Smolt Passage Behavior and Flow-net Relationships in The Forebay of John Day Dam

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November 1984

COASTAL ZONE AND ESTUARINE STUDIES

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Annual Report of Research
financed by
Bonneville Power Administration
(Agreement DE-A179-83BP39644)

and

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National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112

November 1984

ABSTRACT

During 1984, this research program in the forebay of John Day Dam had three separate but complementary phases--monitoring current patterns, defining fish distribution with purse seine sampling, and assessing the value of a new application of radio tag methodology designed to examine passage behavior of juvenile salmonids.

Preliminary results from the purse seining operations in FY84 support observations made in 1983, i.e., the discharge from the John Day River and the turbid plume it forms in the forebay may have a pronounced effect on the distribution of smolts as they approach the dam. The implication of these data is that the plume may be shunting salmon toward the Washington (spill) side of the river where they would be more susceptible to spill passage. These findings will be subsequently analyzed in conjunction with 1983 data and therefore must be considered preliminary at this time. Data describing the current patterns during 1983 and 1984 will be incorporated into an overall analysis of the relations of current patterns and John Day River discharge to fish migration patterns.

A new research application of radio tag methodology was successfully executed. From 57 to 100% (ave. = 79%) of the individuals in various groups of smolts fitted with radio tags and released 6 k upstream from John Day Dam successfully migrated to and were detected at the dam. Furthermore, it was possible to positively identify the specific passage route (spillway, powerhouse, fishladder, or navigation lock) used by each uniquely coded individual.

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INTRODUCTION

Even though collection and transportation facilities are operating at key dams in the Snake-Columbia River System, significant numbers of juvenile salmonids continue to migrate downstream past dams on their own volition (Sims et al. 1982). Mortality through spillways is approximately 3% (Bell et al. 1972) contrasted to mortalities of 15% and higher through turbines (Long et al. 1968). Improved fingerling bypass systems are being developed to ensure the safe passage of these migrants as they encounter the numerous dams on their seaward journey (McConnell and Muir 1982; Swan et al. 1983).

Special flows, spills, and operating techniques at dams such as John Day that have inadequate bypasses are also being used to enhance smolt survival (Sims and Johnsen 1977). These strategies are executed on the premise that the current system (flow-net) in the forebay responds to dam operations and that smolts in turn respond to the flow-net, as suggested by previous juvenile radio tracking studies conducted by the National Marine Fisheries Service (NMFS) in the forebay of John Day Dam (Sims et al. 1981; Faurot et al. 1982).

The ultimate objective of the research program reported herein is to define the flow-net in the forebay of John Day Dam over a range of flow conditions and dam operations and relate it to smolt passage behavior. Such information is fundamental in assessing the effectiveness of providing special flows and dam operations and may also be useful in the design of fingerling bypass systems. To advance toward the ultimate objective, it was necessary to begin systematically gathering current data and developing the computer software required to process and analyze the data. During

1982, 1983, and 1984, efforts were concentrated on these important facets of the program.

In 1983, two additional phases were implemented--a purse seining program to define the distribution of fish in the forebay and a radio tracking study designed to identify the routes which juvenile salmonids take as they move downstream.

In 1984, the purse seine sampling area was expanded upstream from the John Day River. In addition, a new application of radio tag technology which can provide statistically sound fish passage data was assessed.

FISH DISTRIBUTION AND CURRENT METER DATA

Methods and Materials

Purse Seining

From 9 May to 6 June 1984, purse seine sampling activities were conducted with the Northwest and Alaska Fisheries Center's (NWAFC) research vessel Columbia, an 11-m power block seiner. Nine sampling stations were established, three across each of three transects (Figure 1). At the nearshore stations (1,3) nets were set approximately 50-100 m from shore. The lower two transects were also sampled in 1983; the upper one was sampled for the first time in 1984. Upstream sets were typically made between 0500 and 1300 h; salmonid catches were enumerated by species. With each set a secchi disk reading was taken and representative surface water temperatures were recorded. Data are detailed in Appendix A. In addition, vertical profiles of temperature and turbidity were taken across each transect on most sampling cruises. These data will be displayed in graphical form but are not finalized as yet.

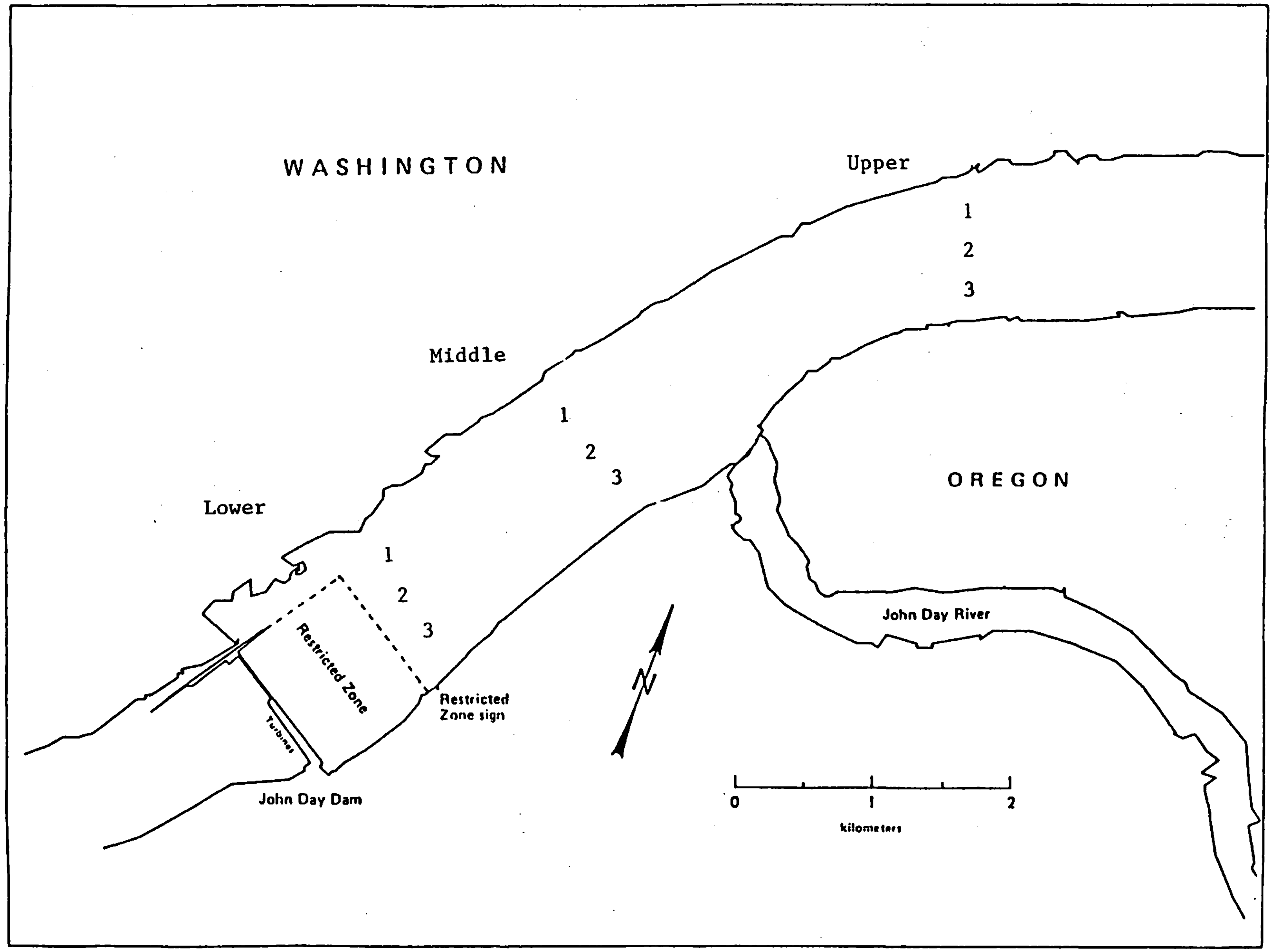

Figure 1.--Purse seine/limnological sampling transects (upper, middle, and lower) and stations.

Current Meter Data

From 25 April to 18 September 1984, 11 self-contained, magnetic recording current meters were deployed in the forebay of John Day Dam. The current meters were secured to a self-adjusting buoy system which maintained them at a constant depth, 3 m below the surface of the reservoir. The 1984 sampling grid was the same as in 1983 extending upriver nearly 2 km from the dam. A 12th meter was used to take readings at various other locations in the forebay and also acted as a backup when any deployed in the grid malfunctioned. Current velocity and direction were measured for an 8-min interval each hour, synchronized among all instruments. Cassette tapes and battery packs were replaced monthly to ensure that the meters continued to operate throughout the field season.

Cassettes with encoded data were read into the Burroughs 7800 mainframe computer at the NWAFC.1/ Two different tasks in software development continued: (1) data error checking and editing and (2) data base evaluations.

Results

Fish Distribution

From 9 May to 6 June 1984, 76 purse seine sets were executed (Appendix A). Over the course of the study, 8,564 juvenile salmonids (4,094 yearling chinook salmon, 1,455 steelhead, 1,218 sockeye salmon, 139 coho salmon, and 1,658 subyearling chinook salmon) were caught, identified by species, and released. The number of sets on a given sampling date ranged from two to

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

six depending on prevailing weather conditions and the number of fish which were captured and had to be sorted. The 1984 purse seine catches are expressed both as the number of fish in catch/set and the percent of the total of each transect catch (Appendix A). The 1983 data have also been expressed as the percent transect catch and are reported in Appendix A. In 1984, the general distribution patterns for yearling chinook salmon, sockeye salmon, and steelhead were similar to those observed in 1983; fish were concentrated near the Washington shore and were rarely encountered at sampling stations near the Oregon shore, especially at Station 3 (Figures 2 through 4). Subyearling chinook salmon sampled during the spring outmigration for the first time in 1984 displayed distribution patterns similar to the other juvenile salmonids, avoiding the Oregon shore area (Appendix A).

The John Day River enters the Columbia River approximately 3 km upstream from the dam (Figure 1). The John Day River during the spring runoff is typically very turbid in comparison to the Columbia River, so much so that a visible turbid plume emanates from its mouth and can often extend to the Washington shore. As a result over the course of the spring migration, water clarity (secchi disk reading) varied throughout the forebay from 25 to 97 cm (Appendix A). As observed in 1983, the low water visibilities (41-60% of the maximum secchi disk reading each day) were consistently exhibited near the mouth of the John Day River and downstream near the Oregon shore, whereas the higher visibilities (81-100%) occurred in areas farthest from the John Day River near the Washington shore (Figure 5). As in 1983, this year's data suggest that fish distribution may be affected by the discharges from the John Day River.

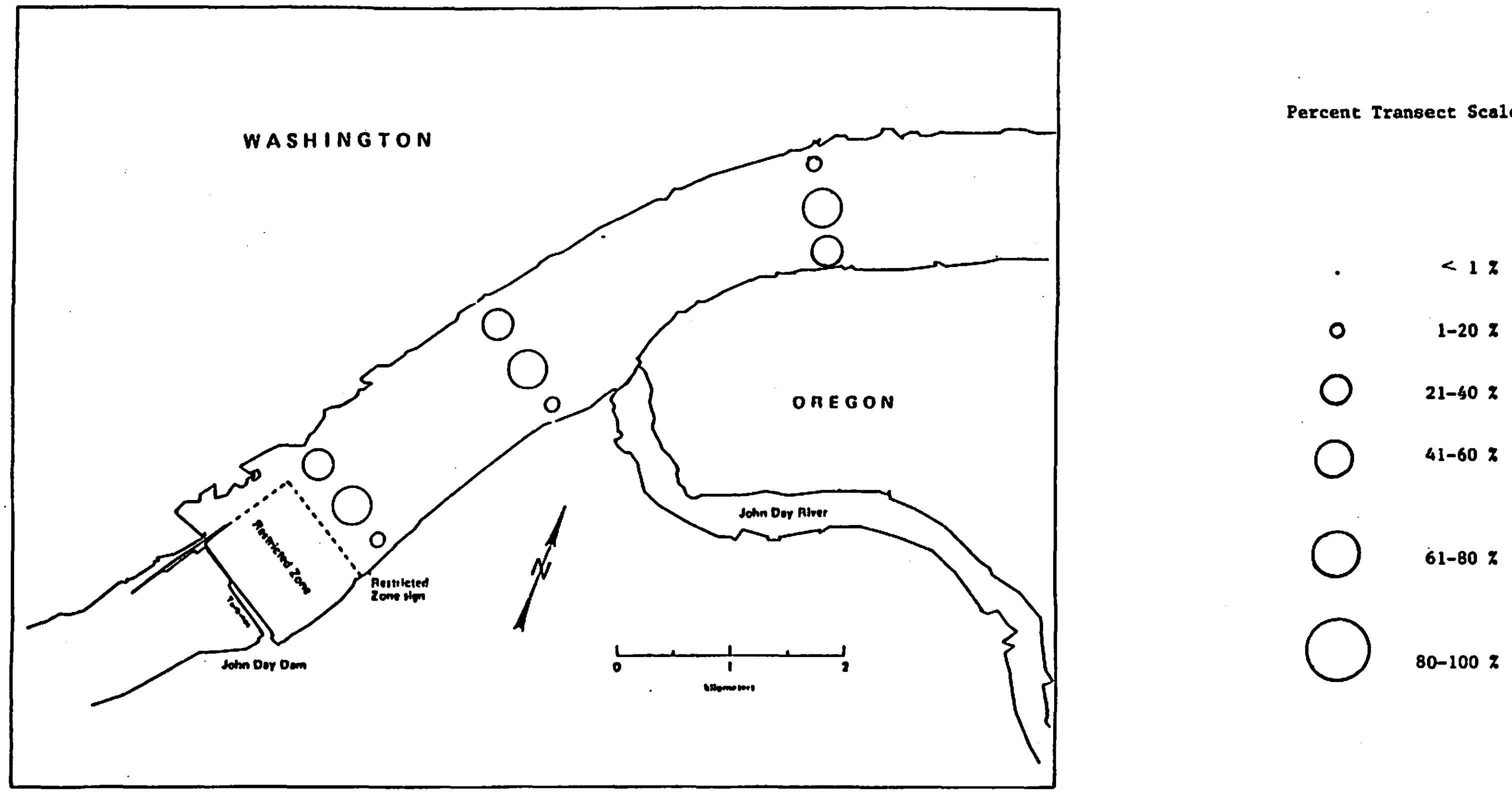

Figure 2.--Seasonal mean value of steelhead, expressed as percent transect catch, spring 1984.

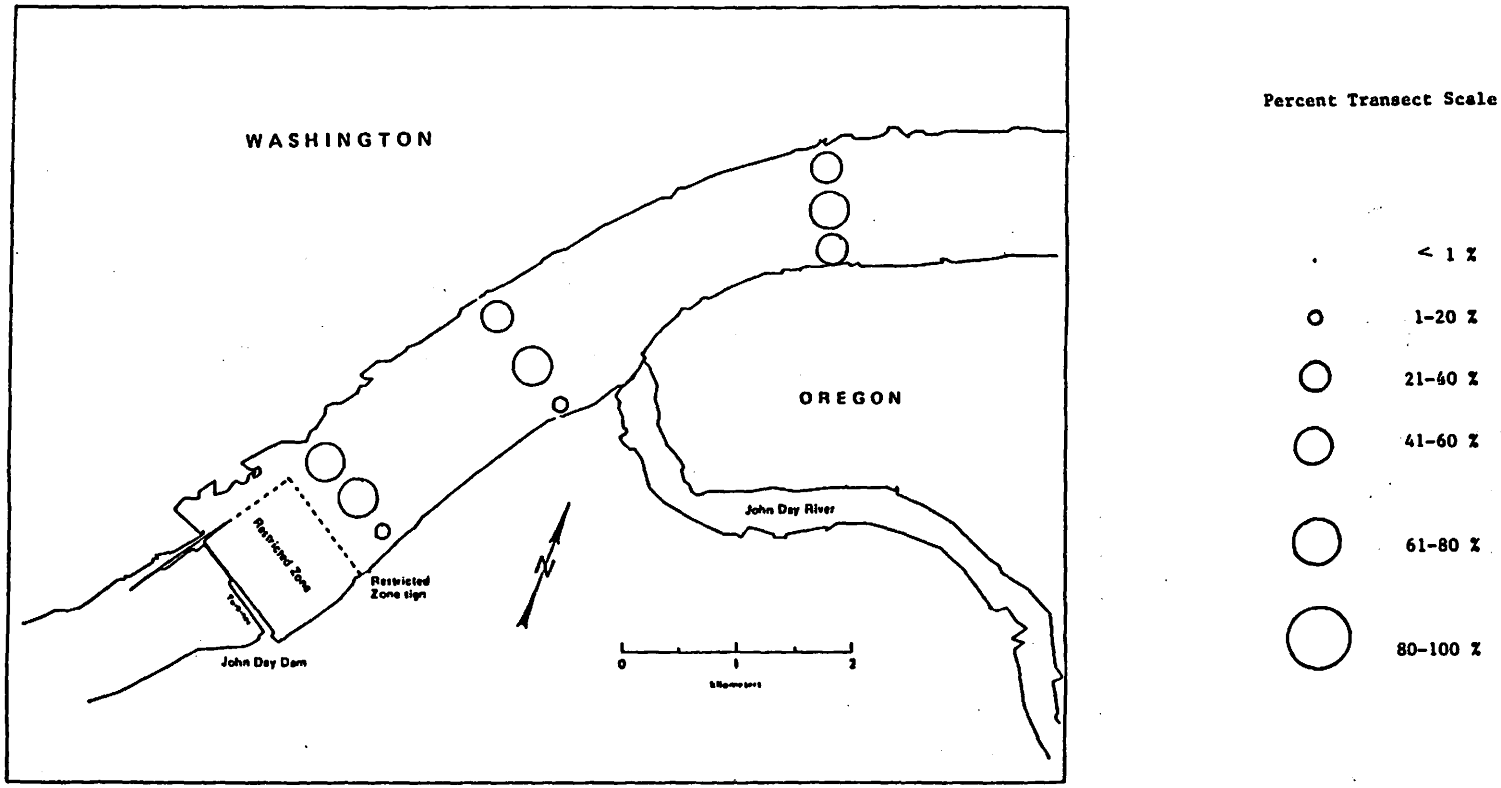

Figure 3.--Seasonal mean value of yearling chinook salmon, expressed as percent transect catch, spring 1984.

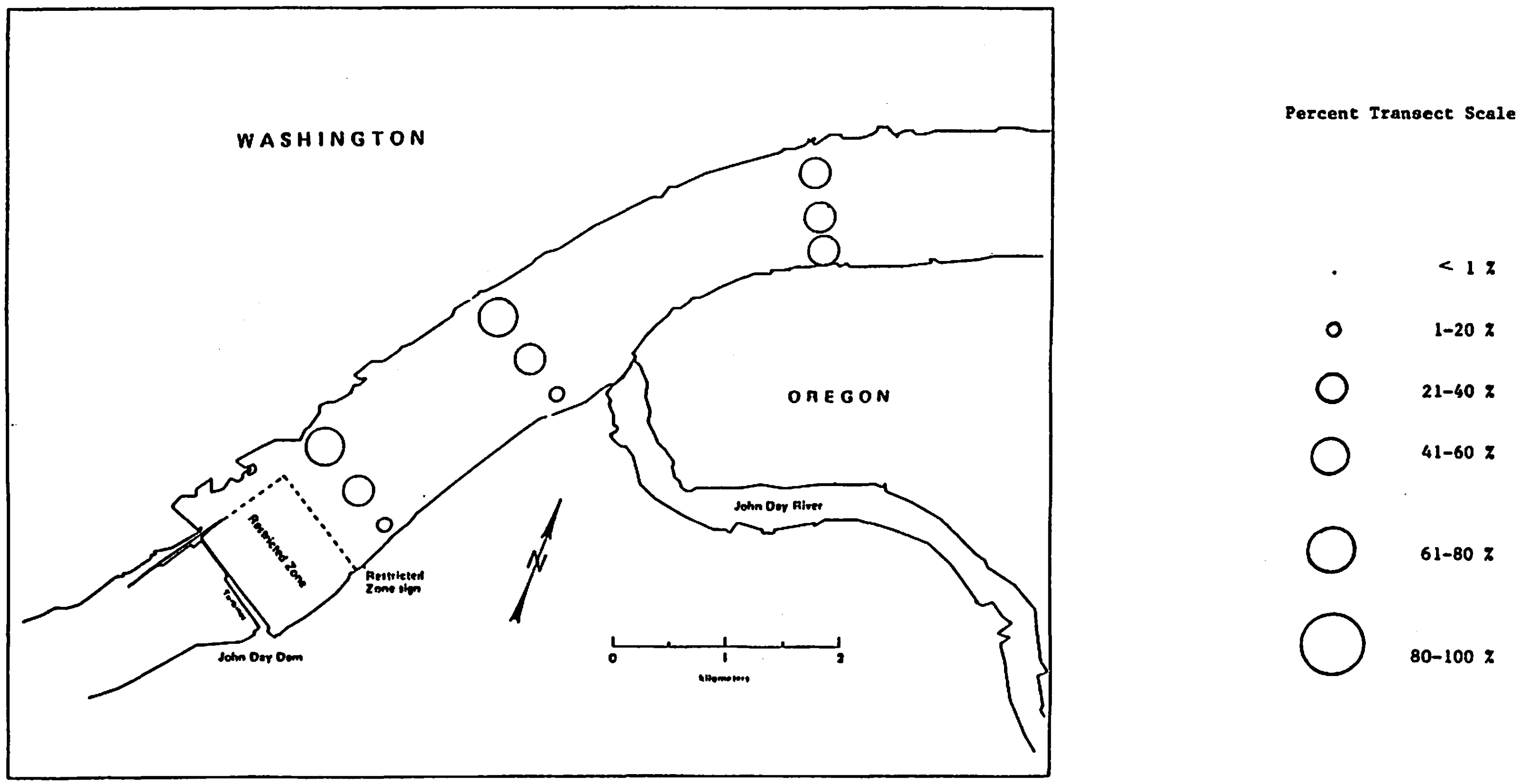

Figure 4.--Seasonal mean value of sockeye salmon, expressed as percent transect catch, spring 1984.

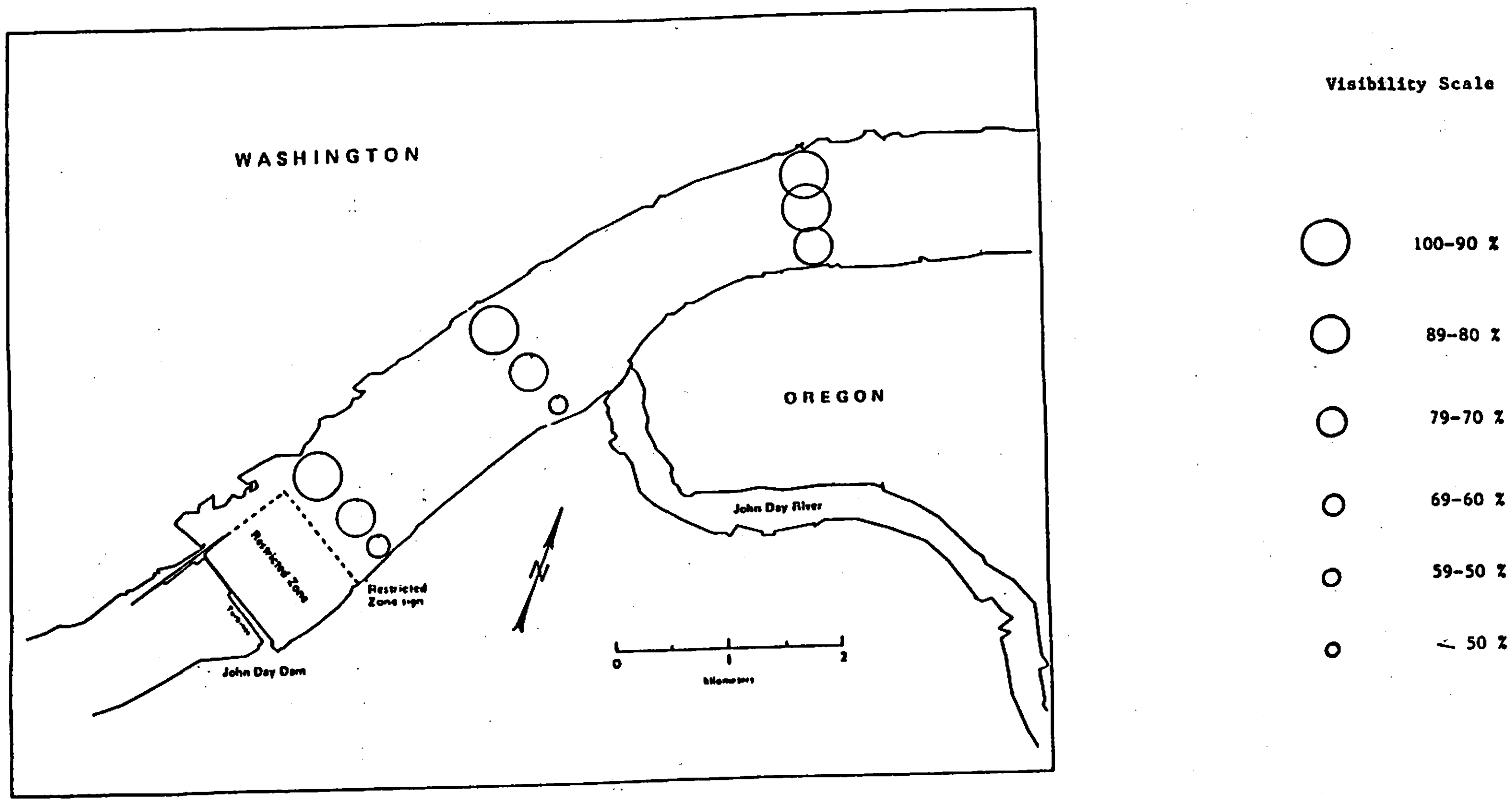

Figure 5.--Seasonal mean value of water clarity, expressed as percent of daily maximum secchi disk reading, spring 1984.

Current Velocity and Dam Operations

In addition to the influence of the John Day River, there are several other variables which must be examined before the effector(s) can positively be demonstrated. The two most apparent ones are the water velocities at different locations in the forebay and the amount of spill provided during the purse seine operations. These data have been extracted from the flownet data base for 1983 and 1984 and are presented in Appendix A. We are presently evaluating a number of non-parametric statistical tests for use in analyzing these data. The objective of these tests will be to identify which factor(s) significantly affect the distribution of juvenile salmon as they migrate through the John Day forebay. Analyses will be detailed in the final research report in FY85.

RADIO TRACKING

Introduction

Between 1980 and 1982, the NMFS, with funding by the U.S. Army Corps of Engineers, utilized the recently developed juvenile radio tag to monitor migration routes of smolts passing through the reservoir and their passage locations at the dam (Stuehrenberg and Liscom 1982). In 1983, a monitoring system was placed on the powerhouse and spillway of John Day Dam to more accurately determine the passage locations of the individual fish. Based on the results of that work, the 1984 study was designed to increase the number of tags released and to change the emphasis from detailing migration routes to identifying passage locations at the dam. The primary objective was to test the concept of using group releases of radio tagged smolts to evaluate these fish passage locations.

Methods and Materials

Study Area

Radio tagged juvenile salmonids were tracked in the immediate vicinity of John Day Dam, upstream to the uppermost purse seine transect (Figure 1). In this area, the river is about 1 km wide, and the John Day River enters on the Oregon side at RKm 351.

Smolts have two primary routes to pass John Day Dam: the spillway or the powerhouse. Other seldom used passage routes include the navigation lock and the two fishladders. Flows through the John Day Dam project typically range from 130 to 450 kcfs during the spring outmigration, and involuntary spill begins when flows reach about 300 kcfs.

The salmonid outmigration at John Day Dam (mid April-early June) normally follows the peak flows from the spring snow melt.

Equipment

The juvenile radio tag was developed by NMFS electronics personnel to provide a means of monitoring movements of individual salmonid smolts. The radio tags are battery powered transmitters that operate on a carrier frequency of approximately 30 megahertz (MHz). The transmitter and batteries are coated with Humiseal and then a mixture of paraffin and beeswax to form a flattened cylinder 26 x 9 x 6 mm, which weighs approximately 2.9 g in air. A 127-mm long flexible whip antenna is attached to one end of the tag. For identification purposes, each tag transmitted on one of nine frequencies spaced 10 kilohertz apart (30.17 through 30.25 MHz). Individual tags on each frequency were pulse coded to provide individual identification of each tag. Tracking range of the tag varied from 100 to 1000 m depending on the output of the tag and the depth of the fish. The pulse rate was two per second, and the tag life was a minimum of 3 days.

Two types of tracking receivers were used, one for mobile operations and the other as a stationary monitor. Smith-Root RF-40 receivers in conjunction with hand held directional loop antennas were used during mobile operations, and a combination of our search unit, a pulse decoder, and a digital printer were used with antennas at the fixed monitor locations. Fixed monitors were located in each of the two fishladders, at the upstream end of the navigation lock, and at the centers of the spillway and active turbine bays. In the fishladders, two underwater antennas provided signal input for the monitors. At the navigation lock a single loop antenna, shielded from the watermass in front of the spillway by concrete, provided signal input. The powerhouse and spillway were monitored with two systems of 10 loop antennas linked together with 10 signal amplifiers.

A 6.3-m long boat was used as a tracking platform in the forebay.

Tagging

Juvenile chinook salmon were collected at John Day Dam from an airlift pump in the gatewell of Turbine Unit 3. All were longer than 149 mm and showed a minimum amount of descaling. Before tagging, the fish were mildly anesthetized with MS-222. After a fish was measured, the tag was dipped in glycerin and inserted into the fish's stomach. The tag's flexible antenna extended out of the fish's mouth and trailed back along the side of the fish.

Tagging was conducted between 2000 and 2400 h, and the fish were released the next day, one group at 0800 h and another at 1300 h. The

10-12 h period between tagging and release provided a test of the tags reliability and allowed the fish to adjust to carrying the extra weight. In cases where fish did not recover, another fish was tagged. Recovery time was shortened for those individuals. After recovering, tagged fish were placed in a live well on the tracking boat, transported 6.3 km upstream to the release site just above the upper purse seine transect (Figure 1), and released into the river.

Experimental Design

The experimental design called for morning and afternoon releases of 14 tagged fish each on three separate days. This provided the means to assess whether arrival time at the dam influenced passage location or success, and to assess the influence of varying spill modes and the John Day River plume on passage at the dam. After the morning fish were released, water samples were taken, meteorological data were recorded, and the location of the John Day River plume was plotted. Subsequently, a random search pattern was executed with a radio tracking vessel to locate as many of the early release fish as possible. As the morning fish approached the dam, the afternoon fish were moved to the boat and the monitors were turned on. The afternoon fish were held in the live well on the boat, upstream from the monitors until the afternoon release time. After the afternoon fish release and near sunset, random searches were made for tags in the forebay.

Monitor operation was checked before tests, at least twice during the night after the releases, and twice a day between tests. Range tests, for the monitor antenna systems were conducted on the day before the fish were released.

The evaluation of group radio tag release techniques was based on the number of fish from each release that were detected at the dam, and the ability of the antenna systems to separate powerhouse, spillway, navigation lock, and fishladder passage locations.

Results

A total of 95 chinook salmon smolts were radio tagged and released; 28 fish each on 1, 10, and 14 May and 11 on 25 May. Results are detailed in Appendix A.

Passage locations through the spillway and powerhouse were: 5 and 14 from the 1 May release; 12 and 13 from the 5 May release; 15 and 8 from the 14 May release; and 5 and 3 from the 25 May release, respectively. During periods of spill, 68 fish passed the dam--41 (60%) through the spillway and 27 (40%) through the powerhouse.

On the day of the first release (1 May), the John Day River plume was very small, and the percentage of the total river flow being spilled during the night passage period (1900-0500 h) was approximately 24%. During the two subsequent paired releases (10 and 14 May), the percentage of the river flow being spilled during peak passage hours was increased to over 40%, but occurred only between of 2000 and 0500 h, and the John Day River plume moved across the Columbia River toward the Washington shore (Figure 6). In addition, during the third release (14 May), the wind blew out of the southwest in excess of 20 mph most of the day. Such intense winds tend to push the John Day River plume upstream along the Oregon shore (Figure 6). On 25 May, spill (49%) occurred only from 1800 to 0500 h.

Analysis regarding the relation of the percent spill and prevailing plume conditions to dam passage will not be presented in this report. It

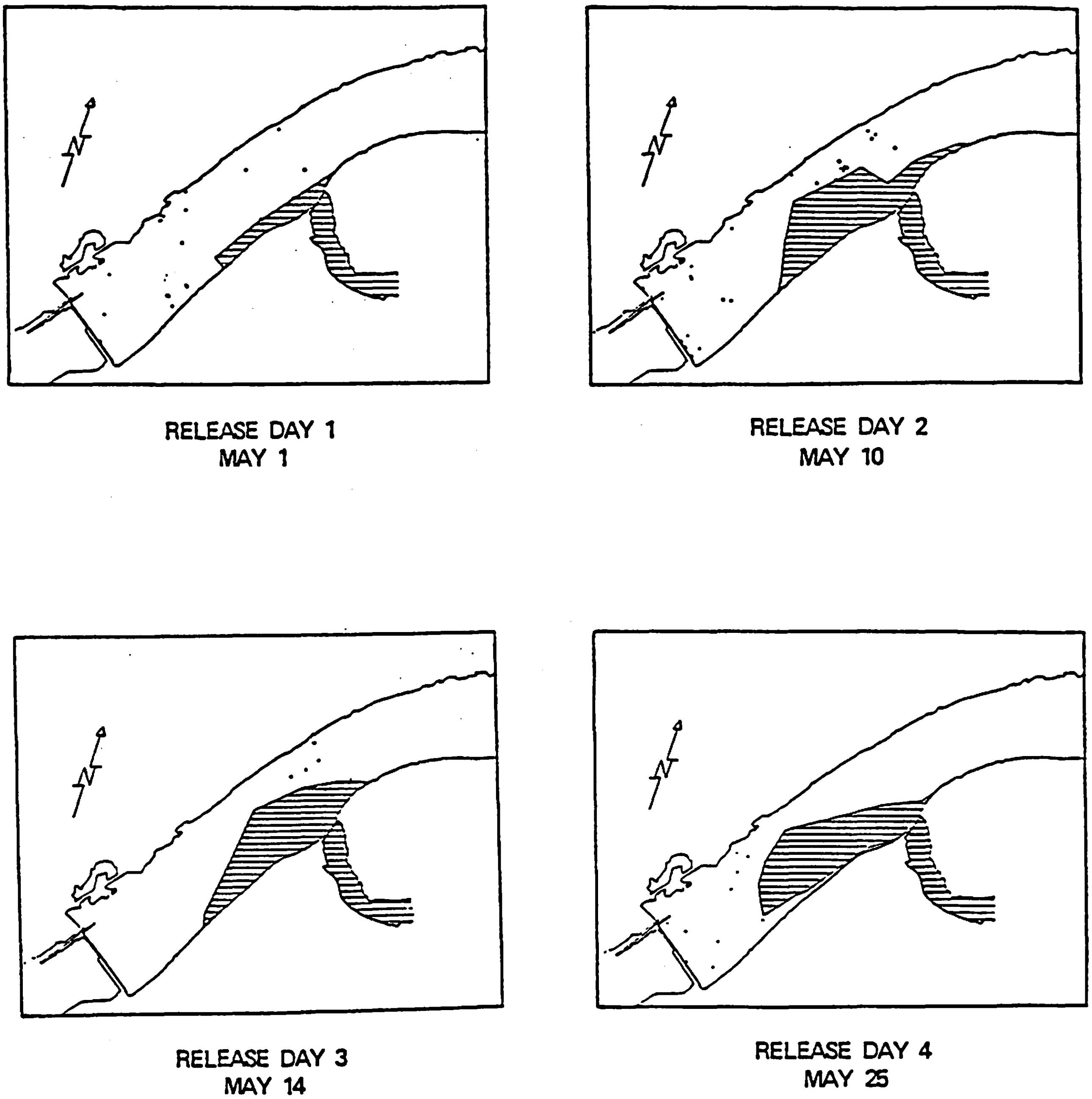

Figure 6.--Location of the John Day River plume and radio-tagged chinook salmon on each release day, 1984.

is necessary to interpret these data in conjunction with the 2 years (1983, 1984) of purse seine and limnological data which are presently being analyzed. Statistical treatment of the radio tag data will be presented in the final research report (FY85).

Data on the 75 fish that were detected as they passed through John Day Dam are presented in Appendix A. Passage rates for individual release groups ranged from a high of 100% for the morning release of 10 May to a low of 57% for the afternoon release on 1 May (Table 1). The overall passage rate for all tagged fish released was 79%, with the best rates demonstrated by the morning release groups (average 90%).

The reasons for the lower passage rates of afternoon releases are unclear, however, the fish that were still up in the reservoir after sunset from both morning and afternoon releases, were the fish that were not recorded at the dam. The battery life for these tags had not been exceeded.

The separation of passage locations was very clear. The overlap of the antenna ranges of the powerhouse and the spillway monitors fell within the four empty turbine bays that separate the active turbines and the spillway. Fish detected on both monitors while some distance upstream from the dam, were only detected on one of the monitors at the time they were last heard. No fish passed downstream via the fishladders or navigation lock. The navigation lock monitor did record tag data while the fish were near the upstream gate. Those fish were later recorded as they passed downstream via the spillway. Separation of the spillway and navigation lock approaches by using a concrete corner to shield the navigation lock antenna from fish in the spill channel was successful.

Table 1.--Passage rates of individual release groups.

Release			No. detected at dam			
Date	Time	No. released	Spillway	Powerhouse	Nav. lock/ fishways	% detected at dam
1 May						
	0850	14	4	7	0	79
	1339	14	1	7	0	57
10 May						
	0851	14	6	8	0	100
	1413	14	6	5	0	79
14 May						
	0836	14	7	6	0	93
	1405	14	8	2	0	71
25 May						
	1405	11	5	3	0	73
TOTALS		95	37	38	0	79

As in 1983, fish were noticeably absent within the John Day River plume, as determined by the random search patterns conducted in the forebay. Only 1 of the 67 fish detected in the forebay was found in the water that we could visually classify as John Day River water.

SUMMARY

During 1984, the research program had three phases--defining fish distribution with purse seine sampling, monitoring current patterns in the forebay, and evaluating a new application of radio-tag methodology. Comprehensive data analysis and conclusions for the 3 years of field work will be presented in the final researh report (FY85), however, several preliminary observations can be summarized as follows:

1. Purse seine data demonstrate that during the spring migration all juvenile salmonid species alter their distribution pattern upon intercepting the mouth of the John Day River. Relatively few were found along the Oregon shore downstream from the John Day River. This is consistent with patterns observed in 1983. Other factors, such as the amount of spill and prevailing current velocities could also affect smolt distribution in the forebay. A comprehensive analysis relating the effects of the various physical factors on smolt distribution is in progress. Results will be included in the final report in 1985.

2. The third and final season of forebay current system monitoring was completed. These data will be analysed in conjunction with purse seine and radio-tag data collected over the course of the 3-year study, and the results will be presented in the final report.

3. Data from the group releases of radio tagged chinook salmon smolts demonstrated that the concept of using telemetry as a means of evaluating fish passage location at hydroelectric projects is feasible. Approximately 90% of the fish released above the dam can be expected to pass the dam and be detected by the monitoring system used at John Day Dam, thus providing data identifying specific passage locations at the dam.

RECOMMENDATIONS

Originally, the objective of this study was to define the flow-net in the forebay of John Day Dam and relate smolt passage behavior to the prevailing current patterns, a seemingly straight forward endeavor. However, the 1983 fish distribution and radio tracking data suggested a more complex situation. This required the focus of the program to be expanded to determine which physical characteristics, e.g., flow-net, John Day River discharge, or some other as yet unidentified factor(s), either separately or in concert, affect the migration routes and ultimate passage location of salmonid smolts and to assess the effect of dam operations on these factors. Since we have just recently concluded our field activities and are in the process of analyzing the 3 years of data in its entirety, it would be premature to make any specific recommendations regarding the utilization of spill in this report.

However, our first attempt at testing the concept of using group releases of radio tagged salmonid smolts as a research tool was successful. Detectability of tags at the dam was high. It is reasonable to expect that 90% of tagged fish released will survive to and be detected at the dam. Furthermore, identification of specific passage routes (spillway, powerhouse, navigation lock, or fishladder) used by uniquely coded individuals was easily interpreted. Consequently, we recommend that this methodology be considered to address certain issues of concern at hydroelectric facilities.

ACKNOWLEDGMENT

Support for this research came from the region's electrical ratepayers through the Bonneville Power Administration.

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APPENDIX A

1984 DATA

Appendix Table A1.--Purse seine and associated limnological data, 1984. Stations 1, 2, and 3 were located near the Washington shore, center of the reservoir, and Oregon shore, respectively.

				No. of fish (catch/set)					Secchi disc reading		
Date	Transect	Station	Time	Chin 1's	Coho	Sockeye	Steelhead	Chin 0's	cm	% of daily max	Temp (°C)
050984	downstream	1	1310	53	0	8	52	0	-	-	10.0
		2	1030	60	0	17	18	0	69	97	10.0
		3	1150	28	0	11	12	0	64	90	10.0
		1	0820	95	0	33	41	0	71	100	10.0
		2	0530	62	0	11	24	0	61	86	10.0
		3	0650	13	0	26	10	0	61	86	10.0
051084	upstream	1	1145	44	0	5	19	0	79	94	10.0
		2	1300	67	0	3	46	0	84	100	10.0
		3	1420	29	0	7	11	0	66	79	10.0
051184	upstream	1	0530	47	0	6	6	0	74	91	10.0
		2	0635	115	0	13	19	0	81	100	10.0
		3	0750	14	0	1	7	0	69	85	10.0
	midstream	1	1230	43	0	11	19	0	79	98	10.5
		2	1115	171	0	21	26	0	76	94	11.0
		3	1000	8	0	22	18	0	38	47	13.5
051584	downstream	2	0605	-	-	-	-	-	58	-	11.0
		3	0530	-	-	-	-	-	53	-	11.0
051684	midstream	1	1010	-	-	-	-	-	71	100	11.5
		2	0930	-	-	-	-	-	58	82	11.5
		3	0910	-	-	-	-	-	28	39	12.0
	downstream	1	0800	-	-	-	-	-	66	93	11.5
		2	0630	68	0	8	40	0	56	79	11.5
		3	0510	40	0	21	24	1	41	58	12.0
051784	upstream	1	1220	29	0	26	8	0	71	78	12.0
		2	1105	79	0	14	16	0	81	89	13.0
		3	0945	57	0	25	30	0	69	76	12.5
	midstream	1	0730	43	0	6	13	0	89	98	12.0
		2	0615	89	0	14	39	0	91	100	13.0
		3	0510	5	0	3	6	0	41	45	12.5

Appendix Table A1.--(cont.)

Date	Transect	Station	Time	No. of fish (catch/set): Chin 1's	Coho	Sockeye	Steelhead	Chin 0's	Secchi disc reading: cm	% of daily max	Temp (°C)
051884	midstream	1	0740	151	0	33	39	0	89	100	12.0
		2	0620	223	0	31	39	0	79	89	13.0
		3	0510	3	0	1	8	0	25	28	12.0
	downstream	1	1000	157	0	19	42	0	74	83	12.0
		2	1120	176	0	42	53	0	76	85	12.0
		3	1235	3	0	3	5	0	36	40	12.0
052284	upstream	1	1000	129	0	46	21	0	91	100	12.5
		2	1115	162	0	23	28	0	84	92	13.0
		3	1225	21	0	10	17	0	89	98	13.0
	midstream	1	0730	204	0	103	22	0	89	98	12.5
		2	0615	97	0	3	74	0	89	98	12.5
		3	0500	11	0	2	20	0	56	62	13.0
052484	upstream	1	1120	143	7	14	22	0	86	97	12.0
		2	1320	-------------no fishing--too windy-------------					86	97	12.0
		3	0955	19	0	22	15	0	81	91	12.0
	midstream	1	0725	126	11	154	33	0	89	100	12.5
		2	0615	108	9	18	36	0	86	97	12.0
		3	0500	16	0	5	11	0	53	60	12.5
052584	midstream	1	0715	103	6	62	13	0	79	98	12.0
		2	0605	151	23	17	17	0	81	100	12.0
		3	0500	14	0	1	2	0	51	63	12.5
	downstream	1	0930	93	28	54	6	0	81	100	12.0
		2	1040	367	32	73	69	0	81	100	12.5
		3	1200	7	0	4	6	0	48	59	12.5
052984	upstream	1	0930	3	0	1	1	16	94	97	14.0
		2	1035	57	7	5	15	1	97	100	14.0
		3	1150	36	7	12	0	5	94	97	14.0
	midstream	1	0500	19	1	13	8	0	94	97	13.5
		2	0605	36	1	0	19	0	91	94	14.5
		3	0710	3	0	1	5	0	56	58	15.7

Appendix Table A1.--(cont.)

				No. of fish (catch/set)					Secchi disc reading		
										% of daily	Temp
Date	Transect	Station	Time	Chin 1's	Coho	Sockeye	Steelhead	Chin 0's	cm	max	(°C)
053184	downstream	1	0600	3	0	1	19	17	94	100	13.5
		2	0705	6	1	2	23	0	81	86	13.5
		3	0500	3	0	0	8	7	51	54	14.0
	downstream	1	1140	4	3	3	17	16	91	97	13.5
		2	1030	9	2	0	21	0	79	84	13.5
		3	0925	1	0	0	4	3	46	49	14.0
060184	upstream	1	0915	5	0	8	2	113	86	97	14.0
		2	1030	27	0	21	13	336	89	100	15.0
		3	1140	7	0	4	6	40	67	75	14.0
	midstream	1	0450	6	0	11	17	69	53	60	15.5
		2	0555	22	1	5	16	62	48	54	14.5
		3	0715	3	0	0	2	9	43	48	15.0
060584	midstream	1	0720	4	0	13	5	156	86	97	12.5
		2	0610	6	0	9	12	79	71	80	14.5
		3	0455	2	0	3	10	9	41	46	15.0
	downstream	1	1130	17	0	10	8	162	89	100	13.5
		2	1030	7	0	0	13	25	56	63	13.5
		3	0920	0	0	0	6	56	43	48	14.0
060684	upstream	1	0935	14	0	13	12	143	89	100	14.5
		2	1040	19	0	9	15	38	84	94	14.5
		3	1145	9	0	8	23	21	64	72	14.5
	midstream	1	0715	9	0	3	11	189	89	100	13.5
		2	0605	13	0	9	23	56	81	91	14.5
		3	0405	1	0	2	19	29	53	60	15.0
	TOTALS			4,094	139	1,218	1,455	1,658			

Appendix Table A2.--Purse seine catches expressed as the percent transect catch for each of these transects over the course of the spring migration, with accompanying limnological data and spill condition.

			Percent of transect catch								
Transect	Station	Date	Yearling chinook	Sockeye	Steelhead	Subyearling chinook	H_2O clarity[a]	H_2O velocity $(C.S^{-1})$	Temp. (°C)	Spill (KCFS)	Percent spill
Upper	1	5/10/84	31	33	25	*	94	*	10.0	0.0	0.0
	2	5/10/84	48	20	61	*	100	*	10.0	0.0	0.0
	3	5/10/84	21	47	14	*	79	*	10.0	0.0	0.0
	1	5/11/84	27	30	19	*	91	*	10.0	8.5	2.6
	2	5/11/84	65	65	59	*	100	*	10.0	0.0	0.0
	3	5/11/84	8	5	22	*	85	*	10.0	0.0	0.0
	1	5/17/84	18	40	15	*	78	*	12.0	36.4	11.3
	2	5/17/84	48	22	30	*	89	*	13.0	36.4	10.5
	3	5/17/84	35	38	56	*	76	*	12.5	50.7	13.3
	1	5/22/84	41	58	32	*	100	*	12.5	3.2	1.0
	2	5/22/84	52	29	42	*	92	*	13.0	3.2	0.9
	3	5/22/84	7	13	26	*	98	*	13.0	3.2	1.0
	1	5/24/84	*	*	*	*	97	*	*	*	*
	2	5/24/84	*	*	*	*	97	*	*	*	*
	3	5/24/84	*	*	*	*	91	*	*	*	*
	1	5/29/84	3	6	6	73	97	*	14.0	3.2	1.1
	2	5/29/84	59	28	94	5	100	*	14.0	3.2	1.1
	3	5/29/84	38	67	0	23	97	*	14.0	3.2	1.0
	1	6/01/84	13	24	10	27	97	*	14.0	3.2	1.1
	2	6/01/84	69	64	62	69	100	*	15.0	3.2	1.1
	3	6/01/84	18	12	29	8	75	*	14.0	3.2	1.1
	1	6/06/84	33	43	24	71	100	*	14.5	38.0	10.9
	2	6/06/84	45	30	30	19	94	*	14.5	38.0	10.9
	3	6/06/84	21	27	46	10	72	*	14.5	38.0	10.7
Middle	1	5/11/84	19	20	30	*	98	0	10.5	0.0	0.0
	2	5/11/84	77	39	41	*	94	1	11.0	0.0	0.0
	3	5/11/84	4	41	29	*	47	6	13.5	0.0	0.0
	1	5/17/84	31	26	22	*	98	4	12.0	31.1	8.5
	2	5/17/84	65	61	67	*	100	1	13.0	7.0	2.1
	3	5/17/84	4	13	10	*	45	0	12.5	3.9	1.2

Appendix Table A2.--(cont.)

Transect	Station	Date	Percent of transect catch: Yearling chinook	Sockeye	Steelhead	Subyearling chinook	H_2O clarity[a/]	H_2O velocity $(C.S^{-1})$	Temp. (°C)	Spill (KCFS)	Percent spill
Middle	1	5/18/84	40	51	45	*	100	5	12.0	3.2	1.0
	2	5/18/84	59	48	45	*	89	6	13.0	3.2	1.0
	3	5/18/84	1	2	10	*	28	1	12.0	5.5	1.7
	1	5/22/84	65	95	19	*	98	8	12.5	3.2	0.9
	2	5/22/84	31	3	64	*	98	8	12.5	3.2	0.9
	3	5/22/84	4	2	17	*	62	13	12.5	170.5	46.0
	1	5/24/84	50	87	41	*	100	6	12.5	3.2	0.9
	2	5/24/84	43	10	45	*	97	10	12.0	3.2	0.9
	3	5/24/84	6	3	4	*	60	13	12.5	174.2	39.4
	1	5/25/84	38	78	41	*	98	3	12.0	3.2	0.9
	2	5/25/84	56	21	53	*	100	2	12.0	3.2	1.0
	3	5/25/84	5	1	6	*	63	15	12.0	163.5	37.8
	1	5/29/84	33	93	25	*	97	6	13.5	180.5	47.5
	2	5/29/84	62	0	59	*	94	14	14.5	172.5	46.0
	3	5/29/84	5	7	16	*	58	11	15.7	7.0	2.4
	1	6/01/84	19	69	49	49	60	8	15.5	180.5	51.2
	2	6/01/84	71	31	46	44	54	8	14.5	180.5	51.3
	3	6/01/84	10	0	6	6	48	9	15.0	10.0	3.4
	1	6/05/84	33	52	19	64	97	10	12.5	86.0	23.5
	2	6/05/84	50	36	44	32	80	13	14.5	173.3	46.0
	3	6/05/84	17	12	37	4	46	8	15.0	180.5	49.4
	1	6/06/84	39	21	21	69	100	9	13.5	51.5	14.4
	2	6/06/84	57	64	43	20	91	10	14.5	177.6	49.8
	3	6/06/84	4	14	36	11	60	5	15.0	180.5	60.9
Lower	1	5/09/84	38	22	63	*	*	1	10.0	0.0	0.0
	2	5/09/84	43	47	22	*	97	9	10.0	0.0	0.0
	3	5/09/84	20	31	15	*	90	12	10.0	0.0	0.0
	1	5/09/84	56	47	55	*	100	0	10.0	0.0	0.0
	2	5/09/84	36	16	32	*	86	8	10.0	3.4	0.0
	3	5/09/84	8	37	13	*	86	6	10.0	0.0	1.4
	1	5/18/84	47	30	42	*	83	8	12.0	64.9	17.1
	2	5/18/84	52	66	53	*	85	23	12.0	64.9	19.0
	3	5/18/84	1	5	5	*	40	24	12.0	62.2	18.3

Appendix Table A2.--(cont.)

Transect	Station	Date	Percent of transect catch: Yearling chinook	Sockeye	Steelhead	Subyearling chinook	H_2O clarity[a/]	H_2O velocity ($C.S^{-1}$)	Temp. (°C)	Spill (KCFS)	Percent spill
Lower	1	5/25/84	20	41	7	*	100	2	12.0	3.2	1.0
	2	5/25/84	79	56	85	*	100	18	12.5	3.2	1.0
	3	5/25/84	1	3	7	*	59	22	12.5	3.2	1.0
	1	5/31/84	25	33	38	71	100	12	13.5	180.5	40.6
	2	5/31/84	50	67	46	0	86	12	13.5	10.1	3.2
	3	5/31/84	25	0	16	29	54	33	14.0	180.5	40.7
	1	5/31/84	29	100	40	84	97	8	13.5	3.2	1.1
	2	5/31/84	64	0	50	0	84	14	13.5	3.2	1.0
	3	5/31/84	7	0	10	16	49	17	14.0	3.2	1.1
	1	6/05/84	71	100	30	67	100	9	13.5	68.1	18.9
	2	6/05/84	29	0	48	10	63	19	13.5	68.6	19.0
	3	6/05/84	0	0	22	23	48	19	14.0	72.8	20.1

a/ Expressed as percentage of daily maximum secchi disk reading.
* = No fish of the indicated species were present.

Appendix Table A3.--1983 purse seine catches expressed as the percent transect catch for each of the three transects (upper, middle, lower) over the course of the spring migration, with accompanying limnological data and spill condition.

			Percent of transect catch								
Transect	Station	Date	Yearling chinook	Sockeye	Steelhead	Subyearling chinook	H_2O clarity[a]	H_2O velocity ($C.S^{-1}$)	Temp. (°C)	Spill (KCFS)	Percent spill
Lower	1	4/20/83	41.0	*	31	*	*	*	10.0	85.4	39.8
	2	4/20/83	5.0	*	23	*	*	*	10.0	55.4	25.7
	3	4/20/83	55.0	*	46	*	*	*	10.0	58.1	28.0
Middle	1	4/26/83	47.0	53.0	52	*	100	15	11.0	200.0	56.8
	2	4/26/83	53.0	47.0	41	*	74	9	*	179.0	50.9
	3	4/26/83	0.6	0.0	7	*	39	*	12.0	184.0	58.5
Lower	1	4/26/83	74.0	100.0	21	*	83	17	*	178.0	51.1
	2	4/26/83	23.0	0.0	36	*	65	27	*	201.0	36.8
	3	4/26/83	3.0	0.0	43	*	48	16	*	219.0	62.4
Middle	1	4/27/83	22.0	14.0	29	*	100	19	12.0	187.0	53.6
	2	4/27/83	77.0	86.0	70	*	72	21	*	210.0	60.7
	3	4/27/83	1.0	0.0	1	*	40	*	13.0	214.0	62.0
Middle	1	4/28/83	69.0	38.0	46	*	93	2	12.0	152.0	49.9
	2	4/28/83	27.0	62.0	33	*	83	7	*	152.0	49.6
	3	4/28/83	4.0	0.0	21	*	67	*	14.0	152.0	50.0
Lower	1	4/28/83	69.0	63.0	32	*	100	14	*	179.0	49.7
	2	4/28/83	16.0	13.0	28	*	65	22	*	179.0	49.7
	3	4/28/83	16.0	25.0	40	*	70	19	*	179.0	49.5
Middle	1	5/02/83	43.0	41.0	42	*	100	8	13.0	120.0	36.7
	2	5/02/83	55.0	59.0	54	*	88	8	*	120.0	36.6
	3	5/02/83	2.0	0.0	5	*	43	*	14.0	120.0	39.9
Middle	1	5/03/83	54.0	62.0	51	*	100	9	13.0	117.0	39.8
	2	5/03/83	46.0	38.0	41	*	68	7	*	117.0	39.6
	3	5/03/83	0.6	0.0	8	*	45	*	14.0	120.0	44.2
Lower	1	5/03/83	53.0	81.0	9	*	89	9	*	123.0	42.6
	2	5/03/83	32.0	8.0	46	*	63	13	*	120.0	41.6
	3	5/03/83	15.0	11.0	45	*	55	14	*	120.0	40.6
Middle	1	5/04/83	84.0	89.0	25	*	100	25	13.0	120.0	34.8
	2	5/04/83	15.0	8.0	66	*	48	7	*	120.0	37.4
	3	5/04/83	1.0	3.0	9	*	43	10	*	120.0	39.0
Middle	1	5/19/83	40.0	38.0	23	*	82	6	15.0	2.0	0.9
	2	5/19/83	57.0	62.0	70	*	71	5	*	3.0	1.1
	3	5/19/83	3.0	0.0	7	*	51	8	16.0	3.0	1.1

Appendix Table A3.--(cont.)

Transect	Station	Date	Percent of transect catch								
			Yearling chinook	Sockeye	Steelhead	Subyearling chinook	H_2O clarity[a]	H_2O velocity $(C.S^{-1})$	Temp. (°C)	Spill (KCFS)	Percent spill
Lower	1	5/19/83	39.0	82.0	36	*	100	11	*	9.0	3.3
	2	5/19/83	42.0	11.0	50	*	95	18	*	3.0	1.1
	3	5/19/83	19.0	7.0	14	*	70	14	*	3.0	1.2
Middle	1	5/24/83	96.0	96.0	92	*	74	12	*	120.0	35.7
	2	5/24/83	4.0	4.0	6	*	60	11	*	120.0	36.0
	3	5/24/83	0.0	0.3	2	*	46	13	17.0	120.0	37.3
Lower	1	5/24/83	52.0	82.0	48	*	100	7	16.0	120.0	45.1
	2	5/24/83	39.0	12.0	29	*	78	16	*	120.0	44.9
	3	5/24/83	10.0	6.0	23	*	68	15	16.0	120.0	44.9
Middle	1	5/26/83	89.0	94.0	59	*	100	7	16.0	120.0	34.9
	2	5/26/83	11.0	6.0	23	*	44	8	17.0	120.0	33.0
	3	5/26/83	0.0	0.5	17	*	38	15	18.0	142.0	37.9
Lower	1	5/26/83	68.0	90.0	48	*	79	15	16.0	196.0	50.7
	2	5/26/83	21.0	7.0	19	*	54	18	*	199.0	51.4
	3	5/26/83	11.0	3.0	33	*	51	20	16.5	199.0	51.3
Middle	1	6/30/83	*	*	*	53	97	4	*	0.0	0.0
	2	6/30/83	*	*	*	10	93	1	*	0.0	0.0
	3	6/30/83	*	*	*	37	76	*	*	0.0	0.0
Lower	1	6/30/83	*	*	*	63	100	*	*	0.0	0.0
	2	6/30/83	*	*	*	20	100	*	*	0.0	0.0
	3	6/30/83	*	*	*	17	91	*	*	0.0	0.0
Lower	1	7/07/83	*	*	*	73	97	*	*	120.3	50.2
	2	7/07/83	*	*	*	19	100	*	*	96.1	36.9
	3	7/07/83	*	*	*	8	97	*	*	4.1	1.8
Lower	1	7/21/83	*	*	*	40	100	6	*	103.4	43.6
	2	7/21/83	*	*	*	25	97	12	*	110.3	45.2
	3	7/21/83	*	*	*	35	96	13	*	150.4	60.0
Middle	1	8/04/83	*	*	*	48	100	0	*	0.0	0.0
	2	8/04/83	*	*	*	36	99	0	*	0.0	0.0
	3	8/04/83	*	*	*	17	97	7	*	0.0	0.0
Lower	1	8/04/83	*	*	*	19	98	3	*	5.0	2.5
	2	8/04/83	*	*	*	9	100	5	*	0.6	0.3
	3	8/04/83	*	*	*	72	100	8	*	0.0	0.0
Middle	1	8/18/83	*	*	*	10	99	1	*	0.0	0.0
	2	8/18/83	*	*	*	28	97	5	*	0.0	0.0
	3	8/18/83	*	*	*	62	91	8	*	0.0	0.0

Appendix Table A3.--(cont.)

Transect	Station	Date	Percent of transect catch: Yearling chinook	Sockeye	Steelhead	Subyearling chinook	H_2O clarity[a]	H_2O velocity ($C.S^{-1}$)	Temp. (°C)	Spill (KCFS)	Percent spill
Lower	1	8/18/83	*	*	*	55	99	6	*	0.0	0.0
	2	8/18/83	*	*	*	29	100	12	*	0.0	0.0
	3	8/18/83	*	*	*	16	96	13	*	0.0	0.0
Middle	1	9/01/83	*	*	*	75	100	9	*	0.0	0.0
	2	9/01/83	*	*	*	15	97	6	*	0.0	0.0
	3	9/01/83	*	*	*	10	90	11	*	0.0	0.0
Lower	1	9/01/83	*	*	*	62	97	5	*	0.0	0.0
	2	9/01/83	*	*	*	29	97	7	*	0.0	0.0
	3	9/01/83	*	*	*	9	95	7	*	0.0	0.0
Lower	1	9/15/83	*	*	*	60	100	2	*	0.0	0.0
	2	9/15/83	*	*	*	25	99	0	*	0.0	0.0
	3	9/15/83	*	*	*	15	98	1	*	0.0	0.0
Middle	1	9/20/83	*	*	*	48	99	3	*	0.0	0.0
	2	9/20/83	*	*	*	4	100	0	*	0.0	0.0
	3	9/20/83	*	*	*	48	95	18	*	0.0	0.0
Lower	1	9/20/83	*	*	*	57	98	4	*	0.0	0.0
	2	9/20/83	*	*	*	2	99	0	*	0.0	0.0
	3	9/20/83	*	*	*	41	97	5	*	0.0	0.0

[a] Expressed as percentage of daily maximum secchi disk reading.
* = No fish of the species indicated were present.

Appendix Table A4.--Radio tag data, 1984.

Tag	Fish	Release		Dam arrival			% Spill		Passage		
Code	Length	Month/Day	Time	Month/Day	Time	Site*	Arrival	Passage	Month/Day	Time	Site[a]
136	161	5/1	850	5/1	1930	2	19	19	5/1	1930	2
256	162	5/1	850	5/1	1510	1	0	0	5/3	1005	1
336	160	5/1	850	5/1	1446	2	0	21	5/1	2038	1
356	173	5/1	850	5/1	1620	2	0	0	5/1	1716	1
455	165	5/1	850	5/1	2008	1	21	21	5/1	2036	1
555	149	5/1	850	5/1	2033	1	21	38	5/1	2319	1
635	165	5/1	850	5/1	1917	2	19	19	5/1	1929	2
656	168	5/1	850	5/1	1344	1	0	0	5/1	1403	1
767	167	5/1	850	5/1	1339	1	0	19	5/1	1930	2
833	185	5/1	850	5/1	2105	1	23	23	5/1	2109	1
864	168	5/1	850	5/1	1818	1	0	19	5/1	1931	2
246	170	5/1	1339	5/2	2107	1	21	21	5/2	2113	1
344	179	5/1	1339	5/1	2130	1	23	23	5/1	2150	1
365	167	5/1	1339	5/1	1948	1	19	19	5/1	1948	1
445	165	5/1	1339	5/1	1758	2	0	21	5/1	2030	1
544	165	5/1	1339	5/1	1617	1	0	23	5/1	2128	1
665	160	5/1	1339	5/2	0028	1	31	38	5/2	0100	1
945	169	5/1	1339	5/1	2133	1	23	23	5/1	2142	1
436	180	5/1	1339	5/1	2122	2	23	23	5/1	2146	2
167	172	5/10	851	5/10	1425	1	0	42	5/10	2055	1
144	158	5/10	851	5/10	1523	1	0	0	5/10	1547	1
278	165	5/10	851	5/10	1344	1	0	0	5/10	1354	1
246	150	5/10	851	5/10	2010	2	42	42	5/10	2010	2
262	159	5/10	851	5/10	2150	2	48	58	5/10	2207	2
373	169	5/10	851	5/10	2002	1	42	48	5/10	2145	1
346	177	5/10	851	5/10	1412	1	0	0	5/12	2007	2
337	149	5/10	851	5/10	1548	1	0	48	5/10	2127	1
446	160	5/10	851	5/10	1527	1	0	48	5/10	2134	2
575	190	5/10	851	5/10	1821	1	0	0	5/10	1834	1
673	167	5/10	851	5/10	1627	1	0	1	5/10	1957	1
741	156	5/10	851	5/10	1717	2	0	42	5/10	2049	2
750	174	5/10	851	5/10	1924	2	0	42	5/10	2008	2
960	157	5/10	851	5/10	1343	1	0	0	5/10	1353	1

[a] 1-powerhouse, 2-spillway

Appendix Table A4.--(cont.)

Tag	Fish	Release		Dam arrival			% Spill		Passage		
Code	Length	Month/Day	Time	Month/Day	Time	Site*	Arrival	Passage	Month/Day	Time	Site[a]
137	192	5/10	1413	5/10	1939	2	0	48	5/10	2139	1
360	177	5/10	1413	5/10	1944	1	0	53	5/10	2307	1
436	172	5/10	1413	5/10	2120	1	48	53	5/11	2333	2
636	192	5/10	1413	5/10	2043	1	42	42	5/10	2055	1
659	160	5/10	1413	5/10	1957	2	0	42	5/10	2018	2
770	154	5/10	1413	5/11	0055	2	46	46	5/11	0055	2
760	165	5/10	1413	5/10	2006	2	42	42	5/10	2043	1
730	175	5/10	1413	5/11	0405	2	40	40	5/11	0408	2
871	159	5/10	1413	5/10	1949	2	0	42	5/10	2032	2
830	173	5/10	1413	5/11	0400	2	40	40	5/11	0410	2
970	170	5/10	1413	5/13	0428	1	49	0	5/13	0440	1
128	182	5/14	836	5/14	2210	2	40	40	5/14	2216	2
152	150	5/14	836	5/14	1526	1	0	0	5/14	1643	1
230	153	5/14	836	5/15	0408	2	47	0	5/15	1111	1
252	160	5/14	836	5/14	1330	1	0	41	5/14	2133	1
332	172	5/14	836	5/14	2303	2	42	42	5/14	2320	2
351	179	5/14	836	5/14	1938	2	0	38	5/14	2045	1
430	165	5/14	836	5/14	1756	1	0	3	5/14	1959	2
451	182	5/14	836	5/14	2251	1	40	42	5/14	2343	2
531	181	5/14	836	5/14	1429	1	0	0	5/14	1647	1
550	173	5/14	836	5/14	2140	2	41	41	5/14	2140	2
628	186	5/14	836	5/14	1925	2	0	3	5/14	1948	2
651	155	5/14	836	5/14	1608	1	0	41	5/14	2114	1
746	173	5/14	836	5/14	1424	2	0	38	5/14	2052	2
272	152	5/14	1405	5/14	1856	1	0	38	5/14	2033	2
340	175	5/14	1405	5/14	2115	2	41	41	5/14	2117	2
371	150	5/14	1405	5/14	1922	1	0	41	5/14	2108	1
440	172	5/14	1405	5/14	2026	2	38	38	5/14	2026	2
736	162	5/14	1405	5/14	1933	1	0	38	5/14	2056	2
758	180	5/14	1405	5/14	2002	2	38	41	5/14	2107	2
834	180	5/14	1405	5/14	2109	2	41	41	5/14	2113	2
864	169	5/14	1405	5/14	2229	2	40	40	5/14	2230	2
935	180	5/14	1405	5/14	2045	1	38	41	5/14	2100	1
971	157	5/14	1405	5/14	2144	2	41	41	5/14	2144	2

[a] 1-powerhouse, 2-spillway

Appendix Table A4.--cont.)

Tag	Fish	Release		Dam arrival			% Spill		Passage		
Code	Length	Month/Day	Time	Month/Day	Time	Site[a]	Arrival	Passage	Month/Day	Time	Site[a]
131	164	5/25	1405	5/25	1911	1	41	41	5/25	1920	1
145	182	5/25	1405	5/25	1944	2	41	41	5/25	1958	2
257	192	5/25	1405	5/25	1919	2	41	41	5/25	1919	2
661	187	5/25	1405	5/25	2028	2	41	41	5/25	2050	2
735	152	5/25	1405	5/25	2005	2	41	41	5/25	2008	2
856	152	5/25	1405	5/25	1843	1	39	41	5/25	2051	1
928	172	5/25	1405	5/25	1902	2	41	41	5/25	1905	2
963	166	5/25	1405	5/25	2054	1	41	41	5/25	2054	1

[a] 1-powerhouse, 2-spillway

APPENDIX B

SUMMARY OF EXPENDITURES

SUMMARY OF EXPENDITURES

Category	Amount
Personnel	108.8
Travel	4.6
Vehicles	4.1
Rent, Communications, SLUC, and Utilities	4.8
Printing	0.0
Contract Services	3.7
Supplies and Materials	28.1
Capital Equipment	0.8
Support	46.7
TOTAL	201.6

Nonexpendable items $1,000.00:

Item	Amount

Sensitive items:

Item	Amount
Turbidimeter	0.8