RADIO-TRACKING STUDIES OF ADULT CHINOOK SALMON AND STEELHEAD TO DETERMINE THE EFFECT OF "ZERO" RIVER FLOW DURING WATER STORAGE AT LITTLE GOOSE DAM ON THE LOWER SNAKE RIVER

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ABSTRACT

Allowable instantaneous minimum river flows are established in the Columbia and Snake Rivers to ensure safe passage of anadromous fish during their migration to the spawning grounds. However, water storage during periods of low power demands (at night and on weekends) would be beneficial to the power producers. This storage procedure is called “zero” river flow and is now permitted on a limited basis when there are few if any actively migrating anadromous fish present in the river system. Requests were made to extend “zero" river flow into periods when anadromous fish were actively migrating and a study was initiated.

Radio-tracking studies were conducted on the Snake River between Lower Monumental and Little Goose Dams to determine the effect of “zero” river flow on the migration of adult chinook salmon, Oncorhynchus tshawytscha, and steelhead, Salmo gairdneri. From July through September, 1981, a total of 258 steelhead and 32 chinook salmon were radio-tagged. The rate of migration was used to determine differences between test and control fish and a gamma distribution model was used to describe the migration rate for radio-tagged fish. Estimates of the parameters of the model were used to statistically compare “zero” flow and normal river flow conditions for the radio-tagged fish.

The results show that the "zero" flow condition delays the migration of adult chinook salmon and steelhead; therefore, extended periods of “zero” flow to store water are not recommended when fish are actively migrating in the river system.

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INTRODUCTION

Increased power demands in the Pacific Northwest necessitate more power production. Water is the principal resource for producing power in the area, and as most major dam sites on the Columbia and Snake Rivers already are being utilized (Fig. 1), more efficient methods of water use must be employed. Multipurpose needs of the resource--power, agriculture, recreation, navigation, industry, fisheries, etc.--complicate its management. Fishery agencies, for example, require that river flows not be reduced below set instantaneous minimums to ensure safe passage of anadromous fish during their migrations to and from the spawning grounds, with flow requirements differing depending on location and amount of total river flow.

Power demands are not constant; less power is needed at night and on weekends. The U.S. Army Corps of Engineers (CofE) (1977) determined that substantial eccnomic and power benefits could be realized if there were reduced on no instantaneous minimum flow requirements for fish. This would enable storage of water in reservoirs during periods of low power demand for subsequent power production during periods of greater demand. Flows would be reduced to where only fishways, auxillary power turbines, and navigation locks would be in operation--an operational procedure termed “zero” flow.

“Zero” flow is now allowed on a limited basis--7 h at night between December and March when there are only minimal numbers of salmon and steelhead migrating upriver. The Bonneville Power Administration (BPA) would like to extend the “zero” flow period to summer and fall as well. A preliminary study by McMasters et al. (1977) examined the effects of nighttime “zero” flow on adult summer chinook salmon and steelhead in 1975 and 1976. In 1975, a small radio-tracking study was carried out along with an analysis of daily fish counts. In 1976, only the daily fish counts were used. Even though neither

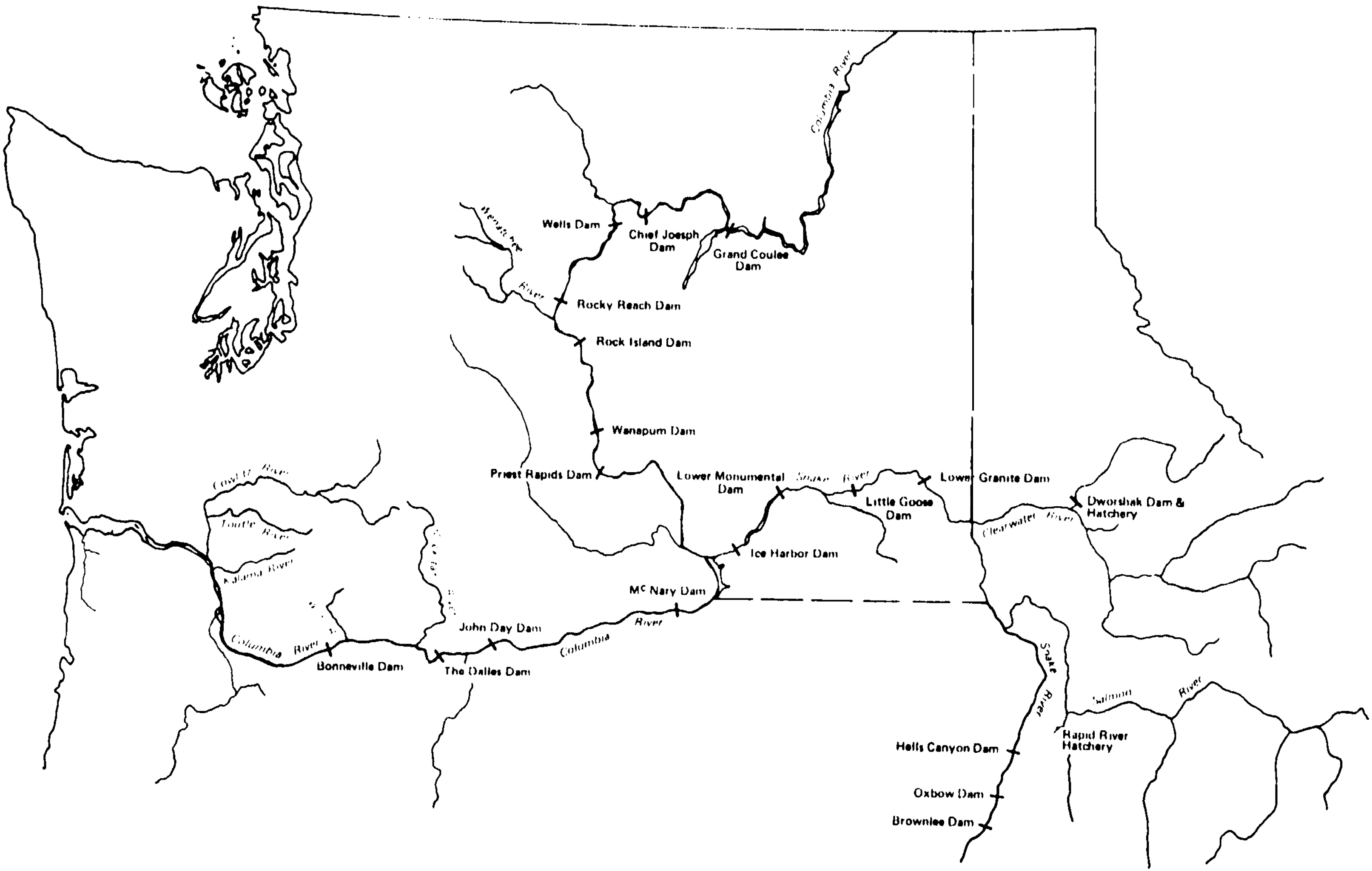

Figure 1 .--l.ocat ion of jamor hydroelectric dams on the Columbia and Snake Rivers.

year showed a difference in travel rates related to the reduced nighttime flows, the fishery agencies felt that the data were insufficient to permit extension of "zero" flow to the summer and fall. Because of the promising results, however, BPA made a request to extend the "zero" flow storage conditions. The new conditions would be as follows:

1. Extend the present nighttime period 2 h (for a total of 9 h--2200 to 0700 h).

2. Have a continuous 35-h period from 2000 h Saturday to 0700 h Monday within which "zero" flow could be maintained for up to a continuous 24-h period.

3. Begin "zero" flow storage schedules in August and continue through April.

BPA stated that the additional three fall months are crucial as total river flow is lowest just before the winter moisture begins, and April is crucial as the total river flow is low just before the spring runnoff begins. The extended period would, however, include times when adult salmon and steelhead would be actively migrating upstream to spawn, and there was concern that "zero" flow storage conditions may adversely affect these migrations.

Realizing the benefits to be derived by power producers from storing water during periods of low power demands and low river flow, but at the same time feeling a deep concern over the effect on fish runs, the fishery agencies felt an in-depth study under the extended storage conditions was warranted. The study would add to the data base and allow decisions to be made as to whether or not to grant the extended periods of storage and if so what limitations would have to be imposed.

In response to the BPA request for extension of "zero" flow, the National Marine Fisheries Service (NMFS) together with the state fishery agencies developed a study plan employing radio telemetry to study the effects of "zero" flow storage on adult summer and fall chinook salmon, Oncorhynchus tshawytscha, and steelhead, Salmo gairdneri. The objectives were: (1) to monitor adult fish behavior at Little Goose Dam in relation to passage and delay, (2) define rates of passage over Little Goose Dam, and (3) determine migration rates between Lower Monumental and Little Goose Dams in relation to test ("zero flow) and control (normal flow) conditions. Fish counts at the fishways were also analyzed in relation to the flow data.

STUDY SITE AND EQUIPMENT

The study was conducted in the late summer and early fall of 1981. The study area included 28.8 miles of reservoir between Lower Monumental Dam and Little Goose Dam and the immediate vicinity of Little Goose Dam itself on the lower Snake River in southeastern Washington (Fig. 2). During McMaster's 1975-76 study, each dam was operating with three turbines. In 1981, the dams were operating with their full complement of six turbines each.

Lower Monumental Dam, the second dam on the Snake River, is approximately 41.5 miles from its confluence with the Columbia River near Pasco, Washington. Lower Monumental Dam has two fish ladders, one on each shore, whereas Little Goose Dam has but one, on the south shore, however, there is a fish attraction system on the north shore with a tunnel under the spillway section of the dam which leads fish to the fish ladder entrance. All of the fish ladders have a facility for counting adult salmonids as they pass over the dam.

The Snake River between the two dams runs through a steep-walled canyon bordered mainly by open grass-sagebrush land and wheat fields. It is not

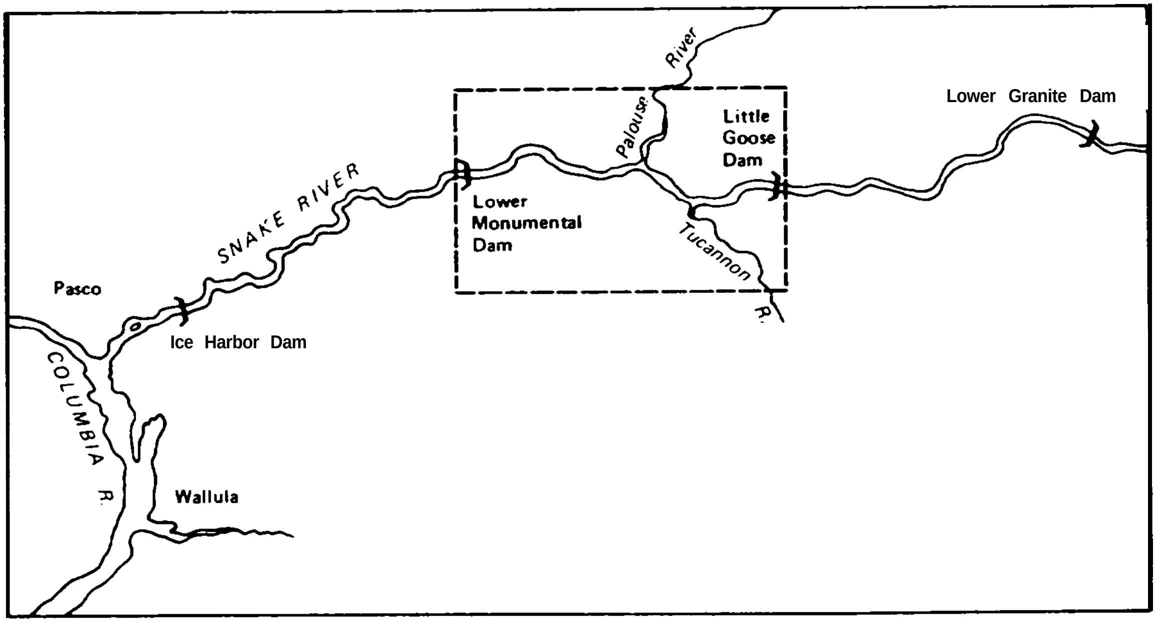

Figure 2.--Location of study area relative to the lower Snake River and established hydroelectric dams.

uncommon for air temperatures to reach the 90° to 100°F range during the months in which the study was conducted. Water temperatures also can become correspondingly high during this time.

The study area was divided into two general areas: (1) the reservoir between the two dams and (2) the vicinity of Little Goose Dam which was further subdivided into north-south shore, powerhouse collection system, and fish ladder.

Base operations for the study were established at Little Goose Dam. Trapping fish and tagging were conducted at Lower Monumental Dam with facilities furnished by the CofE, Fish and Wildlife Section, Portland District. Tagged fish were released just upstream from Lower Monumental Dam.

Radio Tag

The radio tag used is powered by a battery and transmits on a carrier frequency of approximately 30 megahertz (MHz). Transmitter and batteries are sealed in a plastic capsule about 3.5 inches long and 0.75 inch in diameter. Each tag weighs about 1 ounce in water and is carried in the stomach of the fish except for a small wire antenna that extends from the tag into the fish's mouth. The pulse rate and duration are adjusted to determine tag life. The conventional radio tag used by the NMFS Fish Tracking Program in previous years was coded with nine frequencies (30.17 through 30.25 MHz) and had a tag life of up to 60 days. This limited the number of tags that could be released at any one time. The nature of the "zero" flow study required the use of many more codes. The electronic technicians involved in the program developed a new tag with multiple codes on each frequency. The pulse portion of the radio tag was changed by introducing a complementary metal oxide semi-conductor (CMOS) chip to the circuitry to further control pulse rate and duration. The chip also allowed the pulse to be split into two parts. By setting the period between the two parts differently for each tag, a total of 400 individual codes were available for the study. The pulse rate was set at 600 milliseconds (ms), and the total pulse duration was set at 20 ms. This duty cycle reduces the battery life from 60 to 30 days, but this was more than adequate for the study.

Surveillance Equipment

Two different types of receivers were used for locating tagged fish during the study. One was a tuneable receiver that allowed operators to listen to one fish on any of nine frequencies, and a maximum of nine radio-tagged fish could be tracked in any area at one time, if each fish tag was of a different frequency. The first receiver used was a Smith-Root, Model RF-40.[1/] These units were used in vehicles and boats in conjunction with a directional loop antenna when behavior of individual fish was of interest.

The second receiver was called a decoder receiver. Conventional tracking receivers (RF-40) pick up the assigned tag frequencies but cannot separate the codes; therefore, a decoding module was built to complement the new multi-coded tag. The nodule in conjunct ion with our g-channel search receiver, a digital printer, and an antenna system made up a single decoder receiver. Both the decoding module and search receiver were developed and built by program technicians. The search receiver was built several years ago to cont inually monitor all nine frequencies simultaneously and signal the presence of a radio-tag by visually indicating the proper frequency and emitting an audible intermittent tone to alert the equipment operator.

The decoding module scans the output of the search receiver sampling each frequency twice for 650 ms or 1 .3 seconds per channel. When a pulse is

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

received, the pulse width and the period between the ends of the first and second pulse sections are measured to determine the proper code. This information is stored until all nine frequencies have been scanned (1 1 .7 seconds), then all data stored are printed by a digital printer. An internal clock incorporated into the printer allows month, day, hour, and minute information to be printed along with the tag data. The unit operates on 12 volts (DC).

Self-contained automatic monitors were installed to record the presence and activities of radio-tagged fish in specific areas. A monitor consisted of a complete decoding receiver with all but the antenna housed in a metal, watertight container. Monitors were used to record information in three areas: (1) the general area near Little Goose Dam (within 1 mile downstream), (2) the powerhouse fish collection system, and (3) the fish ladder exits (Little Goose Dam and Lower Monumental Dam).

Monitors were located on both sides of the Snake River below Little Goose Dam to record tagged fish entering or leaving the area. The antenna system for each of these monitors consisted of two 3-element beam directional antennas, one positioned to "look" upstream and the other to "look" downstream. The sequence of signal inputs to the monitor provided directional data for fish movement, e.g., lower antenna then upper antenna meant that the fish was moving upstream. The collection system monitor recorded the activities of tagged fish that were within 30 feet of the system or inside the collection channel. It was also used to determine when fish entered the fish ladder. There were 14 underwater omni-directional antennas--one inside and one outside of each collection system entrance. Outside antennas were connected in one series, and the inside antennas were connected in another series. Each antenna had its own amplifier so that signals received by the farthest antenna would reach the monitor at the same signal strength as those nearest the monitor.

Fish ladder exit monitors were like those below the dams but utilized the short range, omni-directional underwater antenna.

Monitoring from aircraft was done from a high-wing Cessna 172 Minimum height flown was 800 feet at 80 miles per hour. Experimentation with available equipment showed that one standard 18-inch diameter directional loop tracking antenna attached to a wheel strut worked best.

Occasional monitoring was done by boat as a follow-up to aircraft surveillance, but this was too slow for principal data collection. Tracking equipment for the boat was the same as for aircraft with the loop antenna being held by a tracker.

EXPERIMENTAL PROCEDURES

The general plan was to tag and track 633 salmonids from 15 July to mid-September. Proposed releases were as follows: 230 summer chinook salmon (15 July-11 August) 100 fall chinook salmon (12 August-17 September), and 300 steelhead (12 August-17 September). Fish would be tagged at Lower Monumental Dam and released into the forebay near the dam. Electronic surveillance of radio-tagged fish would be the principal method of monitoring their progress through the reservoir and in the vicinity of Little Goose Dam. Fish counts taken at Little Goose Dam would also be analyzed. Behavior and passage would be observed during flows from normal operating procedures at the dams (control) and during the “zero” flow storage conditions (test). Movement between dams was to be observed from aircraft flights using radio receiving equipment with an occasional survey by boat. Surveillance at the dams was to be by automatic recording monitors and mobile units.

Trpping and Tagging

Chinook salmon and steelhead used for tagging were taken from the north shore fish ladder at Lower Monumental Dam by blocking the fish ladder orifices and diverting the fish up a 28-foot Denil fish ladder with a 20% slope. At the top on the Denil, the fish swam ever a false weir descending into a tank of l,sine methane sulfonate (MS-222) anesthetic.

Radio-tags were placed in the fish's stomach using the procedures descr ibed by Liscom et al. (1977). No fish under 26 inches in length were tagged to ensure adequate sized fish to accommodate the tag capsule.

Once tagged, fish were placed in a tank truck for recovery and transported above the dam. They were released directly into the Snake River on the north shore about 1,333 feet upriver from Lower Monumental Dam.

Surveil lance Proceedures

Aircraft flights were scheduled to observe tagged fish disposition before and after daytime "zero" flows. Flights took place Saturday evenings and Monday mornings, lasted approximately 1 h, and covered the study area twice. One flight per week included a pass over the reservoir between Lower Monumental and Ice Harbor Dams. During the study, one flight was made between McNary Dam and the Ringold Springs area on the Columbia River.

Monitors operated continuously throughout the study period and provided passage time data for individual fish, as well as fish activity information, particularly upstream and downstream movement in the vicinity of Little Goose Dam.

Mobile units were dispatched to check on fallback fish remaining in one area for extended periods of time, fish ladder monitors at Lower Monumental Dam, and fish activity between Lyons Ferry and Little Goose Dam.

Personnel maintained surveillance activities on a 24-h basis with three 8-i-1 shifts, 7 days a week. Monitors were checked at least every 2 h per shift. Between monitor checks, recovered data were recorded and prepared for computer i input .

Experimental Design

Procedures were designed to study effects of “zero” flow on adult salmon ids as close to the most extreme proposed conditions as possible: (1) weekly nighttime “zero” flow from 2200 until 0700 h each night and (2) a 35-h period during weekends in which a "zero" flow condition may exist for up to 24 consecutive hours. It was assumed that if no significant delay (> 8 hours) in passage at dams or through reservoirs could be detected under extreme conditions, then there was no problem. If there were adverse effects, additional more specific conditions could be addressed in subsequent studies.

The schedule called for l week of “zero” flow test conditions, alternated with 1 week of normal operations from 15 July through 23 September. Tests would begin on Wednesday and terminate the following Tuesday. On weekdays, the schedule called for “zero” flow below Little Goose and Lower Monumental Dams each night from 2200 until 0700 h the following morning. During the weekend an extended period of up to 24 h of “zero” flow would be initiated beginning any time after 2200 h Saturday and terminating no later than 0700 h Monday.

As scheduled, there would be 5 weeks of "zero" flow dam operation and 5 weeks of regular operations. The last “zero” flow would terminate at 0700 h 16 September, and the last regular flow week would end at 0700 h, 23 September.

A total of 50 fish from each species to be studied was to be released at the beginning of each test regime--Z5 fish from each species on Wednesday and 25 on Thursday. The sample size in each release was based on the data obtained during radio tracking work in the lower Columbia River (Liscom et al. 1978). From that study, it was determined that an 8-h difference in passage time between test and control groups could be detected at a 95% confidence level with 27 steelhead and 37 chinook Salmon. Release days would be adjusted to ensure that tagged fish would be present in all areas under all conditions.

RESULTS AND DISCUSSION

When the experimental design was formulated and agreed upon in 1978, it was recognized that the analysis of the data would use travel and passage times to perceive differences between test and control conditions. This would, in effect, measure behavior during the period of the study. Based on variation of travel times seen in the 1977 unaccountable loss study between Bonneville and John Day Dam (Liscom et al. 1978), it was determined that we could detect an 8-h difference between test and control groups at a 95% confidence level with the planned release numbers. However, travel and passage times occurring in the "zero" flow study had significantly greater variability than found in the 1977 study in the lower Columbia River. The difference in variability resulted in the analysis of the data being more complex.

The major cause of variability was an extended period of warm water throughout most of the chinook salmon migration. The warm water caused a drastic reduction in upstream fish movement and consequently the numbers of fish available for tagging. During 16 July through 17 September, 6,662 steelhead passed Lower Monumental Dam. Of these fish, 4,837 passed through the north fish ladder. There were 1,166 passages counted on designated tagging days. A total of 1,631 summer adult chinook salmon passages occurred between 16 July and 13 August; 236 were counted over the north fish ladder with 90 passing on tagging days. North fish ladder passages of adult fall chinook salmon between 14 August through 17 September totaled 117, with 53 counted over on tagging days. The total fall chinook salmon run was 486 fish. This was the lowest count at Lower Monumental Dam in the previous 4 years. A total of 290 adult salmonids were ultimately radio-tagged (258 steelhead and 32 chinook salmon). There were 13 release groups--5 test and 5 control. Table 1 is a summary of the release groups, duration of each release group, date of tagging, and number of each species tagged.

In the subsequent statistical analysis, comparisons were made thatwould balance the warm water influences between test and control groups, and it was found that the statistical differences held up for comparisons under both warm and normal water conditions.

Another factor that made analyses difficult was that nighttime control flows were maintained closer to the 11.3 thousand cubic feet per second (kcfs> 3f instantaneous minimum flows than to the greater genera: daytime flows (Table 2). This meant that comparisons between control and test periods (actual “zero” flow was approximately 200 cfs excluding any lockages) were narrowed more than desired. Whether this narrow range of flows had any effect on the analysis of behavioral differences could not be demonstrated.

General Behavior

Of the 258 steelhead tagged and released, 52 fell back over Lower Monumental Dam. As there was no spill, the fallback routes had to be through

Table 7.--Summary of release groups of radio-tagged chinook salmon and dates of each release group, date of tagging, and number of each species tagged--Lower Monumental Dam, 1981

Release group	Time period	Tagging dates	Species	Number released
	16-22 Jul	16, 17 Jul	Chinook	4
			Steelhead	8
2	23-29 Jul	22, 23, 24 Jul	Chinook	9
			Steelhead	20
3	30 Jul-5 Aug	29, 30 Jul	Chinook	8
			Steelhead	42
4	6 Jun-12 Aug	5, 6, 7 Aug	Chinook	2
			Steelhed	25
5	13-19 Aug	12, 13, 14 Aug	Chinook	3
			Steelhead	22
6	20-26 Aug	19 Aug	Chinook	1
			Steelhead	4
7	27 Aug-2 Sep	29, 30 Aug	Chinook	1
			Steelhead	7
8	3-9 Sep	2, 3, 4 Sep	Chinook	3
			Steelhead	32
9	10-16 Sep	9, 10, 11 Sep	Chinook	2
			Steelhead	46
10	17-23 Sep	16, 17 Sep	Chinook	2
			Steelhead	49
			Total Chinook	32
			Total Steelhead	258

Table 2.--Hourly flows provided for test[a] and control conditions by date and release group [flow cfs) x 1,000].

	Test conditions (zero flow)							Control conditions (minium flow)						
	July (Group 1)							July (Group 2)						
Time	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26	26-27	27-28	28-29
2300	0	0.5	1.3	2.1	55.3*	46.4*	0.2	11.3	49.2	11.4	22.1	11.3	35.7	28.5
2400	0	0	0	0	68.3*	23.4*	0	11.3	49.2	11.6	11.4	11.4	14.1	13.2
0100	0	0	8.6	21.8	0	0	0	11.7	17.6	11.2	11.4	11.3	11.5	11.7
0200	0	0	0	0	0	0	0	11.7	12.1	11.6	11.4	11.5	11.5	11.6
0300	0	0	0	0	0	0	0	11.6	12.1	11.5	11.4	11.5	1.4	11.6
0400	0	0	0	0	0	0	0	11.7	12.0	11.5	11.4	11.5	11.4	11.6
0500	0	0	0	0	0	0	0	11.6	12.1	11.5	11.4	11.5	11.4	11.6
0600	0	0	0	0	0	0	0	11.7	12.8	11.5	11.4	11.5	11.5	11.6
0700	1.5	1.4	4.0	3.2	1.3	1.2	0.8	12.8	19.3	11.4	11.4	11.6	11.8	11.6

	July-August (Group 3)							August (Group 4)						
Time	29-30	30-31	31-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12
2300	21.0	0	0	0	0.6	0.3	1.2	27.8	12.3	11.7	11.7	11.7	11.6	11.6
2400	0	0	0	0	0	0	0	27.2	11.3	11.8	11.7	11.8	11.5	11.6
0100	0	0	0	0	0	0	0	11.4	11.3	11.7	11.7	11.7	11.5	11.6
0200	0	0	0	0	0	0	0	11.4	11.3	11.7	11.7	11.8	11.6	11.6
0300	0	0	0	0	0	0	0	11.3	11.4	11.8	11.7	11.8	11.5	11.6
0400	0	0	0	0	0	0	0	11.3	11.4	11.7	11.8	11.8	11.6	11.6
0500	0	0	0	0	0	0	0	11.4	11.4	11.8	11.7	11.8	11.6	11.6
0600	0	0	0	0	0	0	0	11.3	11.4	11.7	11.8	11.8	11.7	11.6
0700	0	1.0	0.7	0	0.5	0	0.8	12.3	11.5	11.7	11.7	11.8	11.7	11.6

Table 2.--cont.

Time	August (Group 5)							August (Group 6)						
	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
2300	0.1	0.1	0	0	42.0	0.3	2.1	11.9	11.5	15.3	11.4	23.6	17.8	11.5
2400	0	0	0	0	42.0	0	0	22.3	11.5	15.3	11.2	11.2	11.5	11.5
0100	0	0	0	0	21.5	0	0	11.5	11.5	12.7	11.2	11.3	11.4	11.5
0200	0	0	0	0	2.0	0	0	11.5	11.5	11.4	11.2	11.4	11.4	11.5
0300	0	0	0	0	0	0	0	11.5	11.5	11.4	11.2	11.3	11.4	11.5
0400	0	0	0	0	0	0	0	11.4	11.5	11.4	11.3	11.4	11.3	11.5
0500	0	0	0	0	0	0	0	11.5	11.4	11.4	11.3	11.4	11.4	11.5
0600	0	0	0	0	0	0	0	11.5	11.5	11.3	11.3	11.4	11.3	11.5
0700	1.3	1.8	0	0	0.8	0.3	1.8	11.4	11.5	11.3	11.3	11.7	11.4	34.6

Time	August-September (Group 7)							September (Group 8)						
	26-27	27-28	28-29	29-30	30-31	31-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09
2300	8.5	0	1.9	0	1.5	5.7	1.6	38.0	13.3	11.6	11.3	11.4	11.3	11.3
2400	0	0	0	0	0	0	0	11.9	11.8	11.8	11.3	11.2	11.4	11.3
0100	0	0	0	0	0	0	0	11.8	12.0	11.7	11.3	11.3	11.4	11.3
0200	0	0	0	0	0	0	0	11.8	11.9	11.8	11.3	11.2	11.3	11.3
0300	0	0	0	0	0	0	0	11.8	11.9	11.7	11.3	11.3	11.3	11.4
0400	0	0	0	0	0	0	0	11.8	11.9	11.7	11.4	11.2	11.3	11.3
0500	0	0	0	0	0	0	0	11.8	11.2	11.8	11.3	11.2	11.3	11.3
0600	0	0	0	0	0	0	0	11.8	12.6	11.8	11.3	11.3	37.7	11.9
0700	2.1	0	1.4	0	0	2.2	1.3	12.4	38.6	13.1	12.2	11.2	3.6	37.6

Table 2.--cont.

Time	September (Group 9)							September (Group 10)						
	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23
2300	1.5	0	0	0.8	60.2	0	0.3	11.5	11.4	11.4	26.4	11.5	13.3	24.8
2400	0	0	0	0	18.0	0	0	11.4	11.4	11.5	25.0	11.4	11.5	11.5
0100	0	0	0	0	0	0	0	11.4	12.5	11.4	11.3	11.4	11.5	11.5
0200	0	0	0	0	0	0	0	11.4	12.5	11.4	11.4	11.4	11.5	11.5
0300	0	0	0	0	0	0	0	11.4	12.5	11.4	11.4	11.4	11.5	11.5
0400	0	0	0	0	0	0	0	11.4	12.5	11.4	11.4	11.4	11.5	11.5
0500	0	0	0	0	0	0	0	11.4	12.5	11.4	11.4	11.4	11.5	11.5
0600	0	0	0	0	0	0	0	12.7	12.5	11.4	11.4	11.4	11.5	43.8
0700	2.7	0	1.3	0	1.6	1.0	3.0	30.4	12.9	11.4	11.4	32.4	40.8	43.8

a/ Not absolute "zero" flow, ladder and an auzillary power turbine remained in operation. Lockages contributed to some additional flow.

* high night time flow resulted from weekend daytime zero flows.

the navigation locks, turbines, or down the fish ladders. Twenty-three of the fallbacks reascended the dam and reached Little Goose Dam, with 20 of these crossing the dam to continue upstream. Most steelhead dropped downstream no farther than Windust, approximately 3 miles below Lower Monumental Dam. The furthermost downstream movers located were: twc near ice Harbor Dam and two heard in the mainstream Columbia River. One of the Columbia River fish was heard near Wallula, Washington, and the tag was subsequently found on the beach between Wallula and Pasco, Washington, by a fisherman. The second tag was heard at Ringlod and was later recovered at the adult trap at Lower Granite Dam on 31 September. One steelhead tag was returned from the Salmon River in Idaho on 2 April 1982 from a fish last heard below Lower Monumental Dam 1 September 1981. Another tag from a steelhead last heard below Lower Monumental Dam was returned 20 May 1982 from the Pahsimerio Hatchery on the Salmon River in Idaho.

There were six steelhead fallbacks at Little Goose Dam. Two of these fish fell back twice. Three of the six fish were known to have reascended Little Goose Dam, including one that had fallen back twice.

Three fallbacks of chinook salmon occurred at Lower Monumental Dam. None of the three were known to have reascended the dam. One of the fish, however, was recovered at the Priest Rapids artificial spawning channel later in the fall. Of the chinook salmon reaching Little Goose Dam, one fell back but reascended to continue upstream.

Initial numbers of fallbacks at Lower Monumental Dam caused concern that the release site was too close to the dam, but warm water reduced the numbers of fish to be tagged (Fig. 3) which postponed the use of an alternate release site. When the water temperature dropped to where fish began to move again, fallbacks dropped off so there were only two during the release of Groups 7,

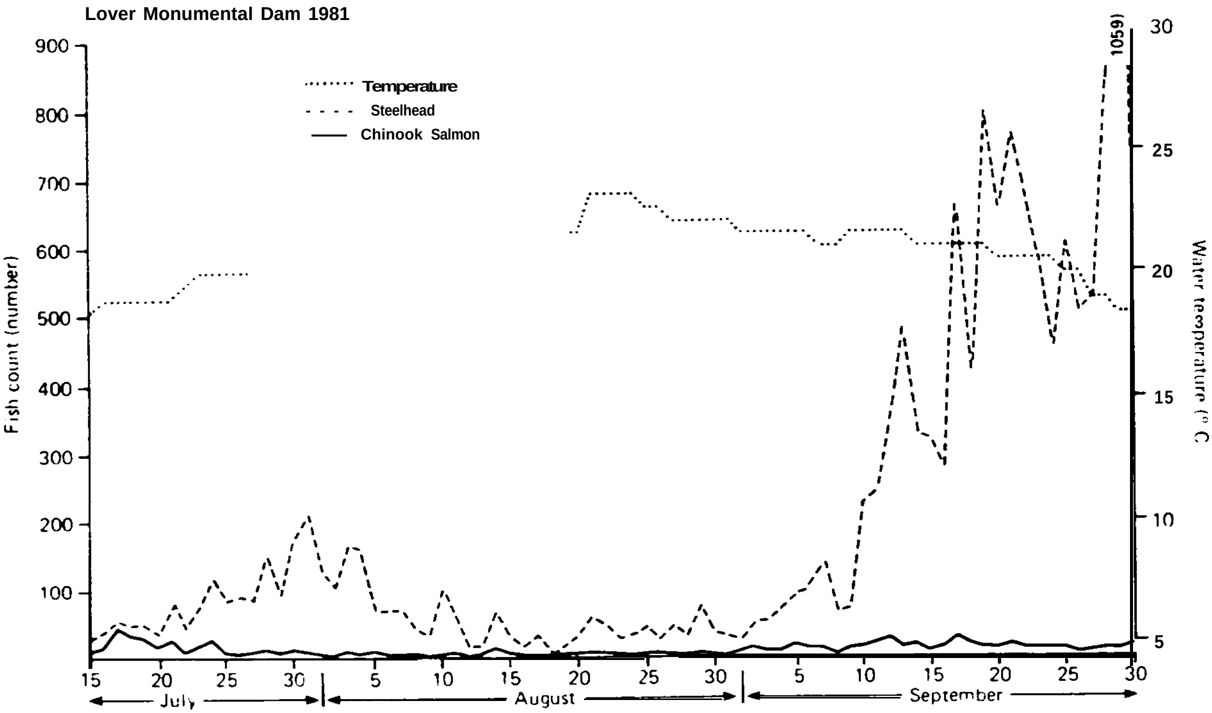

Figure 3.--Daily fish counts and temperatures recorded at Lower Monumental Dam during the "zero" flow study, 1981.

8, 9, and 10. Table 3 shows the disposition of all tagged steelhead at the end of the study. It was assumed that a high percentage of those tags still heard at Lower Monumental Dam near and at the end of the study were mortalities due to fallback through the turbines and perhaps from warm water handling stress. Daily tagging was terminated when water temperatures in the fish ladder reached 72°F.

Warm water influenced swimming behavior through the reservoir. Release Groups 4, 5, 6, and 7 occurred during the period of warmest water, reaching 74°F. However, fish in Group 7 did not clear the study area before lower temperatures prevailed (below 72°F) (temperature recorded by the CofE at Lower Monumental Dam) and were not influenced by the warmer water as much. The highest water temperature recorded in the area was 78°F at Lower Granite Dam.

Raphael (1961) concluded that during periods of low water and exceptionally warm weather, water temperatures will rise markedly in impounded areas of the Columbia River. The effect of slowing down the river and spreading it out over wider areas by dams increased the temperature of the water over its natural increase in an unconfined river gorge.

Travel rates between the two dams varied considerably in the number of hours it took the tagged fish to reach Little Goose Dam (Table 4). Chinook salmon took somewhat less time to swim the 28.8 miles while also showing a wide range in the hours taken to cover that distance. The most extreme travel times for both species are attributed to warm water. Table 5 shows the differences in travel time between cooler water releases (70°F and below) and those releases made when water temperature stayed above 70°F, regardless of whether the release was a test or a control.

Proportionately, steelhead moved through the reservoir better than chinook salmon and also passed Little Goose Dam better during the study

Table 3.--Disposition of radio tags at the end of study for fish not reaching Little Goose Dam (steelhead).

Location	Release groups 1	2	3	4	5	6	7	8	9	10	Total
Battery quit	0	0	0	0	1	0	0	0	0	0	1
Below Lower Monumental Dam	1	5	6	7	2	2	0	0	1	0	24
Between dams	0	3	4	8	4	2	0	2	5	4	32
Total	1	8	10	15	7	4	0	2	6	4	57
										Percent of total tagged	21.7

Table 4.--Median travel time (hours) of all fish reaching Little Goose Dam by test and control releases.

	Test		Control	
	Range	Median	Range	Median
Steelhead	19. j-735.5	48.6	19.9-610.8	50.4
Chinook	13.1-364.8	33.2	15.1-160.0	30.2

Tabie 5.--Median travel time (hours) of al? radio-tagged fish reaching Little Goose Dam dur ing cooler and warmer water periods.

	Cooler water (70°F and below)		Warmer water (above 70°F)	
	Aange	Median	Range	Median
Steelhead	**19.5-455.3**	**52.2**	**35.0-735.6**	**166.3**
Chinook	16.1-366.8	31.7	26.7-29.3[a]	N/A

a/ Only two fish released.

period. Table 6 summarizes the numbers of tagged fish that traversed the reservoir between the two dams and indicates the numbers of those fish that crossed iittie Goose Dam.

Air flights taken during periods of warm water began showing inconsistencies in the ability to locate the same fish's signal during the second flight each day. Many factors can cause this to happen, but flight observer reports warranted a closer look. Surveillances were conducted several times by boat with experienced trackers, and it was found that fish were apparently descending into deeper water for periods long enough to be undetected from either airplane or boat. When a fish was behaving this way, even individual tracking was almost impossible. Although previous studies showed very little temperature stratification in lower Snake River reservoirs (Falter 1973), fish seemed to be going into deeper water (perhaps seeking lower temperatures). Falter did indicate there could be as much as a 3°F difference between top and bottom. This could be attractive to fish when the surface temperatures are in the mid-70°F range.

Fish were holding up in two areas. One was at the mouth of the Tucannon River, but it could not be determined if cooler water from the Tucannon River was responsible or if the location is a natural holding area for fish to congregate. The other area was at the downstream end of the south wingwall of the Little Goose Dam navigational lock. This was explained by the cooler inflow from a spring below the surface of the river. Not only were tagged fish located in the area, but it was a popular place for fishermen.

Travel Times Between Dams

The steelhead data on travel time between dams for each test and control group are given in Table 7. As noted in Appendix A, the scale parameter of

Table 6. Summary of radio-tagged chinook salmon and steelhead that reached Little Goose Dam and those tagged fish that crossed the dam during the study.

Chinook Salmon

	Release group	Total fish tagged	Reached Little Goose	Percent reaching dam	Passed Little Goose Dam	Percent passage of total fish tagged
Test:	1	4	4	100.0	3	75.0
	3	8	8	100.0	2	25.0
	5	0	0	N/A	N/A	N/A
	7	1	0	0	0	0
	9	2	2	100.0	2	100.0
Total		15	14		7	
Control:	2	9	9	100.0	4	44.4
	4	2	2	100.0	0	0
	6	1	0	0	0	0
	a	3	3	100.0	0	0
	10	2	0	0	2	100.0
Total		17	14		6	

Steelhead

	Release group	Total fish tagged	Reached Little Goose	Percent reaching dam	Passed Little Goose Dam	Percent passage of total fish tagged
Test:	1	a	7	87.5	3	37.5
	3	42	32	76.2	22	52.4
	5	22	15	68.2	a	36.4
	7	7	7	100.0	5	71.4
	9	46	40	87.0	35	76.1
Total		125	101		73	
Control:	2	20	12	60.0	11	55.0
	4	28	13	46.4	6	21.4
	6	4	0	0	0	0
	8	32	30	93.8	29	90.6
	10	49	45	91.a	38	77.6
Total		133	100		a4	

Table 7.--Travel time in hours for the steelhead test and control groups from release to first arrival at Little Goose Dam.

Experimental group[a/]									
1	2	3	4	5	6	7	8	9	10
40.8	23.9	23.2	35.0	35.8		22.1	25.2	19.5	23.5
43.9	26.3	25.4	39.9	49.9		26.9	26.7	27.4	19.9
97.5	29.9	27.1	49.8	54.4		40.8	28.5	28.0	30.8
139.8	35.2	30.7	50.9	96.7		54.8	29.4	29.2	30.1
206.6	45.4	30.9	52.4	135.3		216.1	30.1	29.6	31.0
270.4	74.3	33.1	99.4	157.9		283.4	30.2	31.7	33.3
455.3	99.8	35.1	121.6	164.9		173.4	30.6	32.2	35.0
	114.6	35.4	167.7	180.0			32.3	32.3	35.6
	135.7	37.3	172.0	244.0			32.3	32.9	36.2
	136.9	38.8	188.6	248.4			32.6	32.9	37.2
	137.4	43.7	198.7	394.9			33.4	33.0	37.4
	173.9	45.0	270.8	495.4			34.6	34.7	37.7
		46.3	576.4	616.6			34.9	35.1	38.0
		47.5		644.0			35.0	36.7	38.0
		50.1		735.6			35.0	42.9	38.1
		52.2					38.0	43.4	59.0
		52.9					38.4	43.6	41.6
		53.4					43.7	44.1	50.0
		58.8					49.5	45.3	50.3
		60.6					52.3	46.8	52.1
		65.5					54.3	48.8	53.9
		67.2					54.9	55.1	54.0
		85.0					64.3	56.5	50.4
		104.8					64.6	56.8	56.0
		110.5					70.7	60.6	56.2
		122.2					95.9	58.9	56.6
		151.4					117.0	71.5	57.7
		159.0					121.0	74.1	59.5
		358.0					123.8	75.4	52.2
		454.0					126.7	82.2	60.0
		461.8						94.9	60.6
		714.4						96.4	64.6
								103.4	64.9
								113.6	67.4
								166.5	68.0
								169.2	74.2
								182.0	67.5
								190.0	77.5
								218.6	80.8
								244.7	90.1
									94.5
									96.6
									115.6
									123.7
									136.8

a/ Test groups are odd numbers (zero flow) control groups are even numbers <normal flow).

the gamma distribution can be used in statistical inference to compare migration times for the test and control groups. The results given in Appendix Table A2 show a significant difference between Groups 4 and 5 at an $\alpha = 0.062$ level and Groups 8 and 9 at an a = **0.010** level. The comparison between Groups 2 and 3 was not significantly different ($\alpha = 0.92$). Appendix Table A2 also lists the estimated value for the shape parameter for each group. A shape parameter greater than one would indicate that the fish are completing the migration at a progressively faster rate. In Groups 4 and 5, 8 and 9, and 10 and 9, the shape parameters are greater for the controls than the test groups (4 and 5 : 1.32 > 1.22; 8 and 9 : 3.86 > 2.30; 10 and 9 : 6.28 > 2.30). For Groups 2 and 3, the shape parameter is less for Group 2 (2 and 3 : 1.02 < 1.23). However, Group 2 contains a single fish which has a recorded 610.8-h migration time. This fish was a fallback; if it is removed, the estimated Group 2 shape parameter is 1.58 which is greater than the Croup 3 shape parameter. This would indicate that the control groups of fish are migrating in less time than the test groups. The arithmetic means of travel times for test and control groups are 120 and 79 h, respectively. This represents a substantial difference.

The graphs in Appendix Figure Al show the cumulative proportion completing the migration vs time. For steelhead, at a migration time of 150 h, which agrees closely with each experimental run period, the proportion completing the migration is 0.91 for control fish and 0.76 for test fish. This means that at this time, 9% of the control fish had not completed the migration, whereas 24% of the test fish had not. For migratory fish, about 15% of the population would be significantly delayed due to low flow conditions such as those used in these experiments.

If we construct a 2 x 2 contingency table composed of the test and control fish that complete the migration before and after 153 h we obtain:

	Before 153 hours	After 150 hours	Total
Test fish	76	24	100
Control fish	92	9	101
	16 a	3 3	201

These data can be used to test the null hypothesis that test and control fish have the same probability of completing the migration before 150 h by calculat ing a G^2-statistic (Sokal and Rohlf 1981). For these data, we obtain G^2 = 8.60, df = 1, P = 0.0034 The null hypothesis is rejected, and we would conclude that the test and control st eelhead are signif icantly different in their probability of completing the migration in 150 h.

Appendix Figure A1 also reveals the importance of analyzing the tails of the distribution for these data. For instance, the 50% completion occurs at 54 h for control fish and at 58 h for test fish--an insignificant difference at this point. Data collected soley from passage at the dams would not reveal the differences shown here.

The sample sizes for chinook salmon were too small to use in group comparisons (Table 8). The control releases and the test releases were each combined and statistically compared (Appendix Table A4). The comulat ive proportion completion curves were also calculated (Appendix Figure Al). The chinook saimon show significant differences between test and control fish at an a = 0.075 level. The shape parameter for the control fish is greater than that for the test fish (1.670 > 0.716) indicating that the control fish migrate faster. The point at which 50% of the fish migrate is practically ident ical at 25 h for both groups. At 50 h, 33% of the test fish had not completed the migration, whereas 1 3% of the control fish had not. The

Table 8.--Travel time in hours for the chinook salmon test and control groups from release to first arrival at Little Goose Dam.

Experimental group[a/]									
1	2	3	4	5	6	7	8	9	10
13.4	15.1	15.0	26.7				18.5	13.1	
16.1	15.9	17.9	29.3				30.2	29.0	
24.7	16.1	33.2					40.7		
26.3	16.6	33.2							
	17.8	54.8							
	42.9	59.0							
	43.3	281.8							
	77.4	366.8							
	160.0								

a/ Test groups are odd numbers (zero flow); control groups are even numbers (normal flow).

arithmetic mean of travel times for test and control groups are 70 and 40 h, respectively. As in the case for steelhead, these figures represent a substantial difference.

Movement at Little Goose Dam

Statisticaliy, there was no difference in the time it took test and control chinook salmon and steelhead to ascend Little Goose Dam once they arr i ved at the dam. Median passage times were 17.3 and 22.8 h for test and control groups of steelhead respectively (Apendix Table B2). The gamma distribution scale and shape paramenters were 0.017 and 0.83 for test fish, and 0.018 and 3.85 for controls.

There were no differences between steelhead test and control groups for the time spent at Litt le Goose Dam after first arrival. The data in Appendix Table B4 show that the median time spent at the dam after arrival was 18.4 h for test steelhead and 19.2 h for controls. The gamma distr ibution scale and shape parameters were 0.027 and 0.86 for test steelhead and 0.022 and 0 .78 for controls. The scale parameters were not significantly different by the Bain analysis.

The period of time steelhead spent back downstream after their first arrival at Little Goose Dam showed medians of 18.9 and 18.7 h for test and control fish, respectively (Appendix Table B7). The gamma scale and shape parameters were 0.036 and 1.14 for test fish and 0.021 and 0.86 for controls. The scale parameters were not significantly different.

There was a difference shown in behavior occurring between the nighttime test and control flow periods (2200 to 0700 h) . The probability of a steelnead leaving the dam and returning downstream during the nighttime 9-h period of “zero” flow was significantly greater than when fish were at the dam during a controlled minimum flow nighttime 3-h period. For instance, in 125 occasions where tagged steelhead were at Little Goose Dam when “zero” flows went into effect, 68 (54%' returned downstream. Minimum flows went into effect on 114 occasions when tagged steelhead were at the dam, and **29 (25%)** returned downstream ($G2 = 21.18$, $df = 1$, $P < 0.031$). However, the overall effect on travel time was not significant.

Observations also showed that both chinook salmon and steelhead reacted more to flow changes that went from “zero” flow to normal daytime flows than to the change from minimums to normal daytime flows. The react ion was to ieave the flow and return downstream.

Tabie 9 summarizes tagged steelhead passage at Little Goose Dam during specific conditions, In most cases, passages were best under controlled minimum fiow conditions, but the differences were not enough to prove significantly better. This did not hold true in the case where steelhead delayed and were influenced by a different flow condition.

Powerhouse Collection System Behavior

Steelhead and chinook salmon behavior at the powerhouse fish collection system can best be seen by comparing diel movements; their activity began to increase between 0500 and 0600 h during both test and control flows. However, no distinct hourly peak of activity was shown within test weeks, whereas control weeks showed collection system activity peaking at 0700 to 0800 h (Fig. 4). There was no relationship between fish activity (steelhead and chinook salmon combined) and the number of fish entering the fish ladder during test periods (Fig. 5). Under control conditions it can be seen that fish activity was reiated to the number of entrances by fish into the fish ladder entrance. The data indicate differences in behavior between two conditions.

Table 9.--Summary of radio-tagged steelhead passages during specific conditions, Little Goose Dam, 1981 .[a/]

Condition	Passages (no.)		
	"Zero" flow	Control flows	Total
By release groups	75	86	161
Passed within original release period	57	78	135
Delayed into another period	18	8	26
Night and weekend study periods	18	22	40
Weekend daylight periods	6	9	15

a/ Actual monitored passages only; does not include late passages and known passages by tag recoveries but not monitored over dam.

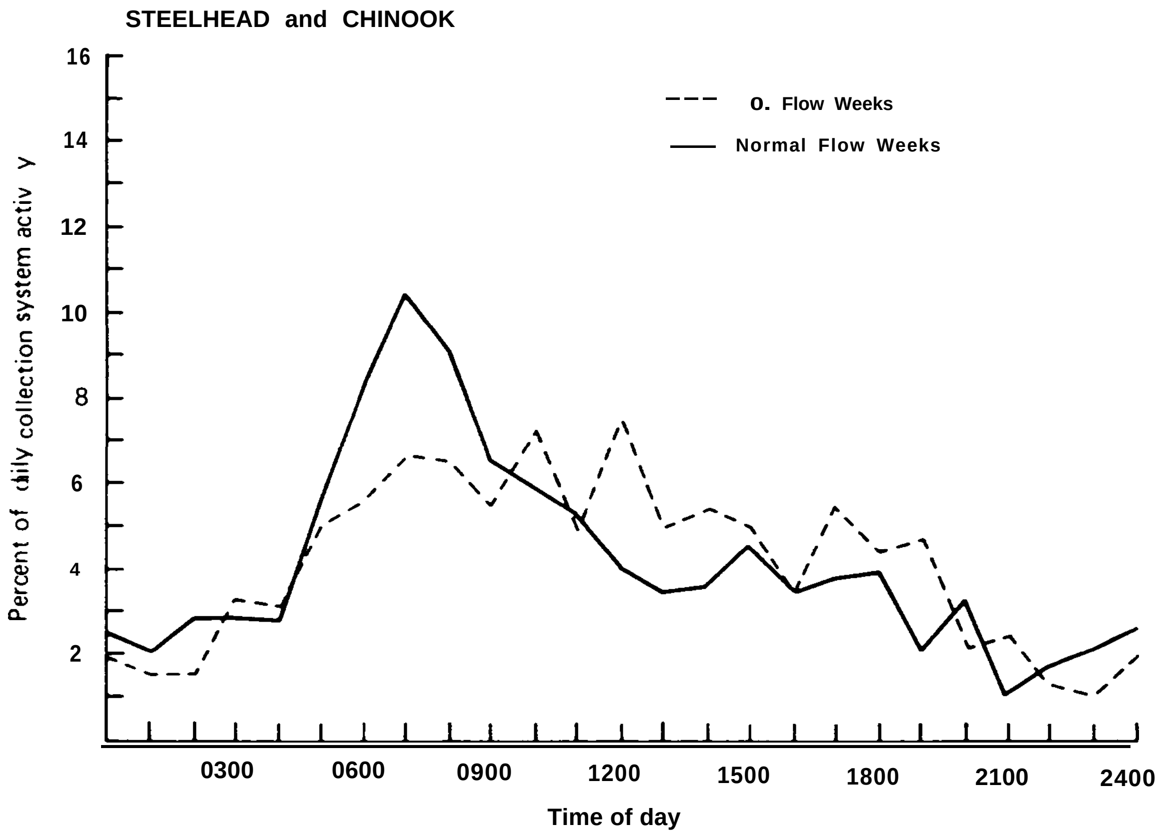

Figure 4.--Fish activity peaks at the Little Goose Dam powerhouse collection systems--test and control groups.

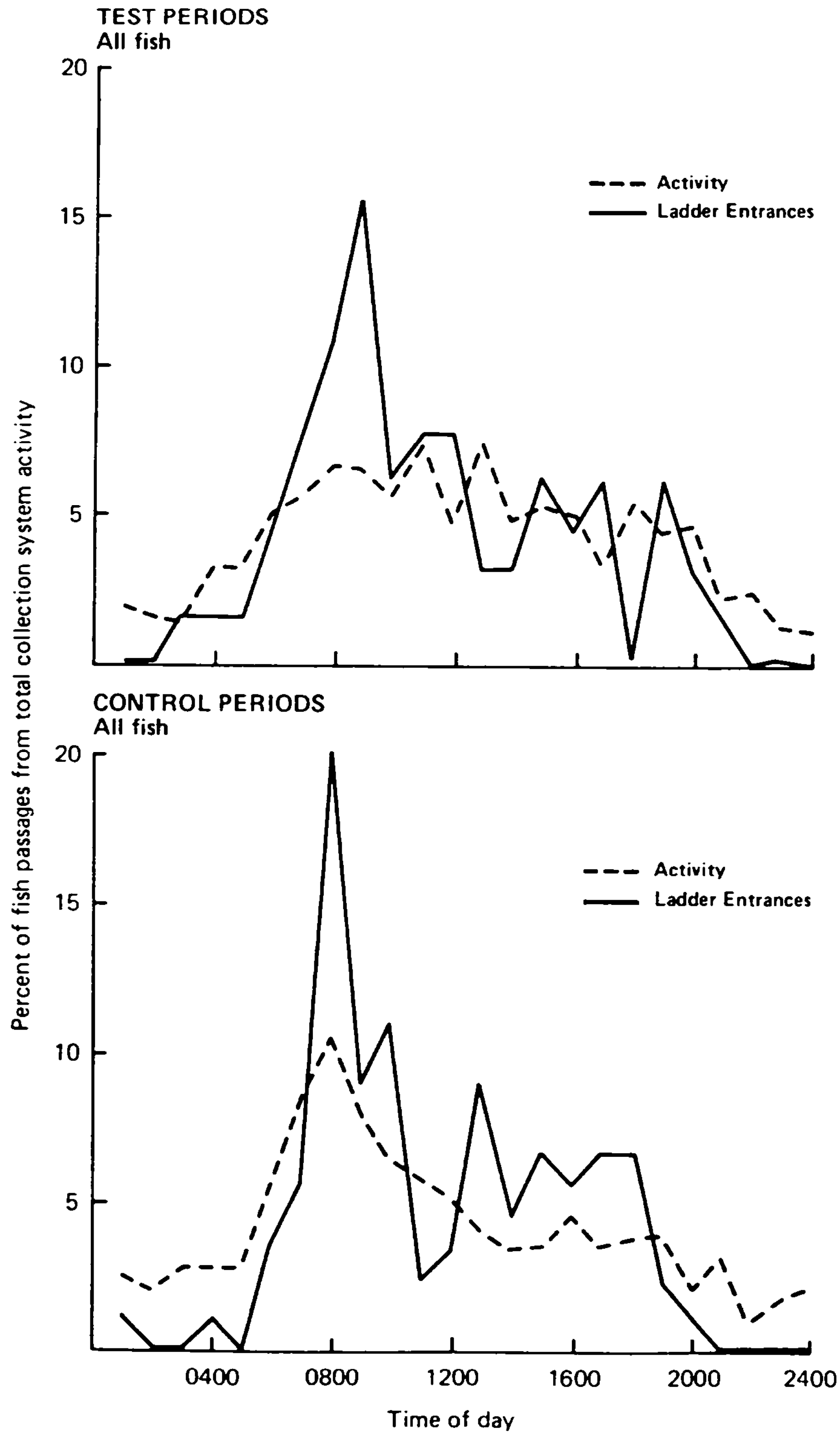

Figure 5.--Correlation between chinook salmon and steelhead and the number of passages over Little Goose Dam--test and control groups.

Another observation noted in relation to tagged chinook salmon and steelhead rear the dam was that during the early morning activity period, 75% of the fish that left the dam and swam downstream between 0600 and 0700 h did SC when "zero" flow conditions were in effect.

Attempts at analyzing fish ladder counts of chinook salmon and steelhead showed too great a variability in the counts within individual study weeks to give reli able or meaningful results. The natural tendency of fish runs to be able to peak and drop off within a week was the principal contributor to the count variations (Fig. 3). The results were the same when counts were considered on a daily basis; no distinguishable differences could be seen. Sunday extended "zero" flow counts were compared to Sunday minimum flows with the same results.

SUMMARY AND CONCLUSIONS

Tests were conducted to study the effects of "zero" flow water storage conditions on the migration of adult chinook salmon and steelhead in the Snake River between Lower Monumental and Little Goose Dams. From July through September, 1982, 258 steelhead and 32 chinook salmon were radio-tagged for the study Automatic radio tag monitors at fixed locations and surveillance equi pment in aircraft, automobiles, and a boat were used to record the movement of tagged fish as they migrated from the release location above Lower Monumental Dam upstream to and over Little Goose Dam. Surveillance was maintained on a 24-h basis for the fixed monitors, on a routine basis for the aireraft surveillance, and on a back-up basis for the boat.

Fallback occurred at both Lower Monumental and Little Goose Dams. The sample size from the steelhead tests were adequate to make statistical comparisons between weekly test and control groups. The weekly data were also combined for an empirical comparison. The weekly sample sizes from the chinook salmon data were inadequate for statistical comparisons but were combined for the empirical comparison. The results of this limited analysis with the chinook salmon data agreed with that of the steelhead data.

There was no difference in the time for test and control fish in ascending Little Goose Dam once they arrived.

The probability that a steelhead would leave the vicinity of Little Goose Dam and return downstream during nighttime periods of zero flow was greater than during nighttime controlled minimum flows.

Tagged fish reacted more to flow change going from “zero” flow to normal daytime flows than from minimums to normal daytime flows.

Early morning powerhouse collection system activity showed no distinct peaking within test weeks, whereas distinct activity peaks were shown during control weeks between 0700 and 0800 h.

Seventy-five percent of the fish that left Little Goose Dam and swam downstream between 0600 and 0700 h did so when “zero” flow conditions existed.

The data on travel times between dams was unimodal with a definite right-hand skew (a large number of fish taking much longer to migrate). These data were best represented by the gamma probability distribution. There was a statistically significant difference in the parameters of the gamma distribution between test and control for some groups of fish. The empirical analysis uses the data directly and shows that the estimated influence of "zero" flow on migrating fish would result in approximately 15 to 20% of the population being delayed independently from the warm water experienced during the study.

In contrast to the differences shown from data provided by fish carrying radio tags, analysis of fish counts showed no distinguishable difference in travel times or other behavior between study weeks.

Conclusions from the aforementioned results are:

1. "Zero" flow water storage procedures as proposed are not recommended to include times when salmonids are actively migrating upstream in the Snake River.

2. Some restriction is recommended for present "zero" flow operations during periods of extended warm water conditions to avoid contributing to the possibility of increasing ambient water temperatures to lethal limits as well as prolonging any existing temperature blocks.

3. While the chinook salmon data were too small for comparisons among release groups, the comparison of combined test and control fish show that "zero" flow significantly delayed their rate of migration to the same extent as that for steelhead.

4. Although there were no statistical differences in delay and passage times over Little Goose Dam between test and control releases of steelhead once they reached the dam, the behavioral differences that were observed did show that "zero" flow was adversely affecting the fish.

5. Fish count data alone will not provide reliable or meaningful information on the impacts of "zero" flow conditions.

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APPENDIX A

Statistical Analysis

The data on travel time between dams for each test and control group for chinook salmon and steelhead are given in Tables 7 and 8. These data were first examined to determine whether a parametric statistical model would appropriately represent the data. The alternative to a parametric model would be to use the more robust but less efficient nonparametric statistical procedures. The nonparametric procedures are free of any requirements concerning the type of probability distribution, but they are much less efficient in the use of data than a parametric model. If considerations of past history, theoretical developments, or other information justifies a parametric model, it is generally the case that the trade-off between the robustness of a nonparametric procedure compared to the efficiency of a parametric procedure favors the parametric procedure (Grice and Bain 1980).

The data are characterized by being unimodal and skewed to the right (having a heavy right hand tail) as shown in the stem and leaf display in Appendix Table Al. An appropriate model for this type of data would be the lognormal, gamma, or Weibul distribution. Applying the procedures given in a paper by Kappenman (1982), the gamma distribution was selected as the most appropriate distribution for these data. The Kappenman procedure consists of computing the logarithm of the maximized likelihood function under each model and selects the model corresponding to the largest of these. As a consequence, it is not required to specify a significance level, and a select ion can be made without passing the data through a gamut of goodness-of-fit tests. Wetherall (1971) in his investigations on chinook salmon found that the choice of the gamma distribution arises naturally from considerations of the swimming behavior of fish. Swimming activity can be represented by a series of stages in which the time spent in each stage is exponentially distributed. The overall migration time is the convolution of

Appendix Table Al.--Stem and leaf display of travel times for steelhead test and control groups, release to first arrival at Little Goose Dam.[a/]

Release group								
1	2	3	4	5	7	8	9	10
xx	xxxx	xxxxxxxxxxx	xx	xxx	xx	xxxx	xxx	xx
	xx	xxxxxxxx	xxx	xxx	xx	xxxxxxx	xxxxxxxxxxx	
xx	xxxxx	xxx	xx	xx		xxxxxx	xxxxxxx	xxxx
	X	X	xxx	xxx		X	xxxx	xxxxxxxxx
X		xx	X				X	xx
X		xx	X	X		xxx	xxx	
	X	X				X	X	xxxxxxx
				X	X	X	xx	xxxxx
						X	X	xxx
					X	X	X	xxxxx
				X				X
			X				X	X
	X			xx				X
					X			
				X		X	X	X
							X	xx
		X						
							X	
						X		
						xx	X	X
								X
		X						
		X					X	

a/ The vertical scale is increasing in time down the column. For purposes of display, the groups are not plotted to the same vertical scale (see Table 7).

these stages and this yields a gamma distribution (Lee 1980). Other studies on the migratory swimming behavior of fish (Madison et al. 1972; Trump and Leggett 1980) have found that fish change their suimming speed in response to flow and diurnal variation. Trump and Leggett developed a mathmatical model of migratory behavior and energetics in fish. They were hampered in a detailed evaluation of their model by the limited number of field studies of migratory behavior in fish. Their model would lend support to the application of gamma distribution to fish migration data. From a consideration of these studies the gamma distribution has reliable qualitative support on _a priori_ grounds. Therefore, further use of the data in goodness-of-fit tests would not be statistically prudent [Bratley et al. (1983) p. 123]. A reason for caution is that pre-analysis of the data with tandem goodness-of-fit tests may affect the distribution of subsequent statistics in ways impossible to analyse mathematically.

For these data, we used the two parameter gamma distribution with probability density function

$$g(t;\theta,\lambda) = t^{\lambda-1}e^{-t/\theta}/\theta^{\lambda}\Gamma(\lambda)$$

$$t>0;\ \theta,\lambda>0.$$

The parameters θ and λ are referred to as the scale and shape parameters, respectively. The scale parameter influences the dispersion of the response variable, and for gamma models, the scale parameter would refer to the relative peakedness or flatness of the domes of the distributions. A flat dome would indicate a more disperse heavy-tailed distribution. The scale parameter of the gamma distribution can be used in statistical inference to determine whether the groups differ by being more disperse and heavy-tailed and hence containing more members which take a longer time to migrate. For this purpose, estimates of the scale and shape parameters were calculated by the method given by Kappenman (1983) and tabulated in Appendix Table A2.

Appendix Table A2.--Two sample F-tests of the equality of scale parameters for matched steelhead release groups.

	Release group						
	2	3	4	5	a	9	10
Sample size; n_1, n_2	14	31	13	15	29	40	45
Arith. mean; $\bar{X}, \bar{Y}$	139.44	93.99	155.92	273.59	50.35	72.15	55.54
Geom. mean; $\tilde{x}, \tilde{y}$	89.11	62.82	110.96	182.04	44.52	58.05	51.38
Scale para; θ_1, θ_2	136.58	76.32	118.24	224.52	13.03	31.39	8.85
Shape para; λ_1, λ_2	1.021	1.232	1.319	1.219	3.863	2.299	6.278
Combined shape para; $\hat{\lambda}$	1.206		1.215		2.636		
$\bar{X} / \bar{Y}$	1.485		0.570		0.698		
df_1 ; ν_1 [a]	34		33		153		
df_2 ; ν_2 [a]	75		38		211		
Critical a - level [b]	0.92		0.06[c]		0.009		

[a] $df_1 = 2n_1\hat{\lambda}$; $df_2 = 2n_2\hat{\lambda}$

[b] Probability level at which the null hypothesis would be rejected.

[c] This value was adjusted according to Table 2 in Shiue and Bain **(1983).** The unadjusted a level was **0.051.**

Somparisons were made between test and control groups which most closely matched in time, sample size, and water temperature. The groups matched were; 2 vs 3, 4 vs 5, 8 vs 9, and 9 vs 10. Groups 1 and 7 were of small sample size and were not used. The 8 vs 9 and 9 vs 10 comparisons are not independent, and the level of significance of the statistical test has to be adjusted (by division by two in this case). If one comparison is chosen a priori, then either Group 8 or Group 10 data would have to be dropped from the analysis (see results below).

It can be seen in Table 7 that some fish required longer than the allotted weekly period to complete the migration. These fish would then experience both conditions. This induces two possibilities in the data analysis. One method would be to truncate the data at the end of the weekly release period and not use data from fish which took longer to complete the migration. This truncation procedure may jeopardize the analysis by causing an unknown influence on the results. Alternatively, we could use the data, acknowledging that a few fish would be subjected to both flow conditions. This would be a more conservative approach. For instance, for those fish whose migration extends beyond 1 week, test fish would experience some control conditions and control fish would experience some test conditions. Actual differences between test and control groups would be reduced, this would result in statistical comparisons being more conservative. For the study here, we will pursue the conservative approach and base analysis and results on the use of all data.

For the above matched groups, the methods given by Shiue and Bain (1983) were used in two-sample tests of the equality of scale parameters for independent gamma populations with unknown common shape parameters.

Suppose that $\bar{X}$ represents the mean from a control sample with gamma distribution $G(X;\theta_1,\lambda)$ and $\bar{Y}$ the mean from a test sample with gamma distribution $G(y;\theta_2,\lambda)$. A test of the null hypothesis

$$H_o: \theta_1 = \theta_2$$

against the alternative hypothesis

$$H_a: \theta_1 < \theta_2$$

is to reject H_o if

$$\bar{X}/\bar{Y} < F(\alpha;2n_1\lambda,2n_2\lambda),$$

where $F(\alpha,\nu_1,\nu_2)$ denotes the lower α percentile of Snedecor's F distribution. If λ is known this is a size α test of H_o. Shiue and Bain show that one can expect good results if λ is replaced by $\hat{\lambda}$, where $\hat{\lambda}$ denotes the maximum likelihood estimate based on the combined sample data x_1, ..., x_{n1}, y_1, ..., y_{n2}. Shiue and Bain compute Monte Carlo simulations for a range of values of λ , α , n_1, and n_2 which verify that with λ replaced by $\hat{\lambda}$, the above formula provides an approximate test with the true level being slightly above the prescribed level for moderate sample sizes (see their Table 1). They also provide (see their Table 2) modifications for α for small sample sizes so that the actual level is close to the prescribed nominal level.

An F-test of the assumption of common shape parameter (H_o: $\lambda_1 = \lambda_2$) can be obtained by using the approximation,

$$2n\,\lambda S \;\tilde{=}\; \chi^2_{(n-1)}$$

given by Shiue and Bain (1983). Where $S = \ln(\bar{X}/\tilde{X})$; $\bar{X}$ and $\tilde{X}$ are the sample arithmetic and geometric means respectively. The results of the test of H_o: $\lambda_t = \lambda_c$ for the matched test and control groups are given in Appendix Table A3. Common shape parameters can be assumed for all comparisons except 10 vs 9. On the basis of these results it was decided not to use the 10 vs 9 comparison and hence not use sample 10 in the group comparison.

Appendix Table A3.--F-tests of common share parameter for matched steelhead release group combinations.

	Range of tabular F-values	Sample F'-value	Conclusion[a]
2 vs 3	0.42 - 2.09	1.16	ns
4 vs 5	0.38 - 2.54	3.64	ns
8 vs 9	3.55 - 1.77	0.57	ns
13 vs 9	0.60 - 1.69	0.36	*

a/ The critical regions of the test are values outside the range of the Tabular F-values.

ns - Nonsignificant result, the sample F'-value is within the range of tabular F-values; there is no reason to reject the null hypothesis of common shape parameter.

* - Significant result at the P = 0.05 level, the null hypothesis of common shape parameter would be rejected.

The computations and results of applying the test for equal scale parameters are given in Appendix Table A2. The results show no significant difference between Groups 2 vs 3, but there are significant differences between Groups 4 vs 5 and 8 vs 9. These results do not unequivocall-establish significant differences between all the control and test groups. For chinook salmon, the groups were combined and the test for equal scale parameters is *given* in Appendix Table A4.

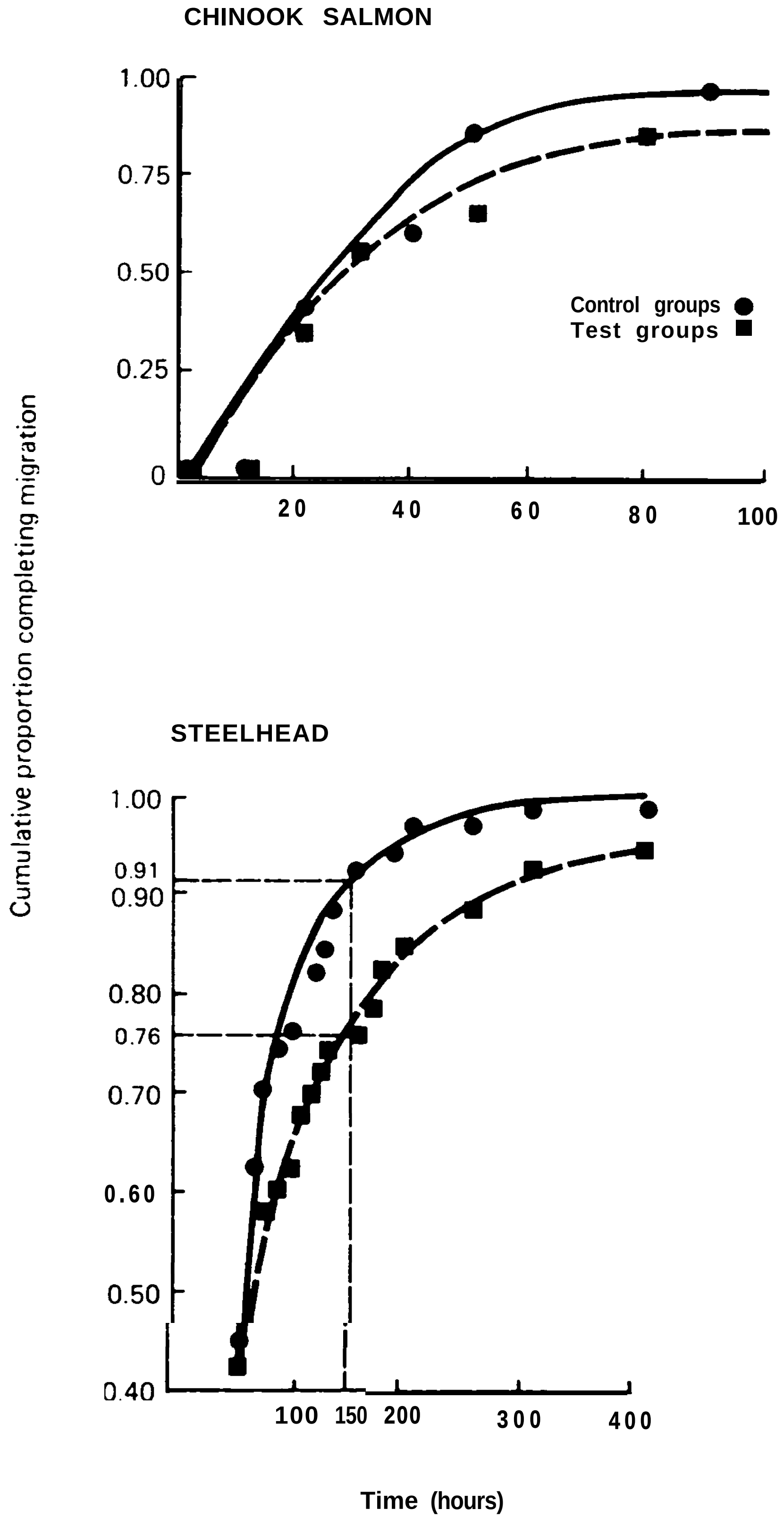
Additional analysis in which all the data are used would be helpful. This can be accomplished by lumping all test groups together (Groups 1, 3, 5, 7, and 9) and lumping all control groups together (Groups 2, 4, 8, and 10) and comparing the overall test and control travel times. A useful procedure for comparing the lumped groups would be a graph of the cumulative proportion of fish completing the migration over time. This would help to compare movement in relation to river flow condition. This type of curve would be analagous to a force of mortality curve as typically used in survival analysis. These curves are shown for chinook salmon and steelhead in Appendix Figure Al and the calculations are given in Appendix Table A5.

Appendix Table A4.--Two-sample F-test of the equality of scale parameters for the chinook salmon combined test and combined control fish.

	Control fish	Test fish
Sample size; n_1, n_2	15	15
Arith. mean; $\bar{X}$, $\bar{Y}$	39.6	69.74
Geom. mean; $\tilde{X}$, $\tilde{Y}$	30.71	37.08
Scale para.; θ_1, θ_2	23.72	97.45
Shape para.; λ_1, λ_2	1.670	0.716
Combined shape para; $\hat{\lambda}$	1.016	
$\bar{X} / \bar{Y}$	0.568	
df_1 ; ν_1	30	
df_2 ; ν_2	30	
Critical α - level[a]	0.075[b]	

[a] Probability level at which the null hypothesis would be rejected.

[b] This value was adjusted according to Table 2 in Shiue and Bain (1983). The unadjusted α - level was 0.064.



Appendix Figure Al.--Cumulative proportion completing migration for chinook salmon and steelhead--test and control groups.

APPENDIX Table A5.--Cumulative proportion of fish completing the migration for combined control and combined test groups.

	Steelhead				Chinook			
	Control		Test		Control		Test	
T.	NC	CPC	NC	CPC	NC	CPC	NC	CPC
10	0	0	0	0	0	0	0	0
20	1	0.01	0	0	6	0.40	5	0.33
30	8	0.09	9	0.09	2	3.53	3	0.53
40	29	0.38	19	0.28		0.60	2	0.67
50	6	0.44	14	0.42	4	0.87	0	0.67
63	19	3.62	12	0.54	0	0.87	3	0.87
70	8	0.70	3	0.57	0	0.87	0	0.87
80	4	0.74	3	0.60	1	0.93	0	0.87
90	1	0.75	2	0.62	0	0.93	0	0.87
100	6	0.81	5	0.67	0	0.93	0	0.87
110	0	0.81	2	0.69	0	0.93	0	0.87
120	3	0.84	3	0.72	0	0.93	0	0.87
1 30	4	0.88	1	0.73	0	0.93	0	0.87
140	3	0.91	3	0.76	0	0.93	0	0.87
150	0	0.91	0	0.76	0	0.93	0	0.87
160	0	0.91	2	0.78	1	1.00	0	0.87
170	1	0.92	3	0.81			0	0.87
180	2	0.94	2	0.83			0	0.87
190	1	0.95	1	0.84			0	0.87
200	1	0.96	0	0.84			0	0.87
250	0	0.96	4	0.88			0	0.87
300	1	0.97	3	0.91			1	0.93
400	1	0.98	2	0.93			1	1.00
00	0	0.98	4	0.97				
750	2	**1.00**	3	1.00				

T: hours to end of time interval.

NC: number of fish completing the migration in the interval.

CPC: cumulative proportion completing the migration.

APPENDIX B

Individual Travel Times, Daily Fish Counts, and Water Temperatures Recorded During the Study

Appendix Table B1.--Travel time (hour) of from their release to their first arrival at Little Goose Dam (includes only those fish that passed dam).

Release period									
1	2	3	4	5	6	7	8	9	10
97.5	137.4	30.7	49.8	35.8		26.Y	70.7	27.4	136.8[a]
40.8	23.9	104.8	52.4	248.4		216.1	52.3	56.5	60.6
43.9	45.4	50.1	50.9	394.9		22.1	64.3	218.6	52.1
	35.2	35.4	188.6	616.6		40.8	64.6	28.0	38.1
	135.7	122.2	99.4	495.4		54.8	117.8	96.4	54.0
	99.8	30.9	121.6	96.7			25.2	32.9	115.6[a]
	136.9	25.4		164.9			30.2	45.3	36.2
	74.3	45.0		644.0			26.7	19.5	37.4
	29.9	35.1					30.1	103.4	59.0
	114.6	60.6					32.6	29.6	38.0
	26.3	151.4					32.3	48.8	37.7
		23.2					95.9	113.6	67.5
		38.8					34.9	32.9	50.0
		27.1					35.0	35.1	53.9
		52.9					54.9	33.0	50.4
		37.3					123.8	36.7	56.2
		47.5					33.4	82.2	77.5
		52.2					49.5	56.8	19.9
		159.0					35.0	169.2	50.3
		67.2					32.3	60.6	52.2
		43.7					34.6	32.2	23.5
		33.1					38.0	94.9	37.2
							30.6	44.1	67.4
							38.4	34.7	56.6
							29.4	71.5	30.1
							54.3	29.2	57.7
							28.5	42.9	64.9
							121.0	43.6	94.5[a]
							43.7	43.4	31.0
								55.1	38.0
								58.9	56.0
								46.8	74.2
								75.4	35.6
								166.5	123.7
								182.0	33.3
									59.5
									41.6
									35.0
									60.0
									30.8
									66.0[a]
									80.8[a]
									90.1[a]
									64.6
									96.6[a]

[a] Passed Little Goose Dam after study was terminated; passage verified by capture at Lower Granite Dam and monitors in fish ladder at Little Goose Dam after last test.

Appendix Table B2.--Hours steelhead spent from arrival at Little Goose Dam through passage including downstream time.

Release period									
1	2	3	4	5	6	7	8	9	10
50.4	19.2	88.4	215.8	6.1		16.4	39.1	11.6	9.0
6.2	22.6	91.1	14.7	13.1		6.8	12.6	88.4	13.3
40.7	26.1	14.9	31.3	404.9		4.2	252.6	24.5	35.7
	237.9	40.5	67.1	39.9		27.3	176.7	4.1	51.2
	5.5	12.1	303.7	60.5		17.3	44.8	24.3	18.6
	18.4	26.9	5.6	18.0			21.1	13.5	13.3
	22.4	35.1		120.3			6.0	8.4	35.7
	8.4	9.1		4.7			20.4	5.3	47.5
	5.1	9.6					9.5	28.0	14.3
	93.9	12.2					32.7	268.4	78.5
	75.1	14.6					11.2	38.1	18.4
		22.6					12.6	23.5	30.5
		98.3					11.8	9.2	15.2
		152.7					23.5	5.8	15.2
		50.4					26.7	22.7	9.5
		42.8					73.7	12.7	7.1
		29.1					38.4	16.8	30.3
		8.0					14.0	12.3	21.7
		6.0					102.1	20.2	20.4
		2.7					92.1	36.3	19.0
		36.3					5.4	39.7	50.3
		20.4					20.2	24.4	12.2
							28.7	41.7	9.2
							3.7	154.3	23.1
							4.4	50.5	98.6
							134.1	39.4	23.4
							45.6	152.1	26.7
							142.7	65.1	16.1
							13.4	142.2	9.8
								12.4	16.3
								94.0	7.7
								78.6	30.6
								16.5	71.0
								17.1	45.4
								25.8	134.5
								31.7	19.8
									9.6
									36.8

Appendix Table B3.--Total hours steelhead spent in reservoir between release area and Little Goose Dam before passage, 1981.

Release period									
1	2	3	4	5	6	7	8	9	10
113.1	137.4	35.4	235.3	210.2		26.9	65.6	33.5	53.9
62.9	45.4	149.7	67.1	286.2		22.1	158.3	56.6	84.2
43.8	35.2	134.5	303.7	186.0		40.8	64.6	223.9	39.8
	136.9	30.9	188.5	408.0		227.8	25.2	28.1	37.4
	74.3	25.4	48.8	494.8		60.7	30.2	96.3	59.0
	138.1	52.1	99.5	35.4			26.7	32.8	37.7
	26.3	44.5		644.0			78.7	45.2	107.0
	103.4	60.6		616.6			98.7	19.5	56.7
	141.8	151.4					32.3	29.6	56.1
	215.5	38.8					95.8	48.8	77.4
	45.7	91.9					133.8	113.6	37.7
		67.1					43.7	40.5	55.2
		73.9					54.3	42.0	52.1
		43.7					29.4	42.9	23.6
		128.7					38.4	82.2	40.6
		135.3					30.6	60.6	67.4
		88.2					44.2	51.7	61.0
		65.3					34.6	55.7	57.7
		73.9					35.0	52.8	30.2
		31.6					49.5	132.8	84.3
		23.1					33.3	125.7	31.0
		38.3					42.5	75.3	67.5
							34.8	119.5	56.0
							154.1	65.3	89.5
							28.4	100.9	35.6
							191.1	169.1	123.7
							117.7	43.0	33.3
							192.0	85.2	59.5
							37.6	55.5	62.5
								128.5	59.9
								32.9	30.8
								75.4	119.0
								166.4	34.9
								209.8	75.5
								182.0	64.6
									57.9
									37.9
									57.3

Appendix Table B4.--Hours spent by all steelhead at Little Goose Dam during the "zero" flow study, 1981.

Release period									
1	2	3	4	5	6	7	8	9	10
6.2	51.6	21.1	102.1	291.4		10.5	12.7	85.4	30.3
18.6	78.1	32.6	14.6	13.7		6.8	31.6	22.4	35.7
33.9	5.1	101.8	31.4	6.1		4.2	6.0	11.5	11.1
9.0	8.4	59.3	36.1	26.8		15.6	15.1	36.5	15.2
2.5	18.8	18.1	195.3	22.7		14.1	26.5	4.1	16.1
10.6	12.3	14.6	6.5	18.4		150.3	13.4	13.6	7.1
23.2	19.2	12.3	59.6	99.2		17.3	11.8	17.1	21.6
	23.8	9.6	377.5	2.1			23.6	5.3	12.3
	26.1	9.1	22.7	4.6			26.7	22.2	9.3
	46.3	25.7	207.1	69.3			14.0	24.4	16.8
	5.5	19.8	38.5	150.4			43.5	9.2	9.6
	95.9	12.1	338.2	179.1			20.2	22.7	15.5
		28.2	11.6	101.7			28.7	5.8	7.7
		14.9		17.4			1.2	6.1	27.0
		5.9		4.7			60.9	24.5	40.2
		12.4					38.5	21.3	7.9
		45.2					4.4	46.7	25.1
		5.5					3.8	10.1	22.4
		5.9					9.5	15.0	42.6
		11.9					44.9	2.4	18.7
		12.1					115.5	36.7	21.0
		172.3					21.1	12.3	9.9
		22.4					59.3	20.2	5.1
		1.3					11.2	17.9	35.7
		19.3					109.4	38.8	14.3
		3.6					5.4	63.3	26.9
		74.2					36.0	90.8	9.1
		21.9					32.3	9.3	18.4
		8.1					12.6	38.9	18.6
		6.0					40.1	21.9	45.5
		2.7						5.8	13.3
		15.2						23.5	14.1
								22.0	15.1
								8.5	49.0
								60.4	76.1
								39.4	13.4
								39.7	16.3
								19.2	9.3
								2.9	20.5
								113.7	32.2
									19.8
									32.5
									0.5
									74.4
									15.9

Appendix Table B5.--Total hours spent by steelhead in study area from release to passage over Little Goose Dam, 1981.

Release period									
1	2	3	4	5	6	7	8	9	10
147.9	142.9	119.1	337.4	308.9		44.2	213.4	68.1	195.1
81.5	261.8	141.1	356.1	434.8		243.4	97.9	342.5	97.5
50.0	71.5	50.3	55.4	285.2		26.3	198.4	243.1	74.9
	48.9	53.5	118.0	53.8		47.6	69.0	213.7	125.0
	54.4	188.1	114.1	662.7		71.2	121.5	32.2	292.2[a]
	154.1	162.7	219.9	648.7			53.9	120.7	66.8
	122.2	43.0		508.5			50.4	46.4	45.1
	145.3	31.4		501.6			32.1	53.7	75.3
	189.7	71.9					122.2	24.8	47.8
	79.4	46.4					134.7	92.5	53.8
	123.8	70.2					46.3	192.2	94.2
		69.7					134.3	141.5	73.4
		161.0					47.5	481.1	152.5
		35.4					74.1	53.1	74.2
		53.4					307.5	58.0	73.5
		49.7					300.5	119.4	65.4
		151.2					78.2	55.6	89.7
		75.2					70.6	47.8	70.2
		141.2					41.0	55.4	69.3
		190.0					52.7	49.8	72.6
		97.9					44.1	49.0	45.2
		95.0					70.7	102.4	50.6
							41.8	93.1	67.5
							51.0	193.6	74.5
							42.8	100.3	66.1
							66.1	73.9	45.3
							52.0	249.2	72.9
							70.4	94.6	95.4
							194.7	74.1	331.7[a]
								223.6	49.4
								94.3	116.5
								189.0	70.3
								55.3	121.7
								137.6	71.3
								122.0	142.3
								75.4	46.6
								143.5	95.2
									92.8
									44.0
									73.3
									281.7[a]

[a] Passed after study ended; monitors still in fish Ladder.

Appendix Table B6.--Daily chinook salmon and steelhead fish counts and temperatures (°F) recorded during "zero" flow study, 1981.

JULY

Date and release no.		Ice Harbor Temp.	Ice Harbor Chinook Sum	Ice Harbor Chinook Fall	Ice Harbor Sthd	Lower Monumental Temp.	Lower Monumental Chinook Sum	Lower Monumental Chinook Fall	Lower Monumental Sthd	Little Goose Temp.	Little Goose Chinook Sum	Little Goose Chinook Fall	Little Goose Sthd	Lower Granite Temp.	Lower Granite Chinook Sum	Lower Granite Chinook Fall	Lower Granite Sthd
	I	60	102	0	19	58	184	0	9	61	226	0	II	62	286	18	
	2	60	150		14	58	70		6	61	204		12	63	259	31	
	3	61	96		12	58	65		7	61	157		10	63	216	53	
	4	62	97		23	00	88		10	61	115		18	66	177	19	
	5	62	79		26	61	67		5	62	77		6	67	104	14	
	6	62	86		37	62	196		8	62	51		17	67	46	8	
	7	62	81		lb	63	lb5		31	62	195		17	66	76	16	
	8	62	89	0	23	63	109	0	13	62	122	0	40	67	136		
	9	62	81		51	63	102		7	64	96			67	176	11	
	10	63	99		45	63	65		31	65	70		24	67	84	27	
	11	64	69		67	63	73		79	65	108		38	68	76	29	
	12	64	42		57	63	66		42	66	60		32	66	90	19	
	13	64	21		63	65	30		26	66	58		43	65	51	23	
	14	65	35		86	65	42	X	68	66	30	X	35	66	48	11	
TL	15	65	38		77	65	7		30	66	41		33	67	49	12	
- -	16	65	19		63	66	19		39	67	26		50	67	42	4	
- -	17	65	22	0	67	66	42	0	57	67	20	0	34	69	18	7	
- -	18	65	29		96	66	31		46	67	28		64	70	21	4	
- -	19	65	22		84	66	28		47	67	63		90	69	27	3	
- -	20	65	22		97	66	17		34	67	28		56	70	26	9	
- -	21	65	22		80	66	24		74	68	47		85	70	38	8	
c2	22	65	18		118	67	4		49	68	23		53	70	18	4	
- -	23	65	11		106	68	15		78	69	29		95	71	29	7	
- -	24	68	8	0	81	68	25	0	118	69	5	0	81	71	30	3	
- -	25	68	II		119	68	9		81	69	11		57	71	19	I	
- -	26	68	7		1 18	68	5		84	69	15		71	72	11	2	
- -	27	68	8		94	68	8		83	70	3		52	75	5	1	
- -	28	68	16		38	68	10		143	70	11		126	75	9	5	
T3	29	69	18		249	68	5		89	70	20		190	73	13	6	
- -	30	68	7		151	68	12		171	70	9		135	70	9	I	
- -	31	68	6	0	128	68	9	0	218	70	4	0	132	70	8	6	

Appendix Table B6.--Cont.

AUGUST

Date and release no.	Ice Harbor Temp.	Ice Harbor Chinook Sum	Ice Harbor Chinook Fall	Ice Harbor Sthd	Lower Monumental Temp.	Lower Monumental Chinook Sum	Lower Monumental Chinook Fall	Lower Monumental Sthd	Little Goose Temp.	Little Goose Chinook Sum	Little Goose Chinook Fall	Little Goose Sthd	Lower Granite Temp.	Lower Granite Chinook Sum	Lower Granite Chinook Fall	Lower Granite Sthd
-- 1	68	7	0	131	69	7	0	131	70	4	0	106	73	10	0	108
-- 2	68	1		60	69	3		102	71	8		105	73	5		112
-- 3	68	7		53	69	8		161	71	8		165	72	10		138
-- 4	70	4		136	69	5		158	71	8		112	72	8		110
C4 5	70	2		89	69	7		64	71	12		159	72	3		125
-- 6	JO	7		56	69	2		70	71	5		109	72	12		80
-- 7	70	1		54	69	1		71	--	6		103	73	4		116
-- 8	70	10	0	113	70	2	0	40	72	2	0	44	73	2	0	50
-- 9	70	3		61	--	0		26	72	0		25	73	2		28
-- 10	70	4		58	70	1		104	72	1		64	74	0		66
-- 11	JO	0	0	55	71	5		53	72	3		46	74	0		12
T5 12	70	0	2	69	71	0		14	72	3		46	77	1		23
-- 13	JO		1	27	71	1		19	72	6		46	78	0		14
-- 14	71		7	39	71	0	11	67	72	1		68	77	1		33
-- 15	71		4	44	71	0	2	34	72	0		43	76	1		is
-- 16	71		4	6	71		1	24	72	0		15	78	0		13
-- 17	72		1	11	71		1	30	72	0	0	44	78	0		8
-- 18	72		4	34	71		0	5	72		1	60	77	0	0	14
C6 >19	72		2	20	71		1	16	73		1	16	77		0	22
-- -20	72		1	32	71		2	34	73		0	58	76		0	10
-- 21	72	0	3	12	74	0	5	59	73	0	3	52	76	0	0	43
-- 22	72		0	24	74		3	49	73		7	39	74		0	20
-- 23	72		0	16	74		1	27	73		2	45	74		0	12
-- 24	72		2	14	74		1	32	73		6	60	74		1	35
-- 25	72		0	16	73		3	41	73		4	103	74		2	76
T7 26	72		2	21	73		4	22	73		1	59	74		1	74
-- 27	72		2	43	72		1	44	73		0	71	74		5	91
-- 28	72		0	55	72		2	28	73		0	31	73		1	57
-- 29	72		5	45	72		4	76	73		2	28	73		2	56
-- 30	JO		5	34	72		3	35	73		2	48	72		2	97
-- 31	73	0	10	30	72	0	0	29	73	0	1	54	72	0	4	46

Appendix Table B6.--Cont.

SEPTEMBER

Date and release no.		Ice Harbor Temp.	Ice Harbor Chinook Sum	Ice Harbor Chinook Fall	Ice Harbor Sthd	Lower Monumental Temp.	Lower Monumental Chinook Sum	Lower Monumental Chinook Fall	Lower Monumental Sthd	Little Goose Temp.	Little Goose Chinook Sum	Little Goose Chinook Fall	Little Goose Sthd	Lower Granite Temp.	Lower Granite Chinook Sum	Lower Granite Chinook Fall	Lower Granite Sthd
--	1	73	0	1	46	71	0	7	22	73	0	5	79	72	0	1	29
C8	2	73		14	119	71		12	52	72		10	69	72		8	69
--	3	--		8	109	71		4	56	72		2	3 7	72		2	35
--	4	72		10	98	71		5	70	72		6	55	71		4	63
--	5	72		9	108	71		15	95	72		4	69	71		9	47
--	6	72		8	161	71		8	10 1	72		3	86	71		4	52
--	7	70		13	82	70		11	139	71		4	106	71		l	76
--	8	71		6	53	70		2	63	71		2	62	71		6	81
T9	9	71	0	21	405	71	0	II	73	71	0	5	426	71	0	3	135
--	10	70		24	585	71		14	225	71		7	135	70		l	171
--	11	70		36	512	71		19	24 3	71		6	426	70		3	83
--	12	70		51	587	71		23	341	71		6	164	70		4	99
--	13	70		28	505	71		10	481	71		20	199	69		4	147
--	14	70		37	284	70		15	336	71		10	331	70		5	136
--	15	70		42	491	70		5	321	71		9	446	70		lb	178
C10	16	70	0	32	562	70	0	12	279	71	0	8	386	70	0	4	259
--	17	72		42	829	70		29	659	71		11	461	71		14	298
--	18	70		24	90 5	70		18	411	71		6	379	69		8	264
--	19	70		34	1,073	70		8	794	71		4	690	68		23	667
--	20	70		20	1,160	69		8	658	70		5	509	68		2	756
--	21	70		28	706	69		lb	769	69		10	1,326	66		6	444
--	22	70		21	756	69		8	688	68		10	1,075	66		2	670
--	23	70	0	23	768	69	0	7	597	68	0	7	680	66	0	16	677
--	24	70		17	884	69		7	440	67		6	634	66		5	861
--	25	68		20	805	68		8	619	66		4	475	66		6	510
--	26	68		lb	847	68		4	504	66		2	580	65		6	598
--	27	68		9	719	66		8	526	66		2	571	64		6	435
--	28	68		10	761	66		10	Y29	64		9	633	61		1	298
--	29	70		15	985	65		7	1,059	65		10	845	63		10	1,396
--	30	70	0	3	658	65	0	11	741	65	0	17	1,025	62	0	6	560

Appendix Table B7.--Hours spent back downstream by all steelhead after their first arrival at Little Goose Dam, 1981.

Release period									
1	2	3	4	5	6	7	8	9	10
15.6	15.8	7.1	133.7	113.5		11.7	66.1	6.2	29.5
22.1	191.6	9.4	31.0	37.8		5.9	48.6	61.3	a.0
	6.1	39.0	108.4	21.1			7.5	6.4	53.2
	3.6	8.2		13.1			5.3	5.3	6.3
	23.5	43.2					6.2	19.5	17.8
		23.9					12.8	11.6	4.9
		85.2					137.1	18.1	5.1
		50.9					83.4	26.3	15.8
		17.8					94.0	6.9	28.4
		21.7					13.3	7.5	3.6
		4.5					67.3	6.9	15.3
		12.3						16.1	3.4
		5.2						7.7	4.4
								31.9	19.4
								57.3	20.9
								28.4	58.4
								73.4	7.9
								78.9	
								114.9	

APPENDIX C

Budget Information

BUDGET

A. Summary of Expenditures

Item	Total spent
Salary and overhead	$190.7
Travel	10.8
Vehicles	5.1
Rent (aircraft)	7.7
Printing	0.1
Supplies	15.8
support	78.8
Total	$309 .0

B. Major Property Items

1. Six Anadesc Printers at **$1,015** each = $6,090.