RADIO TRACKING STUDIES OF SPRING CHINOOK SALMON AND STEELHEAD TROUT TO DETERMINE SPECIFIC AREAS OF LOSS BETWEEN BONNEVILLE AND JOHN DAY DAMS, 1977

by

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INTRODUCTION

Significant losses of adult salmonids between dams on the lower Columbia River have been occurring for several years (Junge and Carnegie 1976). In 1975, for example, only 50% of the 104,104 spring chinook salmon counted over Bonneville Dam were subsequently counted over The Dalles Dam and only 78% of those counted over The Dalles Dam were later counted over John Day Dam. The same year 85,400 adult steelhead trout were counted over Bonneville Dam and only 67% of these fish were counted over The Dalles Dam. Of those counted over The Dalles Dam, only 57% were counted over John Day Dam. Some of the fish count discrepancies occurring over the years can be explained through estimates of gillnet catches, tributary turnoff, overcount caused by fallback, etc. However, there are unaccountable losses still occurring that are over and above the loss estimates from known causes.

Many factors, singly or in combination, may be responsible for the differences in count, and these make the unaccountable loss problem a difficult one to solve. For example, unreported catch; under estimation of tributary turnoff; inflated counts at dams (Monan and Liscom 1975; Liscom, Monan, and Stuehrenberg 1977) mortality associated with stress in passing a particular dam or dams (Oregon Department of Fish and Wildlife 1975); mortality due to gas bubble disease stress; delay between dams (Monan and Liscom 1973; Monan and Liscom 1975); etc., are all potential contributors to the problem.

The present study was initiated at the request of the Directors of state fishery agencies of the Pacific Northwest at their annual meeting in 1975. Its main purpose was to investigate the unaccountable loss problem in depth with spring chinook salmon, and conduct a pilot study on the subject with steelhead trout. Before actual losses can be determined and ultimately eliminated, reduced, or adjusted to, specific areas of loss must be located. Therefore, the radio tracking study conducted during the spring of 1977 had the following objectives: (1) determine specific areas of the Columbia River between Bonneville and John Day Dams within which losses of adult spring chinook salmon occur; (2) monitor major tributaries within the study area to update tributary turnoff estimates for spring chinook salmon; (3) determine the feasibility of radio-tracking steelhead trout in anticipation of a longer in-depth study in subsequent years; and (4) develop means to reduce program costs.

EXPERIMENTAL SITE AND EQUIPMENT

The study area encompassed the Columbia River from Bonneville Dam to John Day Dam, a distance of about 71 river miles (Figure 1). Bonneville Dam, the first dam to be encountered by upstream migrating salmonids, is about 145 miles from the Pacific Ocean. Upstream from Bonneville Dam, approximately 47 miles, is The Dalles Dam, and 24 miles farther upstream is John Day Dam.

Radio tracking check points locations from Bonneville Dam to John Day Dam for unaccoutable loss study, spring, 1977.

CHECK STATION	LOCATION	
1	COOK	R. MILE 161
2	MEMALOOSE IS.	R. MILE 177
3	THE DALLES DAM	R. MILE 192
4	BIGGS	R. MILE 209
5	JOHN DAY DAM	R. MILE 216

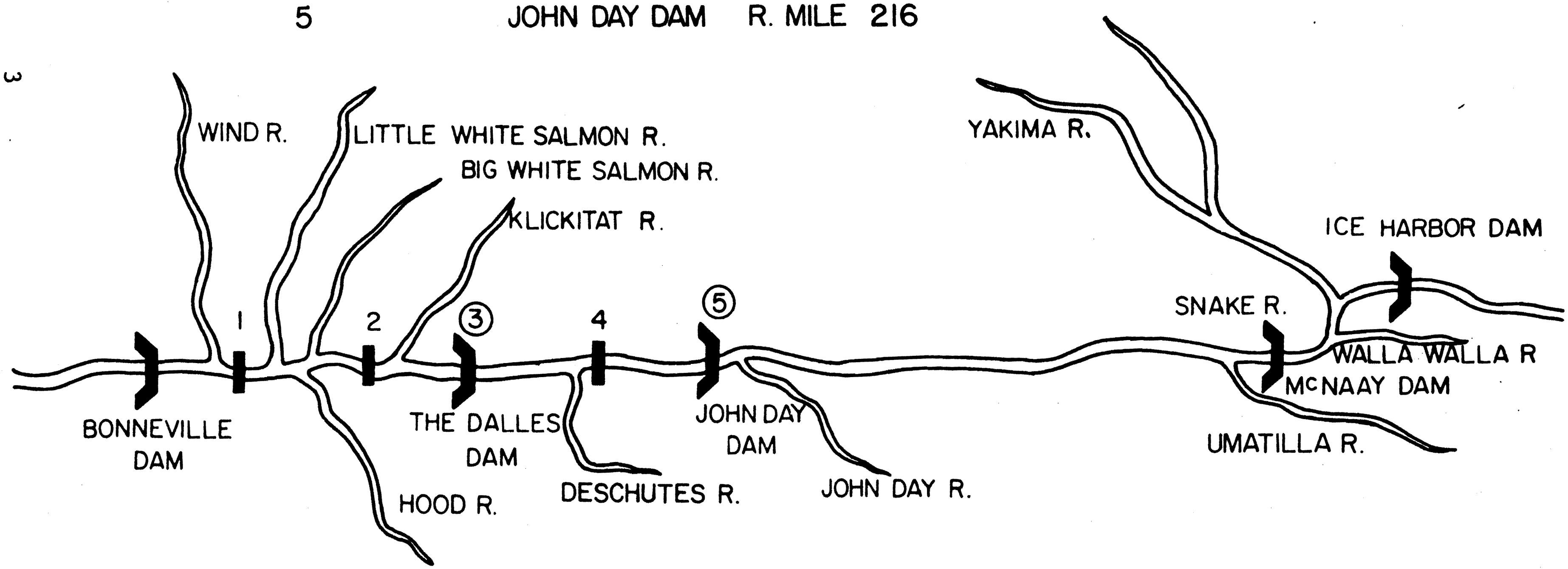

Figure 1.--Diagrammatic sketch of the radio tracking study area showing tributaries and river section boundaries.

The pool behind Bonneville Dam "absorbs" a number of fish before they reach The Dalles Dam through an intensive gillnet fishery, a sports fishery, and five important tributaries: (1) Wind River, (2) Little White Salmon River, (3) White Salmon River, (4) Hood River, and (5) Klickitat River.

Between The Dalles and John Day Dams there also exists an extensive gillnet fishery, a sports fishery, and one important tributary (The Deschutes River).

To localize problem zones, we divided the study area into five sections (Figure 1): (1) Bonneville Dam (river mile 145) to river mile 161; (2) river mile 161 to 177; (3) river mile 177 to The Dalles Dam (river mile 192); (4) The Dalles Dam to river mile 209; and (5) river mile 209 to John Day Dam (river mile 216).

RADIO TAG

The conventional radio tag is a small battery powered radio transmitter operating 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 extending from the tag into the fish's mouth. The pulse rate and duration are adjusted to obtain a tag life of about 60 days. There are nine frequencies we can use (30.17, 30.18, 30.19, 30.20, 30.21, 30.22, 30.23, 30.24, and 30.25 MHz) for identifiable codes. For this study, the tags were made to pulse at two separate rates, a slow rate (1 pulse per 1.5 seconds) and a fast rate (1 pulse per second), enabling us to release 18 separately identifiable codes into the river at one time.

TRACKING RECEIVERS

Tracking receivers were of two types: (1) a search receiver and (2) a receiver for finding fish location. Both units were carried in each vehicle used for tag surveillance.

The search receiver was in operation as the vehicle traveled along the road, constantly searching for radio tag signals. When the vehicle approached the vicinity of a tag, the signal received by the antenna was amplified and converted to an audible tone while at the same time a flashing light indicated which frequency was being received. The operator then switched to the direction finder-receiver to locate the position of the fish.

Once the direction finder-receiver was in operation (which also amplified the tag signal and produced an audible tone), the operator could listen to any one of the nine frequencies at any time, locate the position of any fish in the vicinity, and record it. An improved receiver was used in this study. This receiver is capable of filtering out more extraneous noise than other equipment we have used and it has better fine tuning for more precise direction finding.

MONITORS

Monitors were employed in three different situations: (1) at the border of each study section, (2) at fishway exits, and (3) at the counting stations.

The monitors in the main stem Columbia River recorded tagged fish movement at each check point or monitor station. The monitors consisted of an upstream and downstream antenna, a search receiver, a microprocessor, and a printer. The two antennas allowed for the detection of upstream-downstream directional information, while the search receiver separated the tag signals into the correct frequency channels. The microprocessor controlled the sampling period, stored the data, and controlled the printout of that data. Monitor operation began with the microprocessor sequentially checking each of the nine frequencies. Each frequency channel is sampled for a period of 9 seconds--4.5 seconds on a downstream antenna and 4.5 seconds on an upstream antenna. During the 4.5 second sample period per antenna pulses, are counted, and the count determines the pulse rate or combinations of pulse rates present during the sampling period; for example, one slow tag = 2 counts, one fast tag = 3 counts, one fast and one slow tag = 5 counts, etc. After each antenna is checked, the count number received is stored in the microprocessor memory until all nine frequencies are checked. The data are then checked with the previous scan and any change in count number (meaning a change in fish status) is printed by a digital printer. A fish may remain in one spot for hours, but the unit only prints when the fish moves in or out of range of an antenna. Information printed is: month, day, hour, minute, channel number, pulse rate number, site location, and antenna.

River section monitors were powered by two wet-cell car batteries. At remote sites the batteries were changed daily. If A.C. power was available, the batteries were kept charged by trickle chargers, eliminating the need for battery changes.

Fishway exit monitors were modified telemetry units used in previous radio tracking studies. These monitors were modified to print, on chart recorders, the pulse rate and frequency of each radio tagged fish exiting the fishway. Passage time was determined from time marks on the tape. This was especially important information because for 16 hours of each day, no tracking personnel were on duty to record the information. When no tags were in the area, the tape advanced only when a time mark was imprinted--every 6 minutes. When a tagged fish swam into the vicinity of a monitor, the signal triggered the monitoring unit which began operation and marked each pulse and time mark on the tape until the fish went out of receiving range. Tapes were read each morning before tracking crews began their surveillance to indicate which codes, if any, had crossed any particular dam during the absence of the trackers. Pulse rate was determined by noting the distance between pulse marks,and each frequency appeared on a different line on the chart.

Counting station monitors were simple alert receivers which were battery powered and were placed in the counting house with an antenna located in the fishway pool just below the counting window or board. When a radio tagged fish came within range of the antenna an audible "beep" was heard by the counter, alerting that person to a radio tagged fish about to pass.

ANTENNAS

Four types of antennas were used to pick up tag signals for the various receiving equipment: (1) whips, (2) vertically polarized beams, (3) underwater dipole-types, and (4) directional loops.

Whip antennas, similar to those used for CB communication equipment, were used with the search receivers where direction was not critical. On the mobile unit directional tracking receivers, 18" loop antennas were used. Mobile unit antennas attached to vehicles could be rotated to find the location of a tagged fish.

Vertically polarized, three-element beam antennas tuned for maximum forward gain at 30.21 MHz were used with the monitors on the main river study sections. Two antennas were used at each monitor site and were mounted on 24-foot steel towers approximately 150 feet apart and parallel to the river. One antenna was beamed 45^{o} downstream and one 45^{o} upstream.

Fishway exit monitors and the counting station alert receivers received radio tag signals from an underwater dipole-type antenna. These antennas were resonant underwater at 30.21 MHz and had much less range than the other antennas used.

GENERAL EXPERIMENTAL PLAN

The general experimental plan was to tag and track as many spring chinook salmon and steelhead trout as possible from April 17 through June 10. While chinook salmon studies were the prime objective, steelhead trout would comprise approximately 25% of the total number of fish tagged as a pilot study for that species. The fish would be tagged at and released below Bonneville Dam. Electronic surveillance was to be the principal method of monitoring the progress of radio tagged fish as they swam through the study area. Manned mobile tracking units would follow fish at the dams, within the prescribed river sections, and into the tributaries. Unmanned monitors located at the boundary of each study section (Figure 1) would indicate passage through those areas and localize any fish losses that might be indicated.

EXPERIMENTAL PROCEDURES

TRAPPING AND TAGGING

Chinook salmon and steelhead trout used for tagging were diverted from the fishway on the north side of the Bonneville Dam spillway into a trapping facility in the Fisheries-Engineering Research Laboratory. Fish to be tagged ascended a twenty-foot long Denil type fishway to a short holding area. From the holding area, they swam over a false weir and down a slide into a tank of water containing anesthetic (MS-222). No discrimination was made between injured or uninjured fish, but those under 660 mm in length were not tagged.

Individual anesthetized fish were placed into a tagging rack belly up and the lower jaw raised to fully open the mouth. The tagger then took the radio tag from an antiseptic solution of zephiran chloride, dipped the posterior end (that portion opposite the antenna) in glycerin, and inserted the tag through the esophagus into the stomach of the fish.

The short antenna lead attached to the anterior end of the tag extended from the esophagus to the roof of the mouth where it was attached with a plastic anchor. The main purpose of the anchor was to prevent the fish from swallowing the antenna. The fish was then turned over, and a color coded spaghetti flag tag was attached near the base of the dorsal fin.

After tagging, fish were placed in a fish hauling truck, driven to the point of release, and released directly into the Columbia River. Our first releases were made at Dodson, Oregon approximately 4 miles below the dam. Most releases, however, were made at Skamania Landing about 6 miles downriver on the Washington side. The release site at Hamilton Slough (on the Washington side of the river about 0.9 of a mile downstream from the powerhouse) was used when the river flow was so low fish could not be released safely at Skamania Landing or Dodson.

A total of 92 chinook salmon and 42 steelhead trout were tagged and released below Bonneville Dam, and we attempted to have at least 18 separately identifiable tagged fish in the first 9 miles of the study area at all times. New releases were not made until a fish with a particular code had crossed Bonneville Dam and had progressed upriver about 9 miles (vicinity of Wind River). Data on fish tagged and released are detailed in Table 1.

SURVEILLANCE OF TAGGED FISH

Surveillance of radio tagged fish was done by manned mobile tracking units and unmanned electronic monitoring devices. After radio tagged fish were released into the river, they were monitored only occasionally

Table 1.—Tagging data for chinook salmon and steelhead trout used in the unaccountable loss study between Bonneville and John Day Dams, April 17 to June 3, 1977.

Date released	Location	Flag color	Radio tag code	Fish length cm	Fish weight kg	Fish condition 1/	Species
April 17	Skamania Landing	Blue-orange	F7BS	80	6.5	1	Chinook
April 17	Skamania Landing	Blue-orange	H7AF	71	4.5	1	Chinook
April 17	Skamania Landing	Blue-orange	D7KS	71	5.0	1	Chinook
April 17	Skamania Landing	Blue-orange	D7BF	78	5.7	1	Chinook
April 17	Skamania Landing	Blue-orange	K7MF	83	8.0	1	Chinook
April 17	Skamania Landing	Blue-orange	L7JS	89	8.6	1	Chinook
April 17	Skamania Landing	Blue-orange	I7NF	78	5.4	1	Chinook
April 17	Skamania Landing	Blue-orange	E7AS	72	.4.5	1	Chinook
April 17	Dodson	Blue-orange	I7LS	70	4.2	1	Chinook
April 17	Dodson	Blue-orange	H7IS	72	5.4	2	Chinook
April 17	Dodson	Blue-orange	F7DF	71	4.5	1	Chinook
April 17	Dodson	Blue-orange	G7MS	78	5.9	1	Chinook
April 17	Dodson	Blue-orange	G7KF	67	3.6	1	Chinook
April 17	Dodson	Blue-orange	E7IF	78	5.2	1	Chinook
April 17	Dodson	Blue-orange	J7MS	72	5.0	1	Chinook
April 17	Dodson	Blue-orange	K7LS	71	4.8	1	Chinook
April 17	Dodson	Blue-orange	J7IF	100	15.0	1	Chinook
April 18	Dodson	Blue-orange	L7HF	79	6.1	1	Chinook

1/ Condition code (based on visual examination):

1 = Fish in good to excellent condition.

2 = Fish in fair to bad condition - scars, wounds, dark, etc.

Table 1.--Continued.

Date released	Location	Flag color	Radio tag code	Fish length cm	Fish weight kg	Fish condition	Species
April 20	Skamania Landing	Pink-white	J7GS	74	5.4	1	Chinook
April 20	Skamania Landing	Pink-white	G7GS	72	4.5	1	Chinook
April 20	Skamania Landing	Pink-orange	F7KS	83	7.4	1	Chinook
April 20	Skamania Landing	Orange-green	G7MF	76	5.9	1	Chinook
April 21	Dodson	White-blue	D7BS	71	4.8	1	Chinook
April 21	Dodson	Green-white	E7CS	75	5.7	1	Chinook
April 21	Dodson	Pink-blue	H7CS	72	4.7	1	Chinook
April 21	Dodson	Blue-yellow	E7NF	84	8.2	1	Chinook
April 21	Dodson	Pink-green	F7KF	77	6.5	1	Chinook
April 22	Skamania Landing	Green-blue	K7FS	76	6.1	1	Chinook
April 22	Skamania Landing	Yellow-orange	K7AF	73	5.2	1	Chinook
April 22	Skamania Landing	White-yellow	I7KF	72	4.8	1	Chinook
April 23	Skamania Landing	Yellow-green	L7IS	66	4.2	1	Chinook
April 23	Skamania Landing	Green-white	H7FF	72	5.2	1	Chinook
April 25	Skamania Landing	Pink-white	E7ES	85	7.8	1	Chinook
April 25	Skamania Landing	Pink-orange	G7KS	90	8.6	1	Chinook
April 25	Skamania Landing	Green-white	I7CS	75	5.8	1	Chinook
April 25	Skamania Landing	Pink-blue	J7IS	78	5.9	1	Chinook
April 25	Skamania Landing	Yellow-green	H7MF	89	9.4	1	Chinook
April 26	Skamania Landing	Orange-green	F7FS	72	4.7	1	Chinook
April 26	Skamania Landing	Pink-green	G7DF	66	4.0	1	Chinook
April 26	Skamania Landing	White-yellow	K7NS	73	5.3	1	Chinook
April 27	Skamania Landing	Pink-blue	D7FF	70	4.3	1	Chinook
April 27	Skamania Landing	Blue-yellow	H7ES	77	5.2	1	Chinook
April 27	Skamania Landing	Green-blue	K7NF	69	4.1	2	Chinook

Table 1.—Continued.

Date released	Location	Flag color	Radio tag code	Fish length cm	Fish weight kg	Fish condition	Species
April 27	Skamania Landing	Yellow-orange	L7KS	88	10.2	1	Chinook
April 28	Skamania Landing	Pink-white	I7BF	77	6.1	1	Chinook
April 28	Skamania Landing	Pink-orange	J7HS	70	3.9	1	Steelhead
April 28	Skamania Landing	Green-white	F7LF	76	5.2	2	Chinook
April 28	Skamania Landing	Green-blue	J7FF	75	5.0	1	Chinook
April 29	Skamania Landing	Pink-green	E7AF	75	6.0	1	Chinook
April 29	Skamania Landing	White-blue	H7KS	76	6.2	1	Chinook
April 29	Skamania Landing	Blue-yellow	L7MF	71	5.3	2	Chinook
April 30	Skamania Landing	Orange-green	D7JS	79	6.4	2	Chinook
April 30	Skamania Landing	White-yellow	E7KS	80	7.0	1	Chinook
April 30	Skamania Landing	Green-white	G7BS	72	5.0	1	Chinook
April 30	Skamania Landing	Yellow-orange	K7KS	75	5.0	1	Chinook
April 30	Skamania Landing	Pink-orange	K7HF	67	5.1	1	Chinook
April 30	Skamania Landing	Green-blue	I7MS	71	5.4	2	Chinook
May 2	Skamania Landing	White-blue	F7LS	67	4.7	1	Chinook
May 2	Skamania Landing	Pink-white	G7LF	70	4.4	1	Chinook
May 2	Skamania Landing	Pink-green	H7JF	72	5.9	1	Chinook
May 3	Skamania Landing	Pink-blue	G7CS	68	3.8	1	Steelhead
May 3	Skamania Landing	Yellow-orange	H7NS	66	3.2	1	Steelhead
May 4	Skamania Landing	White-blue	E7GF	82	7.0	1	Chinook
May 4	Skamania Landing	Blue-yellow	I7IF	68	4.4	1	Chinook
May 4	Skamania Landing	Green-white	L7ZS	68	3.6	1	Steelhead
May 5	Skamania Landing	Yellow-green	D7KF	75	6.0	1	Chinook
May 6	Skamania Landing	Pink-white	F7GS	76	6.1	2	Chinook
May 6	Skamania Landing	Pink-green	J7JS	67	3.9	2	Chinook
May 7	Skamania Landing	White-blue	F7EF	74	5.7	1	Chinook

Table 1.—Continued.

Date released	Location	Flag color	Radio tag code	Fish length cm	Fish weight kg	Fish condition	Species
May 7	Skamania Landing	Green-white	G7AF	80	6.1	1	Chinook
May 7	Skamania Landing	Blue-yellow	H7GF	71	3.9	1	Steelhead
May 7	Skamania Landing	Yellow-orange	I7JS	71	3.6	1	Steelhead
May 8	Skamania Landing	Pink-orange	D7CS	75	4.8	2	Steelhead
May 8	Skamania Landing	Orange-green	E7BF	67	3.4	1	Steelhead
May 8	Skamania Landing	Green-blue	I7DF	75	5.4	2	Chinook
May 8	Skamania Landing	Pink-white	L7NS	80	5.3	1	Steelhead
May 9	Hamilton Slough	Pink-orange	H7GS	89	10.0	1	Chinook
May 9	Hamilton Slouth	Green-white	K7HS	72	5.0	2	Chinook
May 9	Hamilton Slough	White-yellow	K7FF	75	4.7	1	Steelhead
May 9	Hamilton Slouth	Yellow-green	L7XF	72	5.3	1	Chinook
May 13	Hamilton Slough	Yellow-green	F7CF	63	3.8	2	Chinook
May 13	Hamilton Slough	Green-white	F7AS	72	5.1	1	Chinook
May 13	Hamilton Slough	Pink-green	J7EF	68	4.3	2	Chinook
May 13	Hamilton Slough	White-blue	J7LS	75	5.7	1	Chinook
May 13	Hamilton Slough	Pink-blue	E7NS	72	3.7	1	Steelhead
May 15	Hamilton Slough	Green-white	H7AS	71	5.2	1	Chinook
May 16	Hamilton Slough	Pink-white	D7CF	68	3.6	1	Steelhead
May 16	Hamilton Slough	Pink-orange	E7MF	68	3.6	1	Steelhead
May 16	Hamilton Slough	Orange-green	H7DF	69	3.5	1	Steelhead
May 16	Hamilton Slough	Pink-blue	I7MF	69	3.5	1	Steelhead
May 16	Hamilton Slough	Blue-yellow	K7CS	69	3.8	1	Steelhead
May 16	Hamilton Slough	Green-blue	L7YF	68	3.4	1	Steelhead

Table 1.--Continued.

Date released	Location	Flag color	Radio tag code	Fish length cm	Fish weight kg	Fish condition	Species
May 17	Hamilton Slough	White-blue	G7FF	74	4.4	1	Steelhead
May 17	Hamilton Slough	Yellow-green	G7ES	69	3.6	1	Steelhead
May 17	Hamilton Slough	Pink-green	I7ES	66	3.2	1	Steelhead
May 17	Hamilton Slough	Green-blue	L7CS	76	6.1	1	Chinook
May 18	Skamania Landing	Orange-green	H7JS	77	6.4	1	Chinook
May 19	Skamania Landing	Green-white	J7FS	71	5.1	1	Chinook
May 19	Skamania Landing	Pink-green	L7MS	77	7.0	1	Chinook
May 20	Skamania Landing	White-blue	J7CF	68	3.7	1	Chinook
May 21	Skamania Landing	Pink-blue	F7ES	79	5.1	1	Steelhead
May 21	Skamania Landing	White-blue	I7AS	72	4.8	1	Chinook
May 22	Skamania Landing	Orange-green	I7FF	68	3.2	1	Steelhead
May 22	Skamania Landing	Pink-green	K7ES	69	4.7	1	Chinook
May 23	Skamania Landing	Pink-white	H7HS	71	3.3	1	Steelhead
May 23	Skamania Landing	Pink-orange	G7JF	69	4.0	2	Steelhead
May 23	Skamania Landing	Pink-blue	H7KF	75	4.2	1	Steelhead
May 24	Skamania Landing	White-yellow	L7FS	70	4.2	1	Steelhead
May 24	Skamania Landing	White-blue	E7LS	68	3.6	1	Steelhead
May 24	Skamania Landing	Yellow-orange	J7BF	68	3.6	1	Steelhead
May 24	Skamania Landing	Blue-yellow	J7BS	71	4.1	1	Steelhead
May 25	Skamania Landing	Orange-green	F7HF	72	3.6	1	Steelhead
May 25	Skamania Landing	Pink-blue	K7GS	73	3.8	1	Steelhead
May 27	Skamania Landing	Green-white	D7AF	70	5.0	1	Chinook
May 27	Skamania Landing	Blue-yellow	G7LS	66	4.5	1	Chinook
May 27	Skamania Landing	Green-blue	G7BF	67	3.6	1	Steelhead
May 27	Skamania Landing	Yellow-green	I7FS	78	6.4	1	Chinook
May 29	Skamania Landing	Pink-green	H7MS	68	4.1	1	Chinook

Table 1.—Continued.

Date released	Location	Flag color	Radio tag code	Fish length cm	Fish weight kg	Fish condition	Species
May 29	Skamania Landing	White-blue	H7NF	71	5.2	1	Chinook
May 29	Skamania Landing	Yellow-orange	I7HF	71	3.4	1	Steelhead
May 30	Skamania Landing	Pink-white	D7HS	68	4.1	1	Chinook
May 30	Skamania Landing	Blue-yellow	F7JF	75	4.8	1	Steelhead
May 30	Skamania Landing	Orange-green	K7JF	74	6.1	1	Chinook
May 30	Skamania Landing	Pink-blue	L7DF	67	3.6	1	Steelhead
May 31	Skamania Landing	Pink-orange	K7DS	71	5.1	1	Chinook
May 31	Skamania Landing	Yellow-green	E7DS	72	4.9	1	Steelhead
May 31	Skamania Landing	Pink-green	F7CS	70	4.1	1	Steelhead
June 1	Skamania Landing	Pink-green	G7IS	72	4.1	1	Steelhead
June 1	Skamania Landing	White-blue	L7LS	73	4.5	1	Steelhead
June 2	Skamania Landing	Blue-yellow	I7HS	69	3.4	1	Steelhead
June 2	Skamania Landing	White-yellow	H7DS	75	4.8	1	Steelhead
June 3	Skamania Landing	White-blue	D7EF	71	5.3	1	Chinook
June 3	Skamania Landing	Pink-white	F7NF	71	5.9	1	Steelhead
June 3	Skamania Landing	Green-white	L7KF	71	5.0	1	Chinook

until they reached Bonneville Dam. Once the fish were in the study area, mobile units monitored their whereabouts from 0700 hours to 1600 hours every day.

Behavior of tagged fish was monitored as closely as possible as they approached a dam and while they remained in the immediate vicinity. Special attention was given to fish exiting the Bradford Island fishway at Bonneville Dam to observe their movement near Bradford Island.

It was necessary to assign a specific mobile unit to monitor the five tributaries between Bonneville and The Dalles Dams. The Deschutes River was covered by regular river-mobiles during their surveillance runs between The Dalles and John Day Dams.

Surveillance between dams was done by mobile units which traveled the highways beside the main-stem Columbia River recording day-by-day progress and location of individual fish on maps made up for that purpose. These mobile units worked in a clockwise pattern within their assigned area. One mobile unit began monitoring tags each morning at Bonneville Dam and traveled upriver along the Washington shore until it reached The Dalles Dam. Monitoring was then done from the Oregon side while returning to Bonneville Dam. Each morning a mobile unit also left The Dalles Dam traveling down the Oregon shore to Bonneville Dam and then back to The Dalles Dam on the Washington side. This same procedure was used to monitor the river between The Dalles Dam and John Day Dam. Each mobile unit carried data forms and plotting maps of the section to be surveyed. Personnel recorded the position, time, and date, of each tag located. This record was kept for each round trip regardless of whether a tag had been heard before or not. Both tributary mobiles and mobiles between dams were able to average one and a half round trips per day.

Data collected were turned in at the end of the shift and each mobile driver, in addition to the tracking maps, wrote out a daily summary of the day's findings and activities. Data were relayed on a daily basis to a central location at Bonneville Dam where the position of each fish was plotted on a master chart of the study area. As each fish was tagged, a data punch card was made up and kept current throughout the study.

OBSERVATIONS OF RADIO TAGGED CHINOOK SALMON AND STEELHEAD TROUT

Our chief objective was to observe the disposition and behavior of spring chinook salmon and steelhead trout moving through the study area and to look for events that might be responsible for discernible changes in that behavior which could be contributing to unaccountable losses.

CHINOOK SALMON

Disposition of Tagged Fish Between Dams

Of the 92 chinook salmon released carrying radio tags, 90 crossed over Bonneville Dam. The two fish not ascending the fishways by the end of the study had been released shortly before the last day of tagging and were still between the point of release and the dam. Tagged chinook salmon that ascended Bonneville, The Dalles, and John Day Dams did so proportionally to the untagged chinook salmon (Table 2).

Table 2.--Comparing the proportion of radio tagged to untagged spring chinook salmon using the Washington shore and Oregon shore fishways at Bonneville, The Dalles, and John Day Dams, 1977.1/

Dam	Washington Fishway		Oregon Fishway	
	Tagged	Untagged	Tagged	Untagged
	(%)	(%)	(%)	(%)
Bonneville	10	12	89	88
The Dalles	5	7	95	93
John Day	34	32	66	68

1/ One radio tagged chinook salmon was known to have passed over Bonneville Dam by way of the navigation lock.

Table 3 is a summary of the disposition of radio tagged chinook salmon within the study area. Between Bonneville and The Dalles Dams the gillnet fishery took 14% of the tagged fish, tributary turnoff accounted for 7%, 2% fell back over Bonneville Dam, and 3% were still actively swimming in the mainstem between the dams. The remaining 73% crossed The Dalles Dam. Of the 66 radio tagged chinook salmon that crossed The Dalles Dam, 3% went into the Deschutes River, 3% were taken in gill nets, 2% were still actively swimming in the mainstem between the dams, and 92% crossed John Day Dam.

Travel Time

Radio tagged chinook salmon migration rates were observed to be steady at about 1.0 mph through the unobstructed sections of the Columbia River, but delay was noted in the vicinity of dams -- Bonneville Dam: 48 hours, The Dalles Dam: 15 hours, and John Day Dam: 45 hours. Additional delay at the dams was noted in 11 fish that had incurred severe injuries prior to tagging. The average time spent by injured fish at each dam was as follows: Bonneville Dam: 57 hours, The Dalles Dam: 38 hours, and John Day Dam: 83 hours. While the average travel rate of 0.88 mph between dams for these 11 fish was not significantly slower statistically, there could be a significant effect on the fish, if the slower rate coupled with the increased delay at dams continued as they progressed further upstream.

Table 3.--Disposition of radio tagged spring chinook salmon within the study area, 1977. (Ninety-two fish were tagged and released below Bonneville Dam.)

Fish Location	Number of Fish	
Never crossed Bonneville Dam 1/	2	
Crossed Bonneville Dam	90	
Ascended tributaries:		
Wind River		4
Little White Salmon River		2
Indian Fishery		13
Fallbacks 2/		2
Between Bonneville and The Dalles Dams 1/		3
Crossed The Dalles Dam	66	
Ascended the Deschutes River		2
Indian Fishery		2
Between The Dalles and John Day Dams 1/		1
Crossed John Day Dam	61	

1/ Still active and being tracked when study was terminated.

2/ Neither fish reascended the dam--one went through turbines and was killed, and the other was still active below Bonneville Dam.

Ten of the injured fish crossed John Day Dam. The eleventh injured fish reached John Day Dam where it remained for 18 days. This fish was subsequently captured in a steep pass fishway 40 miles up the Deschutes River.

Overshoot

Every tagged chinook salmon tracked into a tributary swam beyond that tributary by at least 5 miles before returning to enter the tributary. The average "overshoot" was 12 miles and fish took from 6 to 38 days after initially approaching their tributary stream to enter the chosen stream. Some fish were observed entering more than one tributary, but none were observed entering their final stream more than once. One tagged chinook salmon ascended The Dalles Dam fishway to the counting board, descended the fishway, exited, swam downstream, and entered the Wind River 27 days after crossing Bonneville Dam. A second fish spent 38 days off Drano Lake (mouth of the Little White Salmon River) before entering that system to stay.

Behavior of two tagged chinook salmon that crossed Bonneville Dam, swam a considerable distance upstream and then returned to the dam indicated an overshoot of Bonneville Dam. Both fish were fin clipped -- tag code GAF-right pelvic and tag code IAS-adipose. Extensive inquiry produced no clue as to the origin of these two fish. The fish carrying tag code GAF was tagged May 7; crossed the dam May 8; reached river mile 156 (just upstream from the Wind River) on May 9; and returned to Bonneville Dam, just upstream of the powerhouse intake, on May 10. GAF swam about near the powerhouse until June 7 (a period of 28 days). During this time it was visibly observed on one occasion. On June 7, spillgates in bays 4, 5, 15, and 16 were opened at 0845 hours and each was spilling 22,000 cfs. At 0930 hours spill at each gate dropped to about 10,000 cfs. Between 0900 and 1000 hours GAF swam upstream, out of the powerhouse channel, around Bradford Island, and fell back over the spillway through bay 15 or 16. The fish held for some time by the large rock next to Bradford Island before swimming on downstream and remaining there through termination of tracking. The chinook salmon carrying tag code IAS was tagged May 21; crossed Bonneville Dam May 22; reached river mile 177 (Little White Salmon River) on May 23; and was back to the dam, just upstream from the powerhouse, May 24. The signal from IAS abruptly stopped on May 27 and was never heard from again. Because of the fish's location when the signal suddenly stopped, the fish probably fell back through a turbine.

STEELHEAD TROUT

Disposition of Tagged Fish Between Dams

There were 42 steelhead trout tagged and released below Bonneville Dam between April 28 and June 8. Thirty of these fish crossed Bonneville Dam during the duration of the study, and tag returns showed the subsequent passage of five more, giving a total of 35. As with the chinook salmon, passage of radio tagged steelhead trout through the fishways at Bonneville and The Dalles Dams was proportional to untagged fish (Table 4). However, at John Day Dam relative passage through the fishways did not appear to be as proportional with steelhead trout as it was with chinook salmon -- probably because of the small numbers of steelhead trout

Table 4.--Comparing the proportion of radio tagged to untagged steelhead trout using the Washington shore and Oregon shore fishways at Bonneville, The Dalles, and John Day Dams, 1977.

	Washington Fishway		Oregon Fishway	
Dam	Tagged	Untagged	Tagged	Untagged
	(%)	(%)	(%)	(%)
Bonneville	25	28	75	72
The Dalles	22	16	78	84
John Day	47	29	53	71

involved. Of the seven tagged fish remaining below Bonneville Dam, one was caught by a sport fisherman, three had approached the dam at least once but signals were later lost and never heard from again, one was being monitored about 2 miles below Skamania Landing, and two were being monitored in the vicinity of Bonneville Dam at the study's end.

Table 5 shows the disposition of radio tagged steelhead trout within the study area. Between Bonneville and The Dalles Dams, tributaries accounted for 34% of the tagged steelhead trout, while 3% were taken by gill nets, and 3% were still actively swimming in the river. The other 60% crossed The Dalles Dam.

Of the 21 tagged steelhead trout that crossed The Dalles Dam, 5% went into the Deschutes River, 14% were still actively swimming in the mainstem between the dams, and 81% crossed John Day Dam.

Travel Time

Steelhead trout took slightly longer to negotiate the Columbia River between dams than did chinook salmon; not necessarily swimming more slowly, but tending to wander more. The average swimming rate for steelhead trout between Bonneville and John Day Dams was 0.8 mph. This rate excludes time fish spent in the proximity of the dams. Tagged steelhead trout spent, on the average, 59 hours in the vicinity of Bonneville Dam, 19 hours near The Dalles Dam, and 63 hours near John Day Dam.

Only three fish were tagged with severe injuries incurred prior to tagging. One of these fish had been monitored below Bonneville Dam for 27 days when the study ended, but it was caught by a sport fisherman in the Klickitat River on July 21. The other two fish showed no aberrant behavior while being tracked.

Table 5.--Disposition of radio tagged steelhead trout within the study area, 1977. (Forty-two fish were tagged and released below Bonneville Dam.)

Fish Location	Number of Fish	
Never crossed Bonneville Dam 1/	7	
Crossed Bonneville Dam	35	
Ascended tributaries:		
Wind River		3
Hood River		4
Klickitat River		5
Indian fishery		1
Between Bonneville and The Dalles Dams 2/		1
Crossed The Dalles Dam	21	
Ascended the Deschutes River		1
Between The Dalles and John Day Dams 2/		3
Crossed John Day Dam	17	

1/ One caught below by sport fisherman; three actively being tracked when study terminated; and three tracked in area, but went downstream and did not return pior to end of study.

2/ Still active and being tracked when study was terminated.

Overshoot

Steelhead trout also "overshot" the tributary they eventually entered to stay. Ten fish were tracked into tributaries with seven straying beyond their eventual destination and three proceeding directly into the tributary of their choice. The average distance steelhead trout overshot their intended tributary was approximately 15 miles, and it took them from 3 to 23 days to return and enter. In one instance, a fish swam 25 miles beyond the Wind River before returning and ascending that stream. No steelhead trout returned to Bonneville Dam after they left the immediate vicinity.

RECOVERIES OF TAGGED CHINOOK SALMON AND STEELHEAD TROUT

Tags were returned from fish caught at several areas along the Columbia, Snake, and Salmon Rivers. Of the 69 tags returned, 27 (39%) were from fish taken between Bonneville and John Day Dams. Tags returned represented 57% of the chinook salmon and 40% of the steelhead trout tagged. Table 6 gives a summary of tag return data. It is interesting to note that almost all the steelhead trout recoveries above the study area were in the Ringold Springs area above Pasco, Washington.

DISCUSSION

Based upon observations in the past, unaccountable losses of spring chinook salmon appear to be related to river flow: low flow--small loss, high flow--large loss (Monan and Liscom 1973; Junge and Carnegie 1976). Results of this year's study further substantiated this relationship. In 1977, the flows in the Columbia River were very low and the unaccountable loss of adult spring chinook salmon was very small. At Bonneville Dam the

Table 6.--Summary of tag recoveries from radio tagged chinook salmon and steelhead trout, 1977.

Location of recovery	Chinook Salmon	Steelhead trout
	(no.)	(no.)
Indian fishery:		
Between Bonneville Dam and The Dalles Dam	11	--
Klickitat River	--	1
Sport fishery:		
Columbia River below Bonneville Dam	--	1
Wind River	1	2
Hood River	--	1
Klickitat River	--	2
Deschutes River	2	1
Yakima River	1	--
Columbia River at Ringold	--	7
Icicle Creek	1	--
Camas Creek (Middle Fork Salmon River)	1	--
Columbia River at Vantage, WA	--	1
Hatcheries:		
Carson	3	--
Little White	2	--
Ringold	--	1
Rapid River (Idaho)	1	--
Little Goose Dam:		
Adult trap	28	--
Unknown[1/]	1	--
Total	52	17

1/ Returned from an area upstream from the study area, but specific location not known.

average daily total flow during the study period (April 17 through June 10, 1977) was 136,000 cfs and the average daily spill was 6,000 cfs. There was no spill on 34 of the 55 days involved. In contrast, flows during the same period in 1976, which was not an unusual year, averaged 325,000 cfs daily total flow, and 191,000 cfs for daily total spill. The Oregon Department of Fish and Wildlife estimated the unaccountable loss of adult spring chinook salmon between Bonneville and The Dalles Dams for 1977 at 7%; [1/] losses in 1976 were estimated at 22%. With all radio tags that passed Bonneville Dam accounted for during the study, we found an actual loss of only about 2% due to the two chinook salmon that fell back over Bonneville Dam.

To date, there have been no precise methods initiated for indexing tributary turnoff along the lower Columbia River. Numbers of fish returning to a given stream vary from year to year while estimates tend to remain relatively constant. Our objective was to determine if we could use radio tagged fish to obtain an index of tributary turnoff. Based on this year's work, we believe that radio tracking can be used effectively for indexing tributary turnoff for any given year provided the number of fish tagged is sufficient. It appears that the 92 chinook salmon we tagged in 1977 does not represent a large enough sample, but the results show promise. If we look at the number of spring chinook salmon arriving at Little Goose Dam and compare this number with what would be calculated to arrive, based on

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1/ From personal communications.

data from radio tagged fish, we find the totals very similar. The count at Little Goose Dam was 39,555 fish and the calculated number based on the number of radio tagged fish that arrived at Little Goose Dam was 38,970 2/, an error of only 1.5%.

Similar calculations at lower river tributaries (based on hatchery returns) where the numbers of fish involved were much smaller do not work out as well. However, due to recent improvements in our radio tag that make many more codes available, we will be able to tag much larger numbers of fish during any given period in the future. If we were to concentrate on defining tributary turnoff using tags and techniques that are now available, we should be able to provide a reasonable index of tributary turnoff in the future.

All steelhead trout passing over Bonneville Dam were tracked and accounted for throughout the tracking area and no real problems were encountered during the study. This indicates that an extensive steelhead trout study is feasible. There were behavioral differences between chinook salmon and steelhead trout but not enough to require changes in tracking equipment or techniques.

Evidence of tagged chinook salmon and steelhead trout swimming beyond the tributary they eventually ascended, indicates that this behavior could be prevalent among returning salmonids as they seek a stream in which to spawn. This "overshoot" may explain the occurrence of some fallback where fish cross a dam but want to return downstream. This behavior may also

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2/ $\frac{\text{(Bonneville count)}}{\text{(number radio tagged)}} \times \text{(Number of radio tagged fish reaching Little Goose Dam)} = \frac{(119{,}508)(30)}{(92)} = 38{,}970$

explain instances where tagged fish released below Bonneville Dam, or any other dam, apparently do not ascend the dam at all but remain downstream or even leave the area.

With reference to our objective of reducing cost, we found that costs can be reduced by using light aircraft for surveillance along the main stem of the Columbia River. This was substantiated by two test flights during this spring's tracking. Use of aircraft would require fewer personnel and vehicles, thus reducing costs by about 11%. In addition, more area could be covered in less time and more thoroughly. The automatic monitors used this year for the first time proved reliable for recording fish movement. This will enable a study to be conducted with one 8-hour shift instead of two or three. These monitors can also be used to record movement into tributaries which will further reduce the number of people needed.

While part of our overall objective could not be achieved due to low flows and little loss of fish, the knowledge we gained was valuable. Our methods of surveillance enabled us to keep track of every fish within the study area and the methods should provide equally good results during higher river flows. Data were obtained that can be used to compare with information gathered in future studies. Behavioral changes will be more easily detected during a high flow year now that a base line has been established during low flows.

Based on the effectiveness of this year's study, the cost saving innovations developed, and the current availability of tags with a significantly greater number of codes, a definitive study of the problem of unaccountable losses having a high probability of success is practical.

For the best possible results, the study should be planned, funded, and preparations completed, and then put into effect only in a year when forecasts indicate there will be an above average runoff.

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