Ice Harbor Dam spill efficiency determined by radio telemetry, 1997

Fish Ecology Division

Northwest Fisheries Science Center

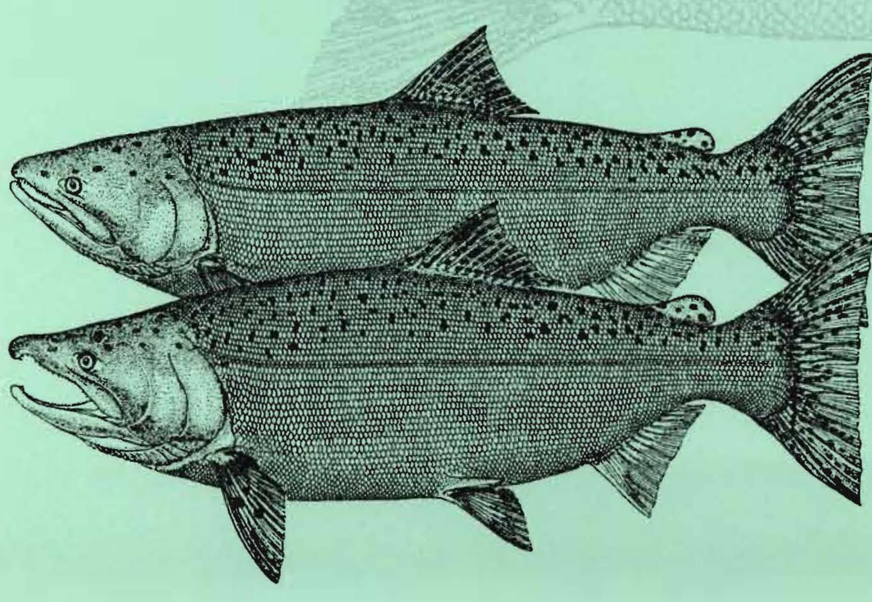
National Marine Fisheries Service

Seattle, Washington

by

M. Brad Eppard, Gordon A. Axel, Benjamin P. Sandford, and Gene M. Matthews

October 1998



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EXECUTIVE SUMMARY

The spill program prescribed by the National Marine Fisheries Service (NMFS) in its Biological Opinion was designed to alleviate migrational delays associated with passage at hydroelectric dams. However, high spill volumes increase total dissolved gas (TDG), often above State and Federal water quality standards deemed "safe" for aquatic organisms. The potential survival benefits for juvenile salmonids from increased spill volumes can be offset by mortality caused by elevated TDG levels.

During summer 1997, radio-telemetry receivers were deployed to monitor the forebay, juvenile bypass system, spillway, fish ladders, navigation lock, and the tailrace of Ice Harbor Dam. Hatchery-reared subyearling fall chinook salmon were collected and radio tagged at Lower Granite Dam, released into the tailrace of Lower Monumental Dam and monitored as they passed Ice Harbor Dam. Radio-tagged fish that entered the study area but were not recorded in the monitored routes of passage and subsequently exited the study area were assumed to have passed the dam through a turbine unit.

Of the 240 radio-tagged fish released, 122 (50.8%) entered the study area at Ice Harbor Dam. Of these, 100 (82.0%) passed via the spillway and 8 (6.6%) passed via the juvenile bypass system. Nine (7.4%) radio-tagged fish were assumed to have passed via a turbine unit and 5 (4.1%) radio-tagged fish entered the study area but were not recorded again.

Daily percent spill during the study (10 July - 13 August) ranged from 39 to 97%, with a median of 69%. Percent spill at the time of passage through the spillway ranged

from 39% to 99%, with a median of 56.4%. Percent spill ranged from 39% to 54%, with a median of 45%, for fish that passed via the bypass system. Spill efficiency, spill effectiveness, and fish passage efficiency were 85.5%, 1.2:1, and 92.3% respectively.

INTRODUCTION

In recent years, spill has been utilized increasingly to expedite the migration of juvenile salmonids past hydroelectric dams and to reduce the proportion of smolts passing through turbines where survival is lower (Iwamoto et al. 1994; Muir et al. 1995, 1996). The spill program prescribed by the National Marine Fisheries Service (NMFS) Biological Opinion was designed to decrease downstream passage delays at hydroelectric dams. The NMFS Biological Opinion dictates a 24-hour continuous spill program at Ice Harbor Dam, beginning 15 April and continuing for the duration of the yearling spring chinook salmon migration. Research on diel passage distributions of yearling chinook salmon at Snake and Columbia River dams has shown that most passage occurs at night and generally peaks at dusk and dawn (Johnson et al. 1990, Martinson et al. 1995). Therefore, the spill program at Ice Harbor Dam may be excessive, resulting in high spill volume with increased TDG, often exceeding State and Federal water quality standards deemed "safe" for aquatic organisms. The potential survival benefits for juvenile salmonids from increased spill volume can be diminished by mortality caused by elevated TDG levels (Cramer 1995, 1996).

Giorgi et al. (1988) reported that spill effectiveness (proportion of fish spilled to the proportion of water spilled) was near 1:1 at Lower Granite Dam for radio-tagged yearling chinook salmon at 20 and 40% spill levels. At other dams the proportions of juvenile salmonids that pass via spillways, turbines, or bypass systems is unknown in relation to various operating conditions.

OBJECTIVES

OBJECTIVE 1: Determine routes of passage for radio-tagged hatchery-reared subyearling chinook salmon under varying operational conditions at Ice Harbor Dam.

Task 1.1 Monitor approach patterns of radio-tagged fish to Ice Harbor Dam.

Task 1.2 Determine passage routes of radio-tagged fish through Ice Harbor Dam.

Task 1.3 Determine travel time to and within the study area for radio-tagged fish.

OBJECTIVE 2: Relate passage distribution of radio-tagged fish to varying levels of spill.

Task 2.1 Determine spill efficiency, spill effectiveness, and fish passage efficiency for radio-tagged fish.

METHODS

Study Area

Ice Harbor Dam, the first dam on the Snake River, is located 15.5 km upstream from the Snake River and Columbia River confluence. The study area included Ice Harbor Dam and the immediate forebay and tailrace about 1 km above and below the dam (Fig. 1). The study was initially planned for the spring out-migration using hatchery-reared yearling chinook salmon. However, delays in radio-telemetry receiver procurement forced us to postpone the study until early July.

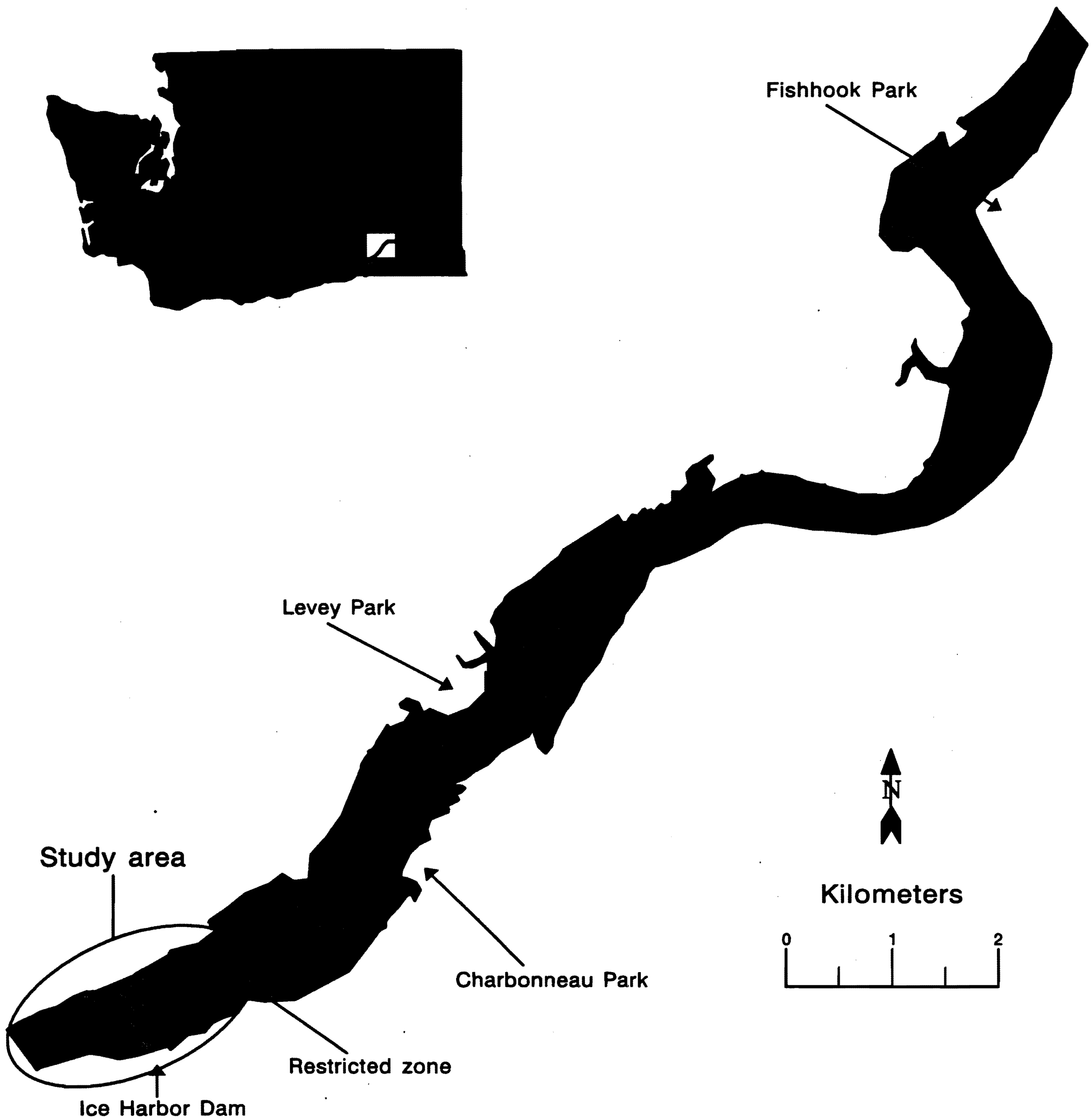

Figure 1. Study area showing location of Ice Harbor Dam.

Test Fish

Fish used for the study were Lyons Ferry Hatchery subyearling chinook salmon which were PIT tagged, transported, and released into the Snake River at Pittsburg Landing (River Kilometer, RKm 346) for the 1997 fall chinook survival study. Our study fish were then collected at Lower Granite Dam (RKm 171) using the PIT-tag separation-by-code system.

Radio Tags and Tagging Protocol

Radio tags, purchased from Advanced Telemetry Systems Inc.[1] were pulse-coded-delay type, measuring 18 mm in length by 7 mm in diameter, and weighing 1.9 g in air. The radio tags had an expected battery life of about 7 days and transmitted a unique identification code with each pulse (base pulse rate 1 second). Upon activation, tags transmitted for 2 hours, shut down for 24 hours, and then restarted continuous transmission until the batteries expired. These delay type transmitters were selected to maximize tag life after fish were released by shutting down transmission during the 24-hour post-surgical recovery period.

Study fish were measured and their condition noted. Fish that were too small and/or heavily descaled were rejected and released into the COE's transportation raceways. Test fish ranged from 128 to 176 mm in length and 22.4 to 68.8 g in weight (Table 1).

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

Table 1. Length and weight data for hatchery-reared subyearling chinook salmon collected and radio tagged at Lower Granite Dam for the Ice Harbor spill efficiency study, 1997.

Group number	Tagging date	n	Length (mm) range	Length (mm) median	Weight (g) range	Weight (g) median
1	10 Jul	64	130 - 150	134.0	23.0 - 41.1	29.6
2	14 Jul	52	128 - 149	137.0	22.4 - 43.6	30.8
3	16 Jul	33	128 - 153	140.0	27.7 - 42.3	33.2
4	17 Jul	36	130 - 158	142.0	23.9 - 46.2	35.9
5	22 Jul	18	136 - 158	146.5	29.8 - 48.2	39.5
6	23 Jul	15	136 - 159	147.0	30.7 - 48.7	39.4
7	24 Jul	12	132 - 155	147.0	28.3 - 50.5	39.7
8	25 Jul	19	137 - 161	149.0	30.0 - 57.8	41.4
9	26 Jul	26	136 - 162	153.0	32.0 - 54.0	44.0
10	27 Jul	10	138 - 161	147.5	33.5 - 57.3	42.0
11	28 Jul	15	130 - 176	152.0	25.9 - 65.4	42.3
12	30 Jul	8	147 - 163	155.0	40.5 - 63.9	49.2
13	31 Jul	14	144 - 166	156.0	40.7 - 61.7	50.3
14	01 Aug	19	141 - 169	154.0	38.0 - 59.1	49.8
15	02 Aug	11	139 - 167	156.0	30.7 - 53.8	49.3
16	03 Aug	16	149 - 171	158.5	42.3 - 68.8	51.6
Overall		368	128 - 176	145.0	22.4 - 68.8	37.4

Fish were radio tagged using surgical techniques similar to those described by Hart and Summerfelt (1975), Ross (1982), and Mellas and Haynes (1985). Radio-tagged fish were held for 24 hours, transported, and released into the tailrace of Lower Monumental Dam. Collection and tagging numbers are shown in Table 2.

Monitoring of Radio-Tagged Fish

Radio-telemetry receivers and antennas were installed at Ice Harbor Dam to monitor the immediate forebay and all routes of passage available to migrating juvenile salmonids except turbine units (Fig. 2 and Table 3). A study area entrance line (about 1 km upstream from the dam) monitored entrance into the study area by radio-tagged fish. The immediate forebay in front of the powerhouse and spillway were monitored to determine approach patterns at the dam. Monitored passage routes included the juvenile bypass system, fish ladders, navigation lock, and individual spillbays (due to budget constraints, turbine units were not monitored). A study area exit line (about 1 km downstream from the dam) monitored radio-tagged fish exiting the study area.

Data Analysis

The passage route used by an individual radio-tagged fish was determined by the last record on a passage route receiver (i.e., spillbay or bypass system). Radio-tagged fish that entered the study area, and were not seen in any of the monitored routes of passage, yet subsequently exited the study area, were assumed to have passed the dam through the powerhouse via a turbine unit.

Table 2. Collection and tagging information for the 1997 Ice Harbor Dam spill efficiency study.

Group number	Release date	Number collected	Number tagged	Number released	Collection mortality Number	Collection mortality Percent	Tagging mortality Number	Tagging mortality Percent
1	11 Jul	304	64	35	73	24.0	29	45.3
2	15 Jul	76	52	39	17	22.4	13	25.0
3	17 Jul	40	33	13	1	2.5	20	60.6
4	18 Jul	51	36	13	9	17.6	23	63.9
5	23 Jul	20	18	14	0	0.0	4	22.2
6	24 Jul	20	15	13	4	20.0	2	13.3
7	25 Jul	18	12	9	1	5.5	3	25.0
8	26 Jul	26	19	14	4	15.4	5	26.3
9	27 Jul	35	26	19	6	17.1	7	26.9
10	28 Jul	12	10	8	1	8.3	2	20.0
11	29 Jul	19	15	12	3	15.8	3	20.0
12	31 Jul	10	8	3	1	10.0	5	62.5
13	01 Aug	15	14	9	0	0.0	5	35.7
14	02 Aug	22	19	16	1	4.5	3	15.8
15	03 Aug	12	11	9	0	0.0	2	18.2
16	04 Aug	17	16	14	1	5.9	2	12.5
Total		697	368	240	122	17.5	128	34.8

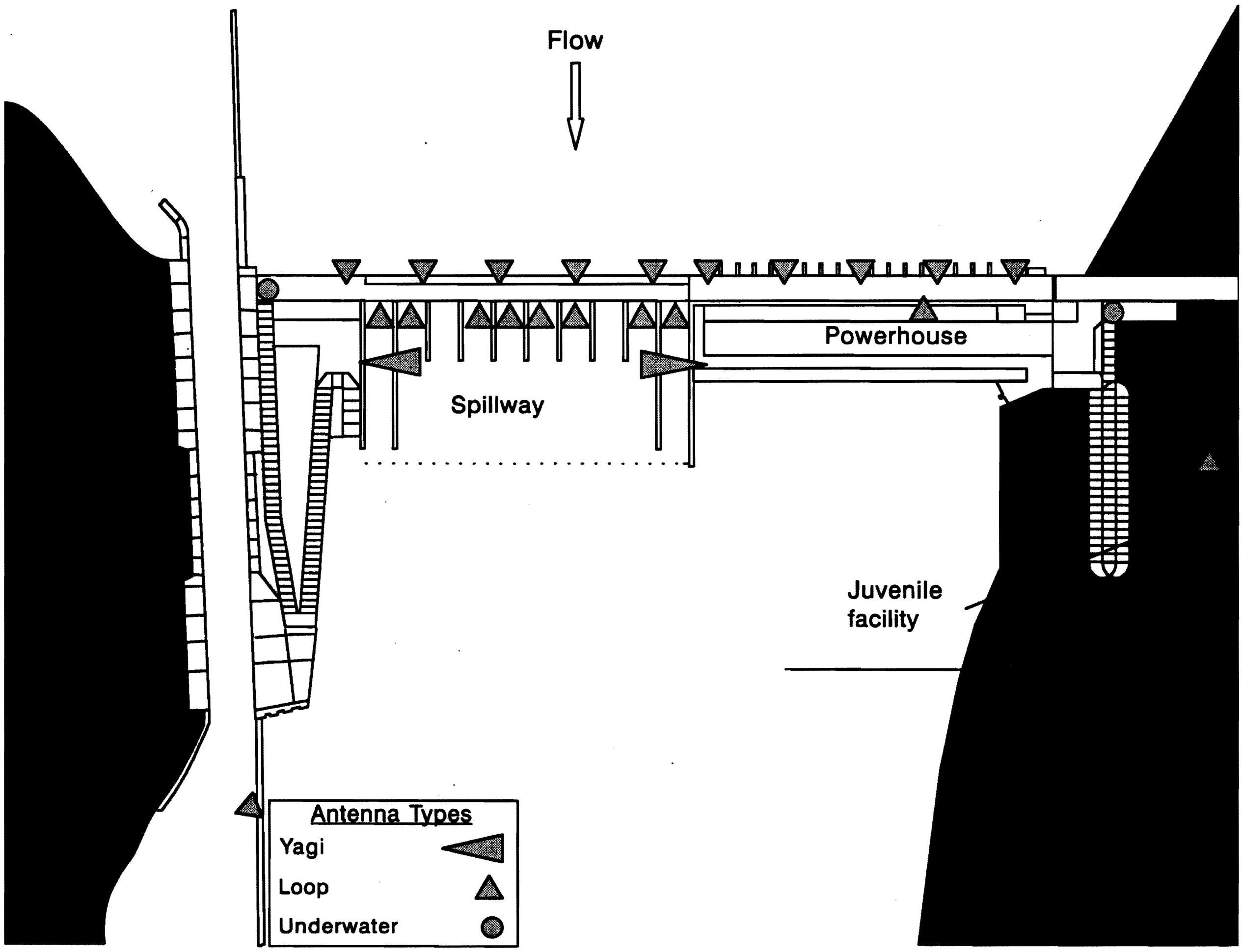

Figure 2. Ice Harbor Dam depicting locations of telemetry receivers and types of antennas (study area entrance and exit lines are not shown). Symbol direction indicates the primary detection area of a given antenna.

Table 3. Location, number of receivers, and antenna types used for fixed-site monitoring stations at Ice Harbor Dam, 1997.

Location	Number of receivers	Antenna type
Study area entry line	3	Yagi and loop
Powerhouse forebay	5	Loop
Spillway forebay	5	Loop
Spillbays[1]	8	Loop
Juvenile bypass system	2	Loop
Fish ladders	2	Underwater
Navigation lock	1	Loop
Spillway tailrace	2	Yagi
Study area exit line	2	Yagi

[1] Spillbays 3 and 8 were not monitored during the study.

Median travel times with 95% confidence intervals to and within the study area were calculated by using resampling (bootstrap) methods (Efron and Tibshirani, 1993). Percent spill was partitioned into groups, less than 40% spill, 40 to 50% spill, 50 to 60% spill, and greater than 60% spill, to compare radio-tagged fish passage routes to percent spill at Ice Harbor Dam. Percent spill for an individual fish was determined by the percent spill during the time of the last record on the study area entrance receivers.

Spill efficiency, spill effectiveness, and fish passage efficiency as used in this analysis are defined as follows:

Spill Efficiency	=	Number of fish passing the dam via the spillway divided by the total number of fish passing the dam
Spill Effectiveness	=	The proportion of fish passing the dam via the spill divided by the proportion of water spilled.
Fish Passage Efficiency	=	The number of fish passing the dam in non-turbine routes divided by total project passage.

RESULTS AND DISCUSSION

During the study period, average daily discharge, spillway discharge, and percent spill at Ice Harbor Dam were 55.9 kcfs, 39.2 kcfs, and 69%, respectively (Table 4). Hourly percent spill varied tremendously during the study, ranging from 39 to almost 100% within a 12-hour period (Fig. 3).

We released 240 radio-tagged fish into the tailrace of Lower Monumental Dam. Of these, 122 (50.8%) entered into the study area at Ice Harbor Dam. Approach patterns

Table 4. Average daily flow and temperature data at Ice Harbor Dam from 10 July to 13 August, 1997 (information provided by U. S. Army Corps of Engineers Northwestern Division at http://www.cqs.washington.edu/ ~ingres/realtime/dart.html)

Date	Total discharge (kcfs)	Spillway discharge (kcfs)	Percent spill (kcfs)	Temperature (°C)
10 July	79.6	40.5	50.9	18.0
11 July	101.2	40.2	39.7	17.7
12 July	65.6	40.7	62.0	17.8
13 July	58.5	40.4	69.0	18.1
14 July	32.7	22.3	68.3	18.3
15 July	11.9	10.9	91.2	18.5
16 July	91.8	39.7	43.2	18.9
17 July	68.9	40.5	58.8	19.3
18 July	64.9	40.0	61.7	19.6
19 July	55.9	37.8	67.5	19.9
20 July	57.8	39.8	68.9	19.9
21 July	63.9	39.9	62.4	19.8
22 July	53.4	38.1	71.4	19.7
23 July	73.2	39.5	54.0	19.8
24 July	35.2	24.9	71.0	20.0
25 July	56.5	39.8	70.4	20.4
26 July	57.9	39.9	68.9	20.4
27 July	51.2	34.9	68.2	20.3
28 July	43.9	30.5	69.6	20.4
29 July	44.5	32.2	72.3	20.4
30 July	49.8	39.4	79.0	20.3
31 July	31.2	29.9	96.0	20.2

Table 4. continued.

Date	Total Discharge (kcfs)	Spillway discharge (kcfs)	Percent spill (kcfs)	Temperature (°C)
01 August	51.0	30.0	58.8	20.3
02 August	32.9	31.9	97.3	20.5
03 August	47.5	35.1	74.0	20.6
04 August	53.6	35.7	66.6	20.7
05 August	58.1	39.1	67.3	20.9
06 August	57.1	37.9	66.4	21.1
07 August	59.9	42.7	71.2	21.1
08 August	54.5	39.3	72.0	21.2
09 August	78.1	43.6	55.8	21.1
10 August	53.0	37.1	70.0	21.0
11 August	52.9	39.6	74.7	20.9
12 August	58.6	39.2	66.9	21.1
13 August	50.1	38.9	75.9	21.1
Median	55.9	39.2	68.9	20.3

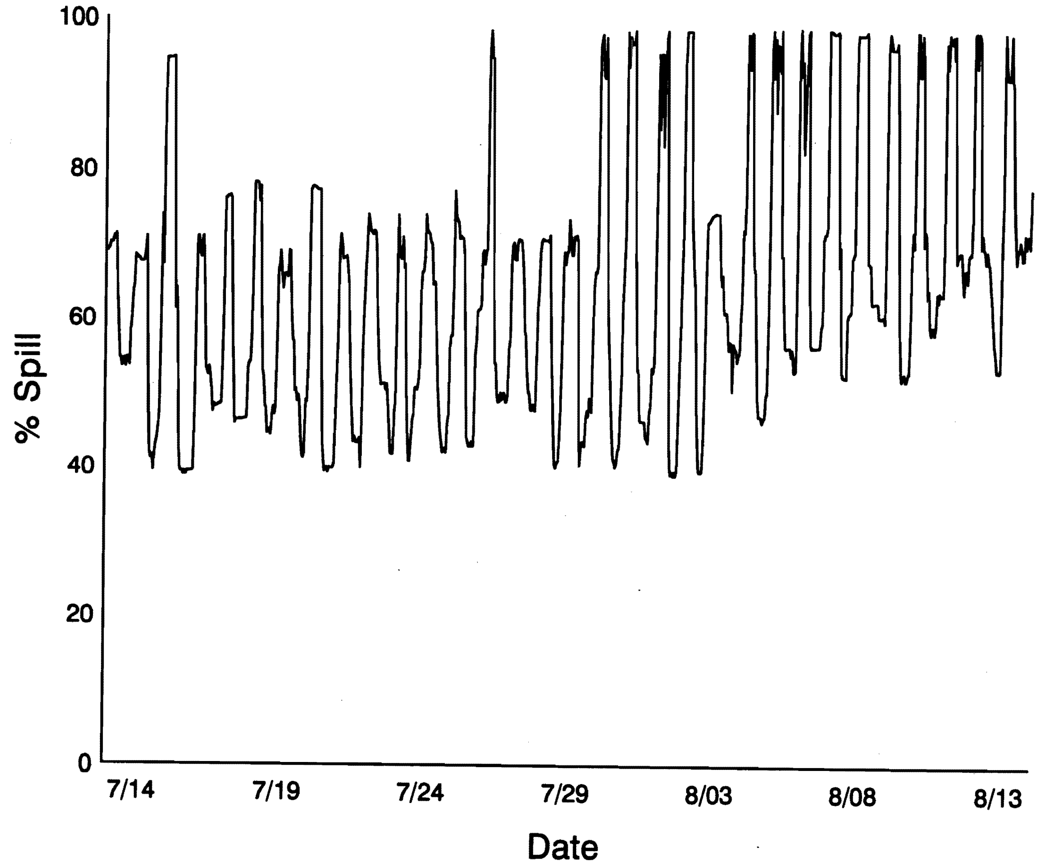

Figure 3. Hourly percent spill at Ice Harbor Dam from 13 July to 13 August, 1997.

were recorded for 115 of the fish that entered into the study area. Eighty-eight (76.5%) were first recorded at the spillway vs. 27 (23.5%) at the powerhouse (Fig. 4).

Of the 122 fish that entered the study area, 100 (82%) passed the dam via the spillway, 8 (6.6%) passed via the juvenile bypass system, and 9 (7.4%) were assumed to have passed via a turbine unit (Fig. 5). Five (4.1%) were not recorded again after they entered the study area. Percent spill ranged from 39 to 54%, with a median of 45%, for radio-tagged fish that passed via the bypass system. Percent spill ranged from 39 to 99%, with a median of 56.4%, for radio-tagged fish that passed via the spillway. Passage through the spillway was concentrated in Spillbays 4 and 5, at 32 and 27%, respectively (Fig. 6).

Construction of flow deflectors in the spillbays at Ice Harbor Dam was scheduled for completion prior to the spring out-migration. However, due to high flows, construction was stopped with only four spillbays completed (Spillbays 4, 5, 6, and 7). Spillbays 3 and 8 were not in operation during 1997, and the majority of water was spilled through Spillbays 4, 5, 6, and 7 (Chris A. Pinney, U.S. Army Corps of Engineers, Walla Walla District , pers. commun.).

We report diel passage distribution as a function of the percent of fish/hour that passed Ice Harbor Dam during one of the following time periods: nighttime, daytime, civil dusk, and civil dawn (civil dusk is the period of time between sunset and when the sun is 6° below the horizon and civil dawn is the period of time when the sun is 6° below the horizon until sunrise). A majority of the fish (64.8%) passed the dam during time periods of little to no light (Fig. 7).

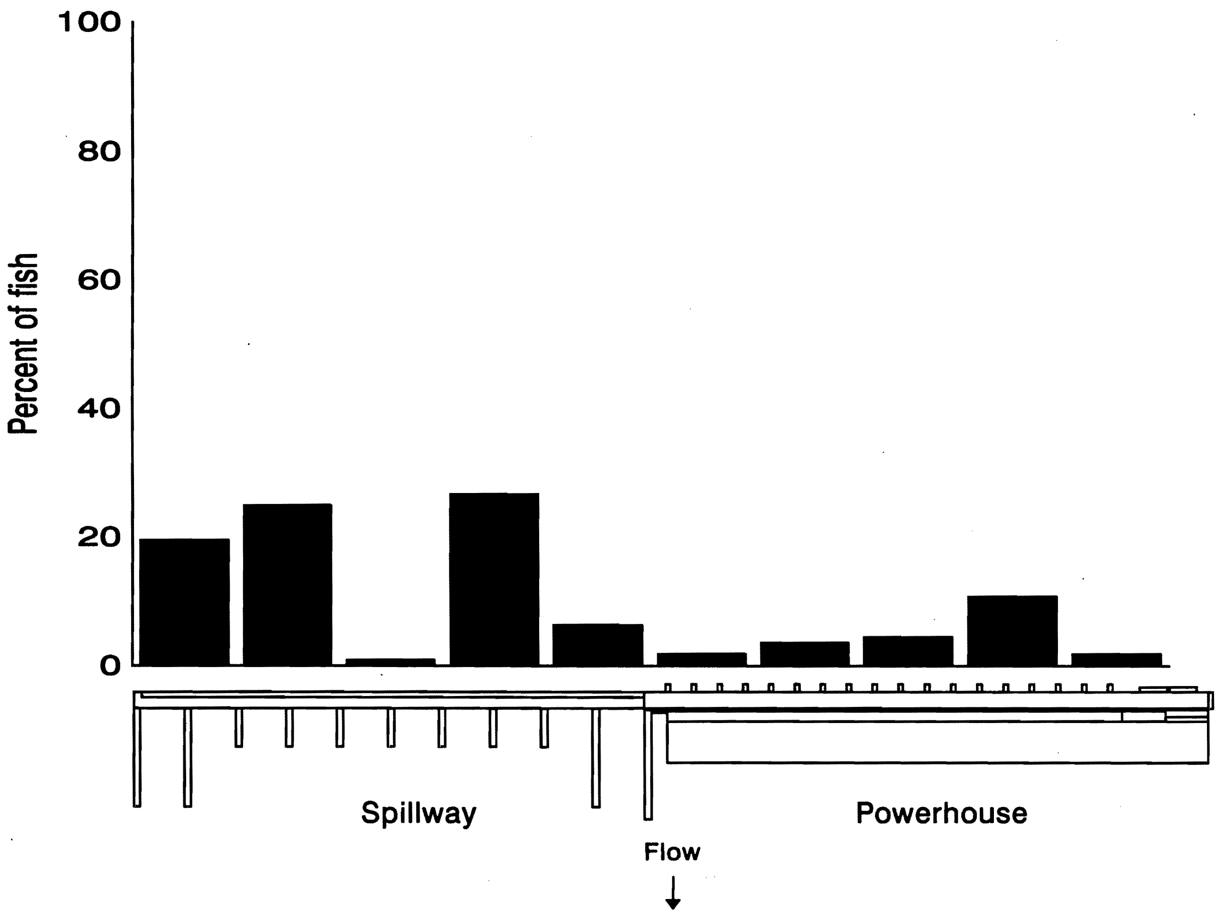

Figure 4. Approach patterns for radio-tagged hatchery-reared subyearling chinook salmon to Ice Harbor Dam, 1997.

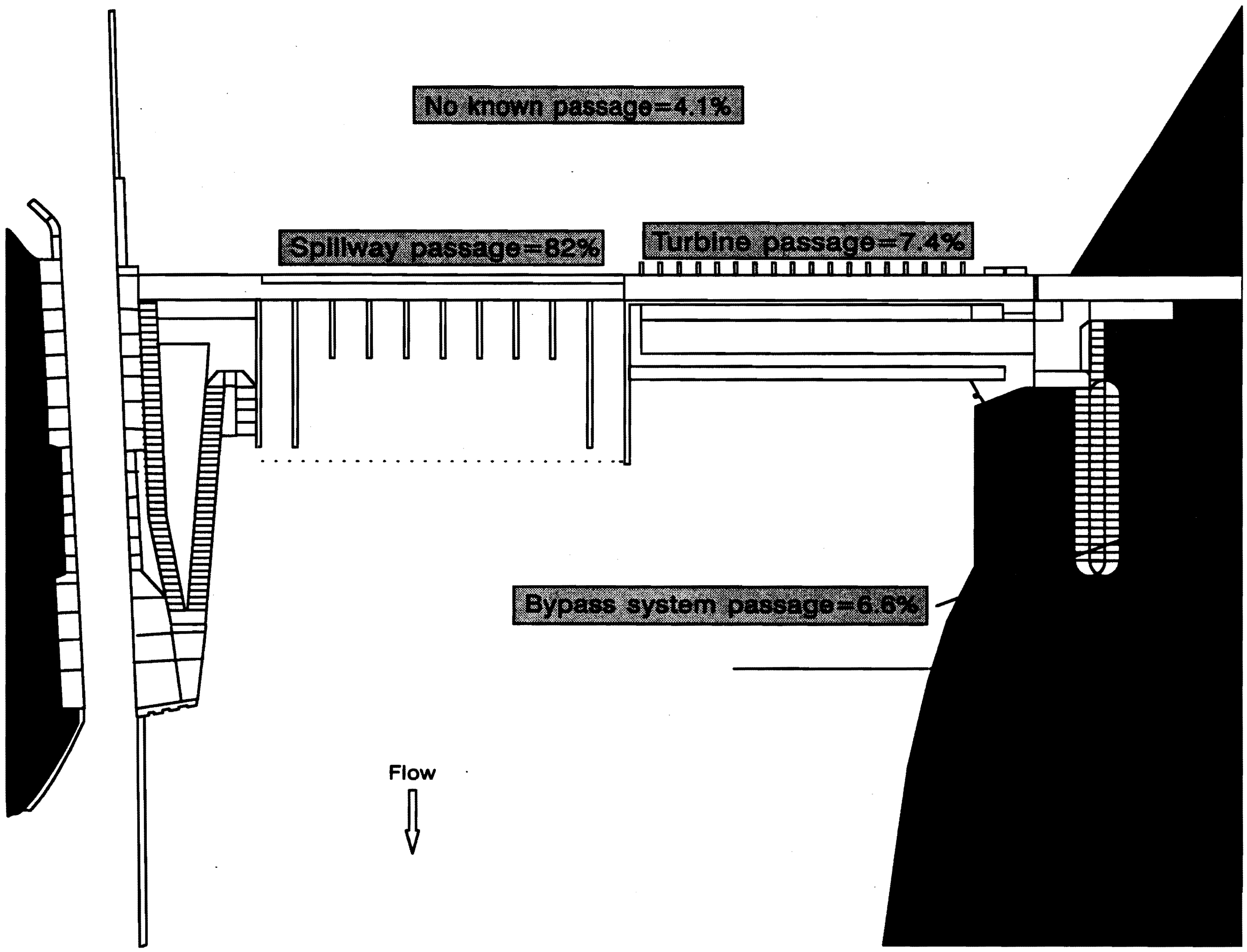

Figure 5. Passage distribution for radio-tagged hatchery-reared subyearling chinook salmon at Ice Harbor Dam, 1997. (Note: Radio-tagged fish with records on the entry and exit lines but with no record of passage at the dam were assigned turbine passage).

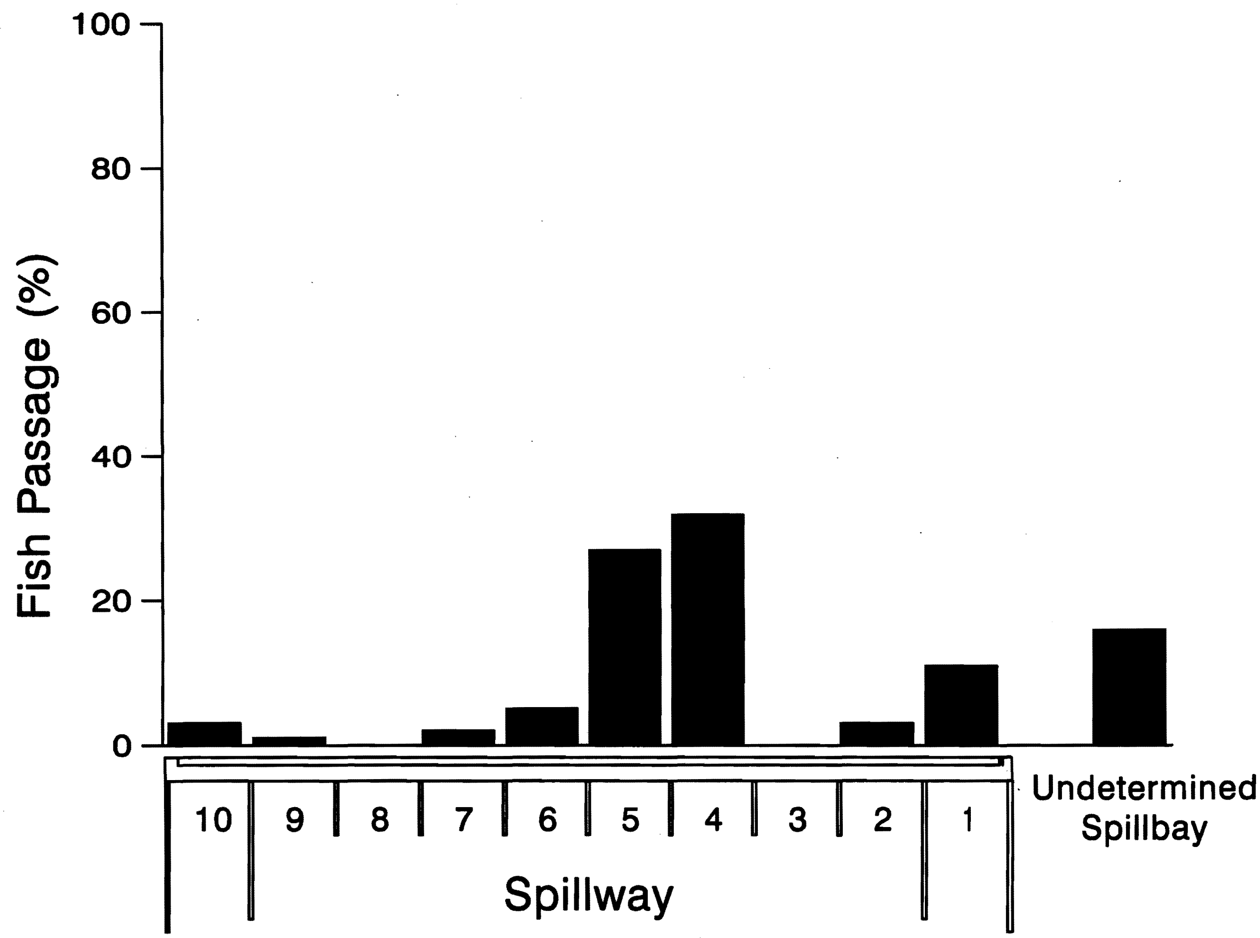

Figure 6. Spillway passage distribution for radio-tagged hatchery-reared subyearling chinook salmon at Ice Harbor Dam, 1997 (Spillbays 3 and 8 were closed throughout the duration of the study).

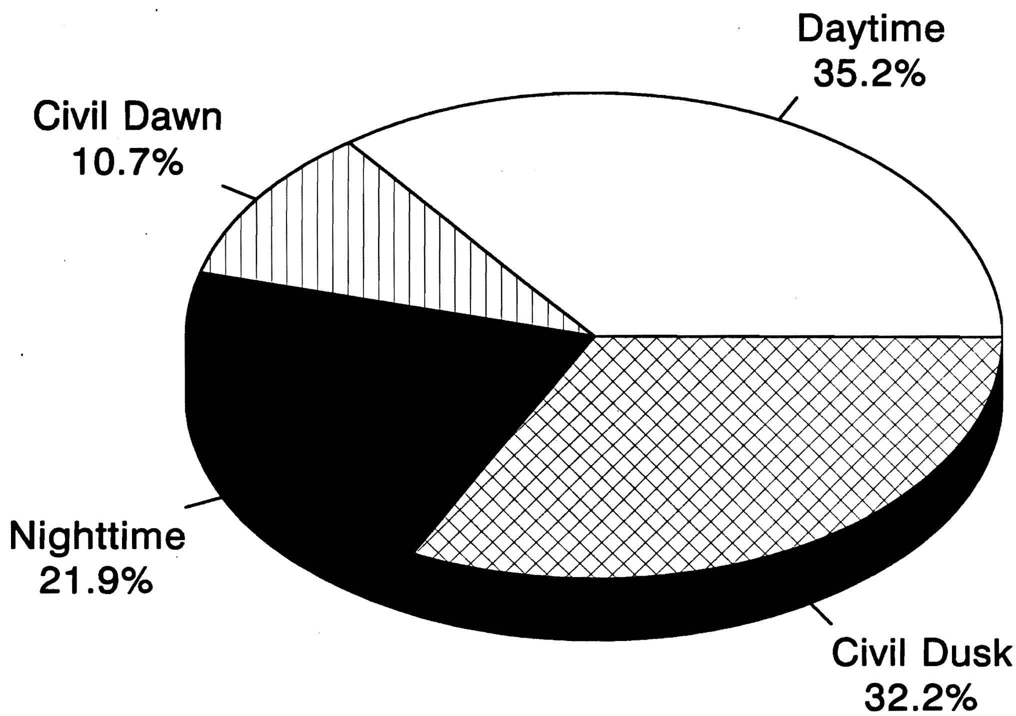

Figure 7. Diel passage distribution (%fish/hour) for radio-tagged hatchery-reared subyearling chinook salmon at Ice Harbor Dam, 1997.

Median travel times for radio-tagged fish from release at Lower Monumental Dam to entrance into the study area (approximately 51 km) was 2.8 days (95% ci: 2.5, 3.0 days). Median travel time within the study area (entrance to exit) was 0.15 days (95%: 0.11, 0.19 days). No delays associated with passage or exit from the immediate tailrace following passage were noted.

Overall spill efficiency, spill effectiveness, and fish passage efficiency for radio-tagged fish at Ice Harbor Dam was 85.5%, 1.2:1, and 92.3%, respectively. For groups of fish under the four spill scenarios's (<40%, 40 - 50%, 50 - 60%, and >60%), the spill efficiency, spill effectiveness, and fish passage efficiency are presented in Figure 8. Spill efficiency, although highest at spills less than 40%, showed no significant change with increased spill levels. However, spill effectiveness decreased when the percent spill increased.

RECOMMENDATIONS

High flows in 1997 resulted in high spill levels throughout the spring and summer out-migrations. Therefore, results reported here may not be applicable to low or medium flow scenarios. We recommend using radio telemetry to conduct a spill efficiency and/or effectiveness study with controlled spill levels at Ice Harbor Dam as well as at other dams on the Snake and Columbia Rivers. These studies should include low and/or moderate spill scenarios.

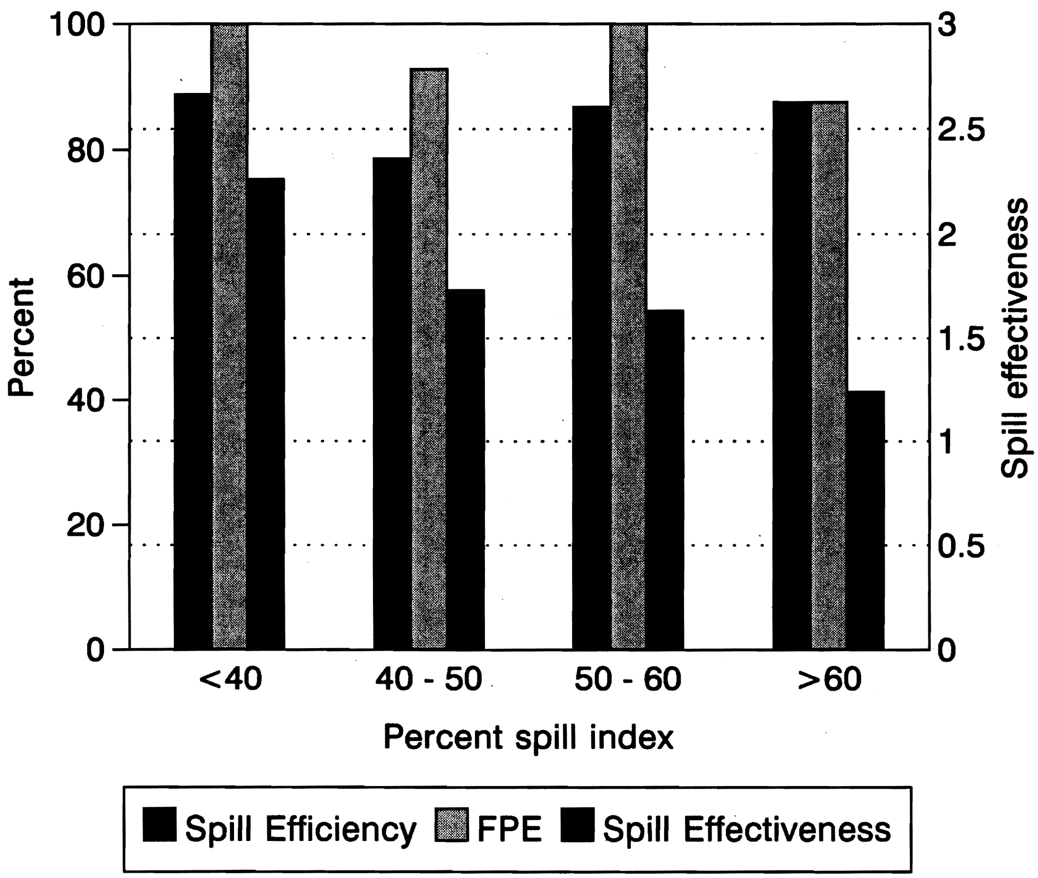

Figure 8. Spill efficiency, spill effectiveness, and fish passage efficiency (FPE) for radio-tagged hatchery-reared subyearling chinook salmon at Ice Harbor Dam, 1997.

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