DEVELOPMENT OF AN IMPROVED FINGERLING PROTECTION SYSTEM FOR LOWER GRANITE DAM - 1984

Final Report

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Financed by
U.S. Army Corps of Engineers
Contract DACW68-84-H-0034

and

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May 1985

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INTRODUCTION

Lower Granite and Little Goose Dams are the two collector dams for the fish transportation efforts on the Snake River (Fig. 1). Acceptable fish collection efficiency at these dams is necessary for the success of the program. The U.S. Army Corps of Engineers (CofE) and the National Marine Fisheries Service (NMFS) are continuing their efforts to improve fish collection at these dams. Submersible traveling screens (STS), that divert smolts from the turbine intakes into gatewells, and orifices in the gatewells, that allow the fish access to the fingerling bypasses, are vital components of these collection systems (Fig. 2). Turbine intakes at Lower Granite Dam are unique because there is a special fish screen slot (FSS) as well as the normal bulkhead slot (BHS) and operating gate slot (OGS) (Matthews et al. 1977). Earlier studies determined that the FSS were not as efficient as the BHS for STS operation and, therefore, are no longer used (Park et al. 1976 and 1977).

Fish guiding efficiencies (FGE) of about 75% and orifice passage efficiencies (OPE) of 70% have generally been considered acceptable levels for collector dams. Studies conducted at Lower Granite Dam in 1982 revealed that FGE for yearling chinook salmon was only about 50%, considerably below acceptable levels (Swan et al. 1983). Flow patterns from model studies performed in the fall of 1982 suggested the fish might be diverting under the STS. These model studies also showed that raising the operating gate reduced the amount of flow deflecting under the STS and increased the flows up the BHS.

Prototype tests of these options conducted at Lower Granite Dam in 1983 showed a positive improvement in FGE (to 74% $\pm$ 7 from 53% $\pm$ 7) by raising the operating gate about 20 feet (Swan et al. 1984). In addition to raising the

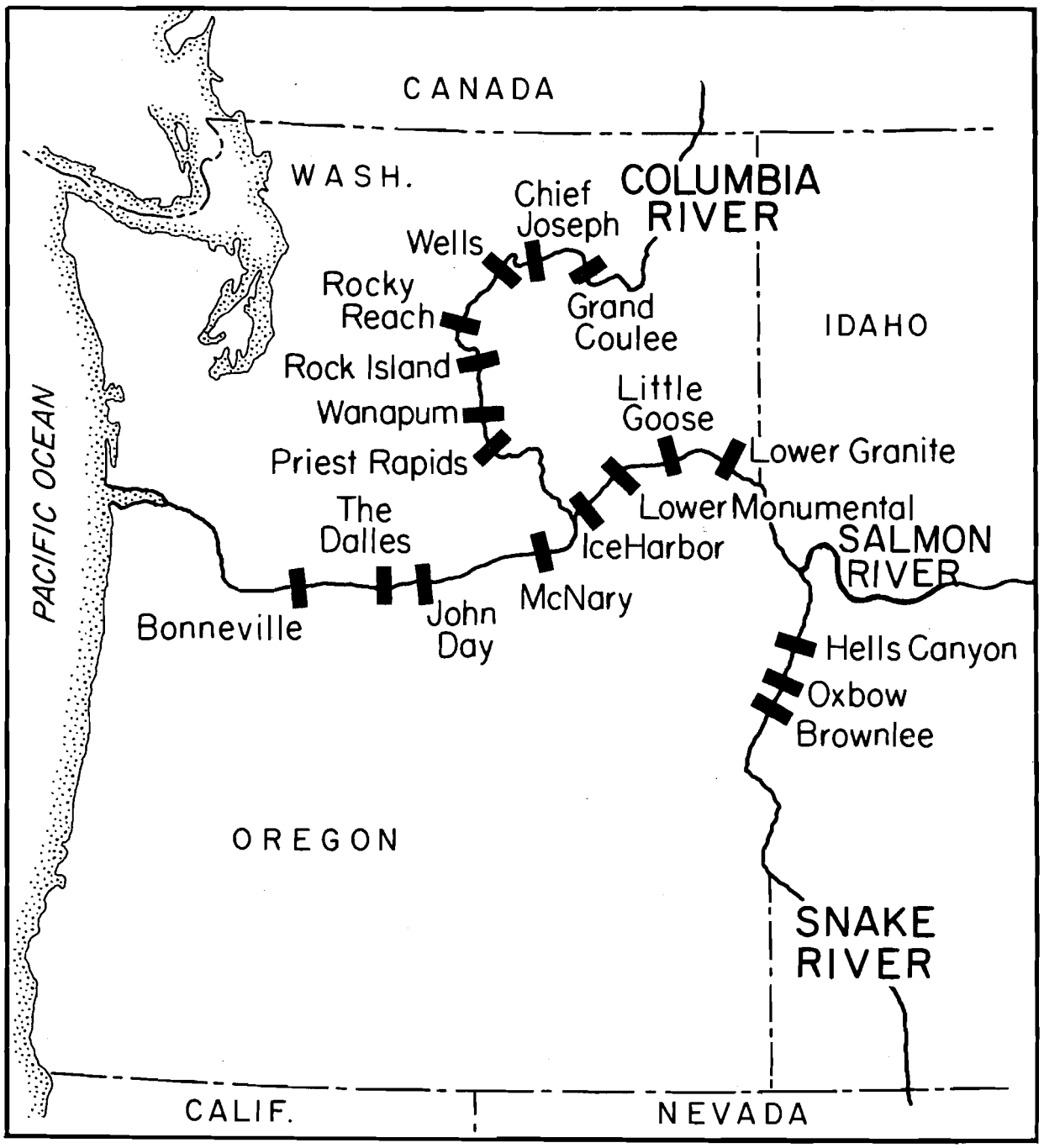

Figure 1.--Main stem dams in the Columbia River basin.

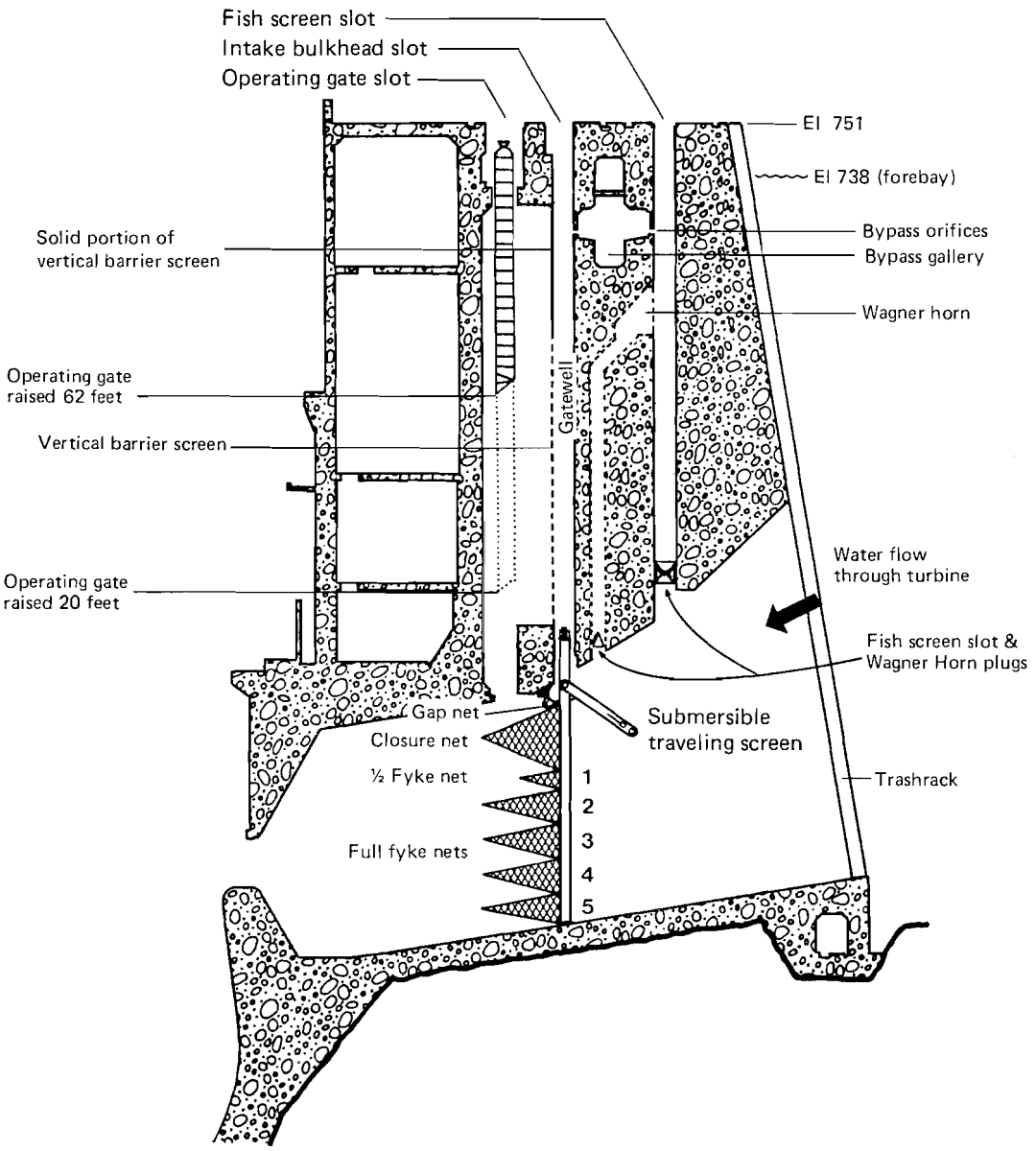

Figure 2.--Cross section of Unit 4-A turbine intake at Lower Granite Dam showing STS, fyke nets, and position of operating gates when raised 20 ft and 62 ft for FGE testing.

operating gate in 1983, the following modifications were made: (1) lowering the STS, (2) adding a ceiling beam extension relative to lowering the STS, (3) replacing some of the solid plates from inside the STS with perforated plates in an effort to increase screen porosity, and (4) closing the FSS. An analysis of the model studies regarding these modifications led to an assumption that the major reasons for the improved FGE were the raised gate and, to a lesser degree, the removal of the solid plate.

Testing in 1984 was designed primarily to determine the effects of a fully raised operating gate (up 62 feet) on FGE. It was also necessary to determine if a balanced flow vertical barrier screen (BFVBS) would be required to prevent injury or descaling problems caused by the increased flow into the BHS.

Vertical distribution tests were not included in the initial research plan (based on the positive results of 1983 testing). However, after measuring low FGE in the early tests of 1984, a decision to include vertical distribution tests was made.

In 1982, an evaluation of the standard 8-inch diameter orifices (two per gatewell) resulted in unacceptably low levels of OPE for both yearling chinook salmon and steelhead (Swan et al. 1983). Testing of a single 12-inch diameter orifice in lieu of the standard two 8-inch diameter orifices in 1983 resulted in acceptable OPE for yearling chinook salmon (74% $\pm$ 7) but not for steelhead (52% $\pm$ 11) (Swan et al. 1984). Tests in 1984 used two 12-inch diameter orifices to measure OPE with a fully raised operating gate and to compare a standard vertical barrier screen (SVBS) to a BFVBS. Also, north vs south orifice locations and various placements of solid plate barrier screen modifications for improving OPE were tested.

METHODS AND MATERIALS

Experimental Equipment

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

1. STS 13 and 5 were equipped with a full complement of fyke and gap nets.[1/]

2. Two portable orifice traps.

3. Two gatewell dip nets (Swan et al. 1979).

4. On-deck fish examining facilities.

5. Two mobile cranes.

6. Special plugs to seal off the Wagner Horns to prevent fish entry into the test units.

7. Two 12-inch diameter orifices in 4-A BHS.

8. Two 12-inch diameter orifices in 3-A BHS.

9. Two closure devices in 3-A and 4-A FSS.

10. Modified BFVBS in 4-A and a modified SVBS in 3-A. (A BFVBS consists of a SVBS with a 30% porosity plate attached to the downstream side of the screened panels.)

11. One vertical distribution net frame.

12. CofE services.

    a. Provided gantry crane service for preparation and performance of STS FGE tests.

    b. Drilled out the two 8-inch diameter orifices in 3-A to 12-inch diameter.

[1/] Midway through the testing, internal solid plates of STS 13 were changed to perforated plate (46% open area) at the lower end of the traveling screen and STS 5 was replaced with STS 15 already equipped with perforated plate.

c. Made special provisions for temporarily raising the operating gates in 3-A and 4-A.

d. Assisted the NMFS with the modifications to the barrier screens in 3-A and 4-A prior to the testing season.

Measurements and Procedures

STS Fish Guiding Efficiency

Tests were mainly conducted in Units 3-A and 4-A. Unit 3-A (the control unit) was equipped with a SVBS, a standard STS operating at a 55° guiding angle, and the operating gate stored at the fully raised position (hydraulic cylinder removed and gate dogged at deck level, 62 feet above the lower concrete beam). Unit 4-A (the test unit) was also equipped with a standard STS at a 55° guiding angle, a BFVBS, and the operating gate dogged off at deck level. In addition, this gate had the capability of being raised from its standard setting (0) to 46 feet.

For FGE tests, the STS were equipped with a composite of nets for recovering a percentage of the unguided fish. A net frame suspended below the STS supported a vertical column of five fyke nets. On the upper part of this frame, these nets were flanked on each side by a column of three additional fyke nets (Figs. 2 and 3). The uppermost net (one-half fyke net) in each column was approximately 3.5 by 6.5 ft, and the lower nets (full size fyke nets) were approximately 6.5 ft square. A gap net, attached near the top of the STS, captured fingerlings that passed through the space between the top of the STS and the concrete beam that divides the OGS and BHS. Closure nets attached to the back of the STS captured those fish passing below the STS but over the top of the fyke net frame.

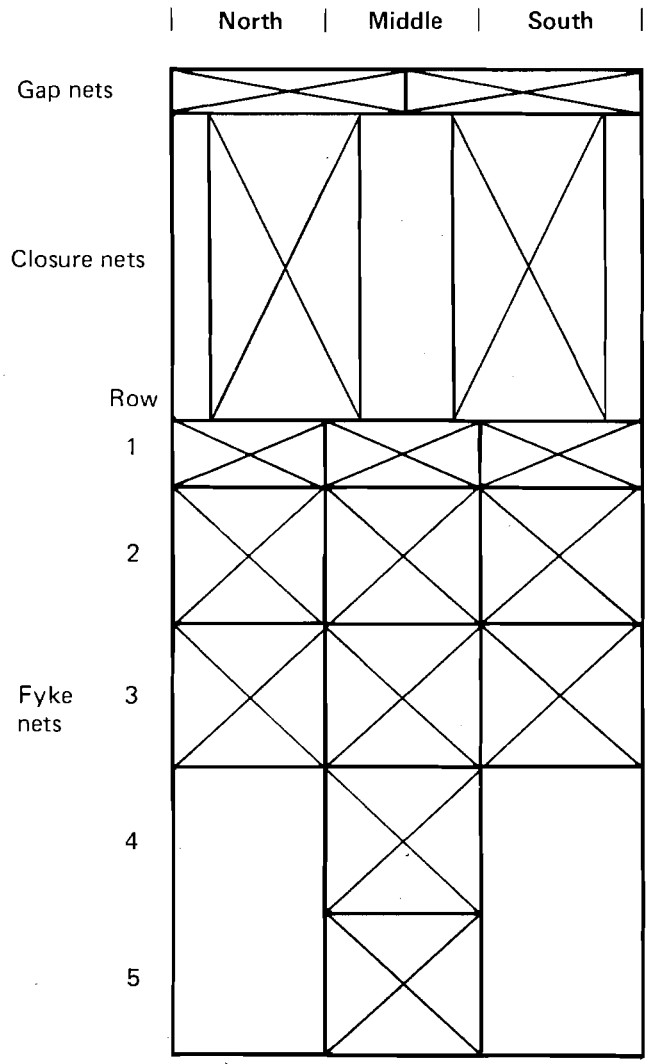

Figure 3.--Layout of fyke nets used to measure FGE at Lower Granite Dam.

The net frame used for determining vertical distribution was constructed from the two STS FGE net frames. It fished a single vertical column of fyke nets in the middle one-third of the cross-sectional area of the intake. Standard fyke nets were used to sample fish from the intake, and the dip basket was used to collect the fish entering the gatewell.

Prior to the testing program, closure devices were installed in the FSS of Units 3-A and 4-A to prevent the entry of fish so all the guided fish could be recovered by only having to dip the BHS. Also, a specially designed bladder type plug was installed to prevent similar entry in the Wagner Horns of Units 3-A and 4-A.

The turbines in Units 3 and 4 were run only during the time of the day that FGE tests were conducted. During the tests, the STS were operated in the standard screen cycling mode, the same as the rest of the STS. Bypass orifices in Units 3A and 4A remained closed throughout the testing season.

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

1. The STS in Units 3-A and 4-A with attached fyke net frames were lowered into the intake with the gantry crane.

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

3. The operating gate in Unit 4A was set for the prescribed test condition.

4. Units 3 and 4 were brought to peak efficiency (135 MW).

5. The numbers of fish entering each BHS were monitored by periodic dipnetting.

6. The test was terminated when adequate numbers of fish for statistical needs were collected.

7. The turbine was shut down, and final cleanout dips were made in the BHS in Units 3-A and 4-A.

8. The operating gate in Unit 4A was lowered (when appropriate) to its normal position.

9. The STS with attached fyke nets and frames were brought to the surface, and the fish were removed from the nets for identification and enumeration.

Each test was about 2 to 5 h long, starting between 1700 and 1800 h and terminating about 2000 or 2200 h when adequate numbers of fish had been guided into the BHS as determined by gatewell dipnetting. For each condition tested, the experimental design called for a goal of 300 fish per replicate (gatewell catch) and a minimum of three replicates to satisfy specified statistical significance levels for detecting relevant differences of a stated magnitude (Appendix A). Contingency table procedures using the G-test were used in the statistical analysis (Sokal and Rohlf 1981).

The procedures for determining FGE were similar to those used in previous experiments of this type (Swan et al. 1983 and 1984). 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. Guided fish included fish from the BHS only. FGE was calculated as guided fish divided by the total estimated 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 (BHS)
GN = gapnet catch
FN = fyke net catch (times 3 when fishing only the center one-third of the intake)
CN = closure net catch; the closure net catch was expanded by 1.5 because the closure nets only fished two-thirds of the area.

Two vertical distribution tests were conducted in Unit 4A midway through the season in an effort to determine the cause for the low FGE. The operating gate was in its normal stored position so that results obtained could be compared with 1982 measurements. A standard replicate for vertical distribution was conducted in a similar manner 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. Since the single column of fyke nets fished the middle third of the intake, each net catch was multiplied by a factor of three to estimate the number of fish in that net level. The sum of these estimates plus the gatewell catch provided an estimate of the total number of fish entering the intakes during the test. The percentage of fish for each net level (vertical distribution) was determined by dividing the computed net level catch by the total intake estimate.

Orifice Fish Passage Efficiency

Tests were conducted to directly compare OPE through 12-inch diameter orifices in gatewells with various modifications to a BFVBS and a SVBS and to determine if there was a bias between north and south locations. Initial tests were conducted with fully raised operating gates.

The 87-foot high vertical barrier screens are made up of six screened panel sections at the bottom and four solid panel sections at the top. For tests in 1984, the lowest solid panel (panel four) in Units 3-A and 4-A were changed to a screened panel section. The second and third solid panel sections were modified in a manner that allowed the center one-third of the total width to remain solid with the option of exposing barrier screen mesh on

either side of the solid portions, either simultaneously or separately. All the screened panel sections in Unit 3-A were SVBS and in Unit 4-A BFVBS.

The north and south orifices in Units 3-A and 4-A were enlarged to a 12-inch diameter. Initially each south orifice was connected to a trap in the bypass gallery to compare OPE for a SVBS with a BFVBS. Following this initial test series, the trap from the gatewell with the lowest OPE (3-A) was disassembled and moved to the north orifice of Gatewell 4-A for north vs south orifice comparisons (space limitations in the bypass gallery did not allow enough room to install traps on all four orifices).

The remainder of the OPE testing was conducted in Unit 4-A and tested various operating gate levels and configurations of the modified BFVBS to induce flow patterns in the gatewell that would better guide fish to the orifice.

Each test was 24 h long, and fish passing into the trap were routinely monitored. Each hour the orifice was closed temporarily while the trap was emptied (approximately 5 min). The catch was anesthetized using MS 222 for species enumeration and held in a recovery box until the next hourly check and then released into the fingerling bypass gallery. After 24 h, the orifice was closed, the turbine was shut down, and the residual fish were dipped from the gatewell. After dipping, the turbine was returned to service and the orifice was reopened. Tests started at 1200 h after dipping out the residual fish and ended 24 h later. The OPE was measured by comparing the number of residual fish to the total number of fish caught at the end of the test. All test conditions except one consisted of three replicates. During the tests, turbines were operated continuously at peak efficiency (135 MW). During peak periods of fish migration, OPE testing was temporarily discontinued to avoid

handling large numbers of fish. Contingency tables utilizing the "G" statistic were used to analyze the data for significance.

Fish Quality

Descaling of fish in the BHS was monitored as a measure of fish quality for each FGE and OPE test. Samples of fish taken from Gatewell 3-B (a standard Lower Granite condition--SVBS and operating gate at the 0-foot level) were used to provide a basis for determining if descaling was significantly different in the test units (3-A and 4-A). Descaling was determined by dividing the fish into five equal areas per side; if any two areas on a side were 50% or more descaled, the fish was classified as descaled. Using this criteria, fish classified as descaled are considered to have a poor chance of survival. Under a separate contract, yearling chinook salmon were sampled from Units 3-A and 4-A and subjected to a standard seawater challenge stress test (Park et al. 1983) in a further effort to measure the effect of a BFVBS vs SVBS on fish condition.

RESULTS

STS Fish Guiding Efficiency

The individual numbers of yearling chinook salmon and steelhead taken during fish guiding efficiency tests and vertical distribution determinations are shown in Appendix B.

Tests on 23 and 24 April with a 62-foot raised gate during periods of heavy spill (40% of total river flow) resulted in exceptionally low FGE (33-46%) for yearling chinook salmon--about half that measured in 1983 (Swan et al. 1984). In a follow-up test on 27 April that compared a 20-foot raised gate with the standard Lower Granite condition (Gate not raised-3B), FGE was

Table 1.--STS FGE Test results for yearling chinook salmon at Lower Granite Dam, 1984.

Test no.	Date	Average % spill[a/]	3-A, SVBS, FSS and Wagner Horn closed		4-A, BFVBS, FSS and Wagner Horn closed		3-B, standard Lower Granite condition	
			Test condition	FGE (%)	Test condition	FGE (%)	Test condition	FGE (%)
1	23 Apr	37	62' gate[b/]	33	62' gate[b/]	34		
2	24 Apr	37	62' gate	38	62' gate	46		
3	26 Apr	40	62' gate, no spill	33	20' gate, no spill during test	37		
4	27 Apr	40			20' gate, no spill during test	39	0' gate, no spill during test	26
5	1 May	14	62' gate	55	20' gate	47		
6	3 May	14	62' gate	53	20' gate, w/perf. plate	49		
7	4 May	24	62' gate, w/perf. plate	65	20' gate, w/perf. plate	56		
8	5 May	24	62' gate, w/perf. plate	60	20' gate, w/perf. plate	53		
9	6 May	24	62' gate, w/perf. plate	71	20' gate, w/perf. plate	58		
10	7 May	25	62' gate, w/perf. plate	67	20' gate, w/perf. plate	66		
11	8 May	25	62' gate, w/perf. plate	69	46' gate, w/perf. plate	63		
12	9 May	25	62' gate, w/perf. plate	66	46' gate, w/perf. plate	57		

a/ Percent spill is the average of the percentage of total river flow spilled during a 3-day period (the 2 days prior to and the day of the test).

b/ The 46-foot gate and the 62-foot gate are considered comparable in terms of the amount of water passing through gatewell.

also about half that measured in 1983 (39 vs 26%, respectively, Table 1). FGE improved as the season progressed, averaging 60-69% during the last series of tests when there was only low to moderate spill [25% of total river flow (Table 1)]. By contrast, FGE for chinook salmon throughout 1983 was consistently between 66 and 78% when spill ranged between 20 and 40%. FGE for steelhead remained high and comparable to 1983 throughout the 1984 season (Table 2).

The FGE was significantly better for the fully raised (46 to 62 feet) gate than for the 20-foot gate for both chinook salmon and steelhead. Because it appeared that spill may have affected FGE for chinook salmon, we used the following analysis of variance tests blocked according to date to eliminate the affect of spill on FGE:

Two-Way ANOVA Table

Source	Df	SS	MS	F	Prob (F)
Gate height	1	45.995	45.995	7.28	0.027[b]
Date	8[a]	763.222	95.403	15.11	
Error	8[a]	50.515	6.314		
Total	17	859.732			

[a] Df reduced by one due to estimation of missing value.

[b] Significant at the 0.05 level.

A similar test on steelhead also yielded a significant benefit for the fully raised gate (F = 6.46, df = (1,6), P of F = 0.04, significant at 0.05). Because it appeared that FGE of steelhead was less influenced by spill, we also ran a paired comparison T-test (no blocking of data to

Table 2.--STS FGE Test results for Steelhead at Lower Granite Dam, 1984.

Test no.	Date	Average % spill[a]	3-A, SVBS, FSS and Wagner Horn closed		4-A, BFVBS, FSS and Wagner Horn closed		3-B, standard Lower Granite condition	
			Test condition	FGE (%)	Test condition	FGE (%)	Test condition	FGE (%)
1	23 Apr	37	62' gate[b]	86	62' gate[b]	76		
2	24 Apr	37	62' gate	79	62' gate	70		
3	26 Apr	40	62' gate, no spill during test	81	20' gate, no spill during test	77		
4	27 Apr	40			20' gate, no spill during test	85	0' gate, no spill during test	77
5	1 May	14	62' gate	85	20' gate	66		
6	3 May	14	62' gate	49	20' gate, w/perf. plate	74		
7	4 May	24	62' gate, w/perf. plate	80	20' gate, w/perf. plate	63		
8	5 May	24	62' gate, w/perf. plate	80	20' gate, w/perf. plate	78		
9	6 May	24	62' gate, w/perf. plate	82	20' gate, w/perf. plate	73		
10	7 May	25	62' gate, w/perf. plate	88	20' gate, w/perf. plate	85		
11	8 May	25	62' gate, w/perf. plate	86	46' gate, w/perf. plate	85		
12	9 May	25	62' gate, w/perf. plate	89	46' gate, w/perf. plate	89		

[a] Percent spill is the average of the percentage of total river flow spilled during a 3-day period (the 2 days prior to and the day of the test).

[b] The 46-foot gate and the 62-foot gate are considered comparable in terms of the amount of water passing through gatewell.

eliminate influence of spill). This test yielded a significant T-value of 2.56, df = 6, P = 0.04 for the fully raised gate condition (Table 2, 1 through 7 May data with 3 May removed as an outlier).

Tests comparing the effects of a BFVBS vs SVBS for both chinook salmon and steelhead showed no gross differences in FGE (Tests 1, 2, 11, and 12; Tables 1 and 2).

Attempts to isolate the cause for the decline in FGE for yearling chinook salmon in 1984 were largely inconclusive. There were two major differences in test conditions between 1983 and 1984: (1) perforated instead of solid plate on the lower end of the STS and (2) a new trash boom in the forebay. The solid plate was replaced with perforated plate midway through the testing immediately upon the discovery that perforated plate had not been installed according to plan. The one test (#6, Table 1) on 3 May that compared solid vs perforated plate showed a slightly but not significantly higher FGE for the STS with a solid plate. The testing conducted in 1982 to compare solid with perforated plate showed a statistically significant but only 6% increase in FGE for yearling chinook salmon and a 6% decrease in FGE for steelhead. If the solid plate were the major problem, then FGE for chinook salmon should have only been down about 6% not 30 to 40%. Also, there was no apparent change in FGE for steelhead throughout the test series (Table 2) as opposed to an increasing FGE for chinook salmon as the season progressed (Table 1).

Early in the study (Tests 3 and 4), a temporary no-spill test condition was examined in an attempt to determine if heavy spill (approximately 43 kcfs) was influencing guidance. No major changes in FGE were seen in this test condition. However, testing a temporary no-spill condition (no-spill only during the test) probably did not allow sufficient time for forebay flow

conditions to stabilize and/or the fish concentrations in the forebay to develop a distribution representative of an extended no-spill or low spill condition.

In 1983, as well as 1984, the FSS in Units 3-A and 4-A were closed near the intake ceiling. In addition, in 1984 the Wagner Horns were also plugged. A decision was made to move the testing from Unit 3-A to Unit 3-B to determine if the plugged Wagner Horn and/or the FSS closure devices were causing the low guidance. The results of the one test (26% FGE, Test 4, Table 1) suggested that this was not the probable cause for the low guidance in 1984.

We, therefore, assume that the major cause for the lower FGE for yearling chinook salmon in 1984 was probably the trash boom. Vertical distribution studies showed that yearling chinook salmon were deeper in the water mass flowing into the intake than steelhead (Appendix Table B2). We suspect that the trash boom generally acted as a skimmer on primarily the surface running (potentially more guidable) yearling chinook salmon--resulting in more of these fish being diverted to the vicinity of the spillway. When there was continuous heavy spill, such as occurred early in the migration, proportionately more surface running fish were passed over the spillway than were the deeper running (less guidable) fish not influenced by the boom. Later in the migration when spill was less, and even on seal during much of he day, fewer surface oriented fish were diverted over the spillway and FGE improved. Vertical distribution measurements showed very little difference in potentially guidable fish from that measured in 1982 (Swan et al. 1983). Unfortunately, these tests were only conducted during the period of lowest spill (16%) in 1984 when diversion would have been minimal.

We assume that the lack of change in FGE for steelhead was because most steelhead were concentrated near the ceiling of the intake. Only a very low percentage were in the water mass that would not be intercepted by the STS [approximately 11 vs 35% for chinook salmon (Appendix Table B2)]. Consequently, even with the trash boom diverting surface running fish over the spill, the impact on FGE would have been minimal. The trash boom apparently did, however, divert a significant portion of the steelhead migration over the spillway; for the first time more steelhead were collected at Little Goose Dam than Lower Granite Dam. Tests are scheduled in 1985 to define the actual impacts of the new trash boom on FGE.

Orifice Fish Passage Efficiency

The BFVBS significantly enhanced OPE for yearling chinook salmon. With operating gates fully raised, the efficiency of a single 12-inch diameter orifice, in the gatewell with a BFVBS (4-A) was 93% $\pm$ 2.8 vs 77% $\pm$ 2.2 for the gatewell with a SVBS (3-A). OPE also appeared better for steelhead (47 vs 31%), but the confidence levels overlapped slightly (Fig. 4). With the operating gate at 20 feet, the OPE for steelhead was significantly enhanced with two 12-inch diameter orifices per gatewell [79% $\pm$ 17 vs 47% $\pm$ 14 (Figs. 4 and 5)]. A modified BFVBS further enhanced OPE for the 20-foot gate position. The OPE with a single orifice in operation (20-foot gate) increased to 98% $\pm$ 0.7 for chinook salmon and an acceptable 86% $\pm$ 0.6 for steelhead when the sections of panels directly below the orifice were screened (Fig. 4). This was only slightly lower than OPE through two orifices with the same BFVBS modification [98% $\pm$ 0.37 for chinook salmon and 94% $\pm$ 0.40 for steelhead (Figs. 4 and 5)].

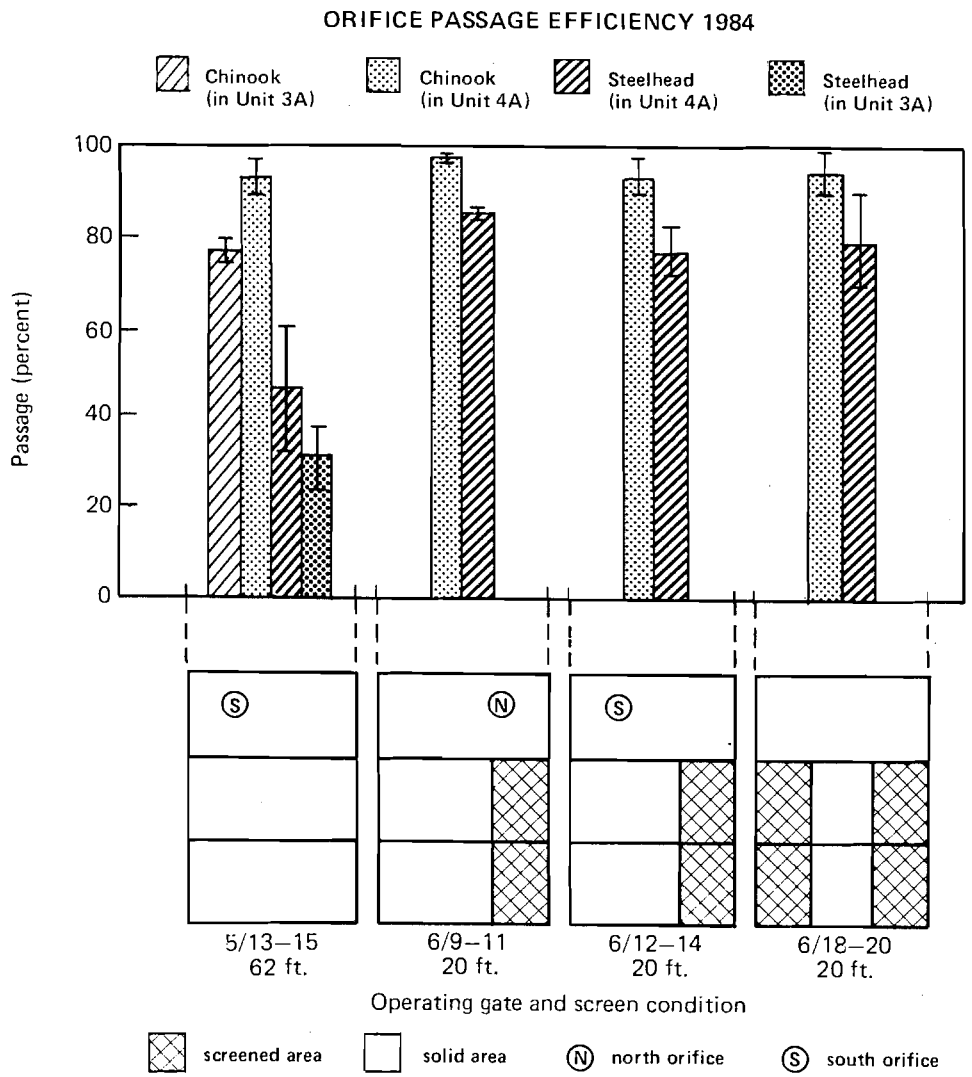

Figure 4.--Average percent orifice passage efficiency of spring chinook salmon and steelhead through a single 12-inch diameter orifice under varying barrier screen configurations (I indicates 95% CI) at Lower Granite Dam - 1984.

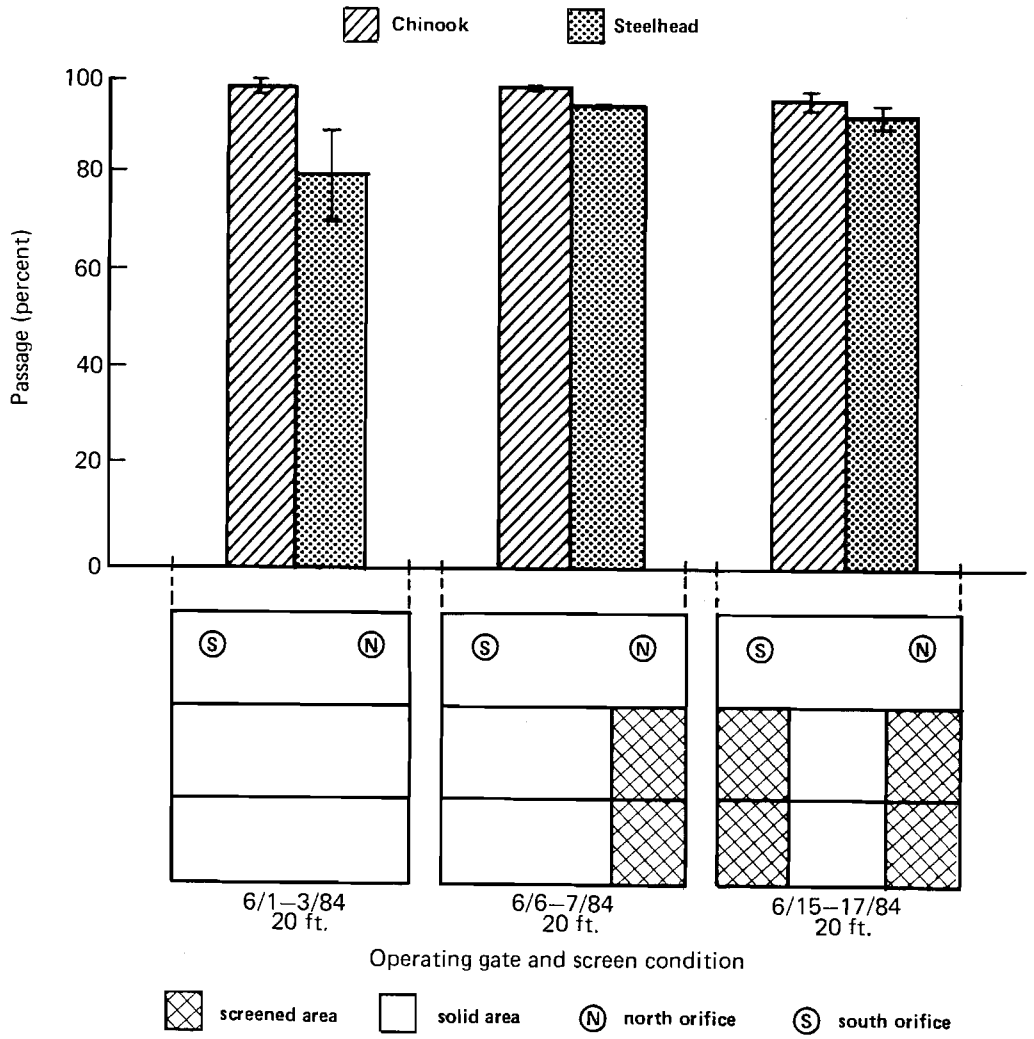

Figure 5.--Average percent orifice passage efficiency and 95% confidence limits of spring chinook salmon and steelhead through two 12-inch diameter orifices under varying barrier screen configurations at Lower Granite Dam - 1984.

Fish Quality

Descaling of fish remained low (<10%) throughout the season for all conditions tested. The average descaling rate for chinook salmon from 23 April to 9 May was 5.9% in gatewell 3-B (control), 5.6% in Gatewell 3-A with a SVBS and the gate raised 62 ft, and 3.6% in Gatewell 4-A with a BFVBS and the gate raised 20-62 ft. The descaling rate for yearling chinook salmon collected during FGE tests with the BFVBS had a significantly lower rate of descaling than those with the SVBS using a G test at the 95% CI with 1 df (G = 17.9966).

No significant difference in stress levels was detected for yearling chinook salmon sampled from Unit 3-A (SVBS) vs Unit 4-A (BFVBS) when subjected to a standard seawater challenge stress test.

CONCLUSIONS

1. The trash boom, especially during high spill, appeared to adversely impact FGE for chinook salmon but not steelhead. Significant numbers of steelhead, however, were diverted over the spillway by the boom.

2. The FGE appeared to be significantly better with the fully raised gate (46 or 62 feet) condition than with the partially raised (20 feet) condition if an adjustment eliminating the effects of spill is made.

3. The BFVBS did not significantly affect FGE, however, the gatewell equipped with the BFVBS did provide significantly lower descaling and better OPE than a gatewell equipped with a SVBS.

4. AN OPE of 98% for chinook salmon and 86% for steelhead was achieved using a single 12-inch diameter orifice and a modified BFVBS when the sections of panels directly below the orifices were screened.

ACKNOWLEDGEMENTS

We wish to express our appreciation to the CofE personnel at Lower Granite Dam for their assistance and cooperation in completing this study. We also extend a special thank you to our maintenance staff and seasonal employees for their extra effort and interest in this project.

LITERATURE CITED

Matthews, G. M., G. A. Swan, and J. R. Smith.
1977. Improved bypass and collection system for protection of juvenile salmon and steelhead trout at Lower Granite Dam. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. MFR 1256, Vol. 39(2):10-14.

Park, D. L., E. M. Dawley, R. F. Krcma, C. W. Long, E. Slatick, J. R. Smith, and G. A. Swan.
1976. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams and review of other studies relating to protection of juvenile salmonids in the Columbia and Snake River, 1975. U.S. Dep. of Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., Seattle, Wash. 27 p. + Appendixes (Report to the U.S. Army Corps of Engineers, Contract DACW68-75-C-0111).

Park, D. L., J. R. Smith, E. Slatick, G. A. Swan, E. M. Dawley,and G. M. Matthews.
1977. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams and review of nitrogen studies relating to protection of juvenile salmonids in the Columbia and Snake River, 1976. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., Seattle, Wash. 48 p. + Appendix (Report to the U.S. Army Corps of Engineers, Contract DACW68-75-C-0111).

Park, D. L., G. M. Matthews, T. E. Ruehle, J. R. Smith, J. R. Harmon, B. H. Monk, and S. Achord.
1983. Evaluation of transportation and related research on Columbia and Snake Rivers, 1982. U.S. Dep. of Commer., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., Seattle, Wash. 48 p. + Appendix (Report to the U.S. Army Corps of Engineers, Contract DACW68-78-C-0051).

Sokal, R. R., and J. F. Rohlf.
1981. Biometry. 2nd edition. Freeman and Company: San Francisco, California, U.S.A.

Swan, G. A., R. F. Krcma, and W. E. Farr.
1979. Dipbasket for collecting juvenile salmon and trout in gatewells at hydroelectric dams. Jan 1979. Prog. Fish Cult. 41(1):48-49.

Swan, G. A., R. F. Krcma, and F. Ossiander.
1983. Studies to improve fish guiding efficiency of traveling screens at Lower Granite Dam. U.S. Dep. of Commer., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., Seattle, Wash. 20 p. + Appendix (Report to U.S. Army Corps of Engineers, Contract DACW68-78-C-0051).

Swan, G. A., R. F. Krcma, and F. Ossiander.
1984. Research to develop an improved fingerling protection system for Lower Granite Dam. U.S. Dep. of Commer., Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., Seattle, Wash. 20 p. + Appendixes (Report to U.S. Army Corps of Engineers, Contract DACW68-78-C-0051).

APPENDIX A

Sample Sizes Needed to Detect Differences Among Test Groups

Typically the information needed to determine the number of replicates and the sample sizes required per test group are the treatment variability expected (which may be expressed as a difference between treatment means of interest), the number of means (or experimental categories) being compared, and the and levels desired from the statistical test.

In these experiments, we have mainly chosen to 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 difference. The exact calculation of the probability is rather complicated. The procedures used provide an approximation that is adequate for design purposes.

Very often in field work conditions may provide the opportunity for more measurements or force some curtailment. In view of field uncertainties, which may result in more or fewer measurements, alternative statistical analyses were planned. The primary statistical analysis used was the categorical data analysis using the count data. The alternative analysis was a data transformation to stabilize the variance and approximate normality and then apply analysis of variance type of procedures. The alternative procedure is usually less powerful than a direct categorical analysis of the count data, but may be necessary in some cases where the requirements for categorical analysis cannot be fulfulled.

Occasionally we plan 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.

The information for sample size determination is applied for the following cases. 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 were 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.

2. More than two groups or multinomial case: The procedures used for obtaining confidence intervals and sample sizes follow methods given by Angers (1974), 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) and Cochran and Cox (1957). 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 sample size formulas:

NT - sample size in the two group comparison.

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

ZB - standardized normal deviate exceeded with probability B. Where B is $1 - \beta$. 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 haltering 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.

T1 - t - distribution value associated with type I error, α.

T2 - 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 of (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 associated with tabulated probability distribution values depends on sample size.

LITERATURE CITED

Angers, C.
1974. A graphical method to evaluate sample sizes for the multinomial distribution. Technometrics 16, 469-471.

Bailey, B. J. R.
1980. Large sample simultaneous confidence intervals for the multinomial probabilities based on transformations of the cell frequencies. Technometrics 22, 583-589.

Cochran, W. G. and G. M. Cox.
1957. Experimental Designs. 2nd ed., Chapter 2. John Wiley and Sons, Inc.: New York, N.Y., USA.

Feigl, P.
1978. A graphical aid for determining sample size when comparing two independent proportions. Biometrics 34,111-122.

Goodman, L. A.
1965. On simultaneous confidence intervals for multinomial proportions. Technometrics 7, 247-254.

Lemeshow, S., D. W. Hosmer, J. P. Stewart.
1981. A comparison of sample size determination methods in the two group trial where the underlying disease is rare. Commun. Statist-Simula. Comta. B10, 437-449.

Miller, R. G., Jr.
1966. Simultaneous Statistical Inference. pp 215-218. McGraw-Hill Book Company: New York, N.Y., USA.

Paulson, E. and W. A. Wallis.
1947. Planning and analyzing experiments for comparing two percentages. Chapter 7 in, Techniques of Statistical Analysis, editors, C. Eisenhart, M.W. Hastay, and W.A. Wallis. McGraw-Hill Book Company: New York, N.Y., USA.

Steel, R. G. D. and J. H. Torrie.
1960. Principles and Procedures of Statistics. pp 90-93 and 154-156. McGraw-Hill Book Company: New York, N.Y.,USA.

Tsao, H. and T. Wright.
1983. On the maximum ratio: a tool for assisting inaccuracy assessment. The American Statistician 37, 339-342.

APPENDIX B

Catch Data for Fish Guiding Efficiency and Vertical Distribution Tests at Lower Granite Dam, 1984.

Appendix Table B1.--Catches of yearling chinook salmon and steelhead during fish guiding efficiency tests at Lower Granite Dam comparing test and control conditions at 135 megawatt turbine load in spring of 1984.

		Yearling chinook salmon												Steelhead											
		Control-3-A BHS						Test - 4-A BHS						Control-4-A BHS						Test-4-A BHS					
Test no.	Date	BHS catch	Gap net catch	Fyke net catch	Total un-guided (est.)	Total guided and un-guided	FGE (%)	BHS catch	Gap net catch	Fyke net catch	Total un-guided (est.)	Total guided and un-guided	FGE (%)	BHS catch	Gap net catch	Fyke net catch	Total un-guided (est.)	Total guided and un-guided	FGE (%)	BHS catch	Gap net catch	Fyke net catch	Total un-guided (est.)	Total guided and un-guided	FGE (%)
1	23 Apr	549	13	993	1,105	1,654	33	581	22	1,016	1,156	1,737	34	275	0	42	43	318	86	172	1	52	53	225	76
2	24 Apr	1,287	45	1,808	2,060	3,347	38	1,834	46	1,971	2,159	3,993	46	139	0	36	38	177	79	69	2	26	30	99	70
3	26 Apr	463	8	822	934	1,397	33	655	29	988	1,097	1,752	37	133	0	28	31	164	81	134	1	36	40	174	77
4[a]	27 Apr	----------see below----------						606	24	839	940	1,546	39	----------see below----------						373	4	64	66	439	85
5	1 May	313	4	234	275	588	55	356	7	344	402	758	47	401	7	66	70	471	85	183	2	89	93	276	66
6	3 May	338	7	278	300	638	53	261	5	248	271	532	49	385	9	360	406	791	49	441	5	141	155	596	74
7	4 May	415	3	204	221	636	65	283	5	205	223	506	56	448	5	101	115	563	80	333	4	169	195	528	63
8	5 May	425	13	254	279	704	60	435	9	348	380	815	53	723	13	163	181	904	80	622	9	163	171	793	78
9	6 May	423	5	161	170	593	71	400	6	264	294	694	58	973	13	202	207	1,180	82	791	15	268	287	1,078	73
10	7 May	285	2	132	140	425	67	279	4	135	146	425	66	1,621	10	202	220	1,841	88	1,453	13	239	255	1,708	85
11	8 May	675	4	254	307	982	69	534	10	277	311	845	63	1,498	9	202	234	1,732	86	1,306	11	218	227	1,533	85
12	9 May	399	5	188	202	601	66	296	6	214	236	532	57	1,205	5	140	151	1,356	89	1,079	8	127	136	1,215	89
		3-B BHS												3-B BHS											
4[a]	27 Apr	314	0	773	915	1,229	26							255	0	63	75	330	77						

[a] Test was conducted in 3-B BHS under standard Lower Granite conditions.

Appendix Table B2.--Catches of yearling chinook salmon and steelhead during vertical distribution tests in Bulkhead Slot 4-A at Lower Granite Dam, 1984.

	Yearling chinook salmon				Steelhead			
Level[a/]	29 Apr	30 Apr	Total	Cumulative (%)	29 Apr	30 Apr	Total	Cumulative (%)
Gatewell	106	162	268	12	87	66	153	25
1	171	312	483	34	129	102	231	63
2	282	399	681	65	84	75	159	89
b/								
3	135	213	348	81	27	15	42	96
4	117	105	222	91	12	3	15	98
5	78	45	123	97	3	6	9	99
6	21	30	51	99	0	6	6	100
7	6	9	15	100	0	0	0	
8	0	0	0		0	0	0	
Totals	916	1,275	2,191		342	273	615	

a/ Levels one through eight refer to the level of the water column fished by the fyke nets used to determine the vertical distribution--Level One being the top net and Level Eight the bottom net.

b/ Approximate depth intercepted by the STS.