85.0	8	87.5	25	79.1	62	78.8
3T[c]	7	80.5	4	79.1	0	85.0	5	100.0	5	83.3	24	85.4
3B[d]	3	83.8	4	87.4	3	92.5	0	100.0	5	87.5	17	90.1
4	12	96.8	3	93.7	3	100.0	0	100.0	9	95.0	21	95.9
5	0	96.8	0	93.7	0	100.0	0	100.0	0	95.0	12	99.2
6	3	100.0	3	100.0	0	100.0	0	100.0	3	97.5	3	100.0
7	0	100.0	0	100.0	0	100.0	0	100.0	3	100.0	0	100.0
8	0	100.0	0	100.0	0	100.0	0	100.0	0	100.0	0	100.0
Totals	92		48		40		40		120		363	

(a) Each vertical distribution test series was followed by 2 days of FGE testing.

(b) Level of sample refers to the level of the water column that fish were captured. Gatewell was the upper portion of the water column and Level 8 was the portion just above the bottom of the intake. Levels Gatewell thru 3B are actual numbers of fish caught whereas Levels 4 thru 8 have been 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 captured in Levels Gatewell thru 3T (top net in the halved net level 3).

(d) Net level 3B (bottom) is the upper most level of theortically unguided fish.