Juvenile radio-telemetry study at Ice Harbor Dam, 1995

CZES

Coastal Zone and Estuarine Studies Division

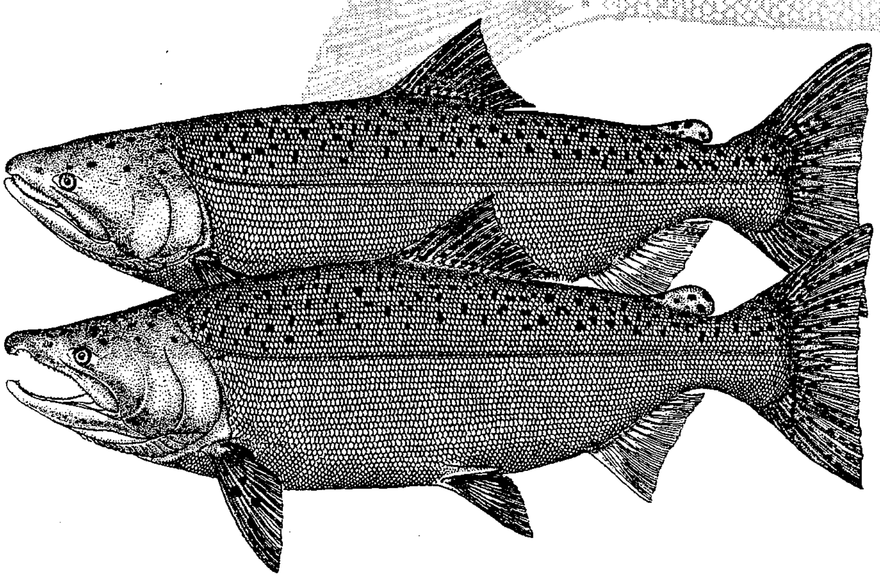
Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by
George A. Swan, M. Brad Eppard,
Eric E. Hockersmith, Benjamin P. Sandford,
Byron L. Iverson, Paul A. Ocker,
Mark A. Kaminski, and Robert N. Iwamoto

October 1997



JUVENILE RADIO-TELEMETRY STUDY AT

ICE HARBOR DAM, 1995

by

George A. Swan
M. Brad Eppard
Eric E. Hockersmith
Benjamin P. Sandford
Byron L. Iverson
Paul A. Ocker
Mark A. Kaminski
and
Robert N. Iwamoto

Annual Report of Research

Funded by

U.S. Army Corps of Engineers
Walla Walla District
Delivery Order E86-95-0113

and

Coastal Zone and Estuarine Studies Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

October 1997

CONTENTS

	Page
EXECUTIVE SUMMARY	iii
INTRODUCTION	1
OBJECTIVES	1
MATERIALS AND METHODS	6
Test Fish	12
Test Conditions	17
RESULTS AND DISCUSSION	19
SUMMARY	32
ACKNOWLEDGMENTS	33
REFERENCES	34

EXECUTIVE SUMMARY

In 1995, the U. S. Army Corps of Engineers (Walla Walla District) installed three types of experimental surface collectors at Ice Harbor Dam: 1) vertical slots mounted on the trash racks of Turbine Intake Slots 1A and 4B, 2) a sluiceway surface-skimming gate at Turbine Intake Slot 2B, and 3) a spillway surface skimmer utilizing stop logs that allowed surface spill in Spillbays 8 or 9. As part of the overall evaluation, the National Marine Fisheries Service conducted a radio-telemetry study to determine the behavior of juvenile salmonids in the vicinity of the surface collectors.

The vertical slots passed water into the sluiceway from the surface to a depth of 12.2 m below normal forebay levels. The vertical slot conditions tested were: 1) Slot 1A - 1.2 m wide (narrow slot) with a water velocity of 0.6 m/s, 2) Slot 1A - 1.2 m wide (narrow slot) with a water velocity of 1.5 m/s, and 3) Slot 4B - 1.8 m wide (wide slot) with a water velocity of 1.2 m/s. Slot 2B skimmed surface water through the existing sluice gates and had a water velocity of 2.1 m/s. The two spillway test conditions were a surface skim of water over stop logs and a deep draw of water under tainter gates.

Radio-telemetry monitors were strategically installed at surface collector/skimmer locations to record the presence and passage of tagged fish. Radio-tags were implanted into the stomachs of 88 hatchery yearling spring chinook salmon and 82 hatchery yearling fall chinook salmon (*Oncorhynchus tshawytscha*) and 44 hatchery yearling steelhead (*O. mykiss*). Due to the small sample size, the results of hatchery yearling spring and fall chinook salmon were combined. Radio-tagged fish were released between 1.6 and 4.8 km upstream from Ice Harbor Dam between early May and mid-June. Spill occurred at Ice Harbor Dam throughout the duration of the study.

One hundred (62%) radio-tagged yearling hatchery chinook salmon were detected at Ice Harbor Dam. Travel time from release points to initial detection at the dam ranged from about 0.5 to 8 hours. Passage distribution was 25% via Spillbay 8 or 9, 53% via the sluiceway, and 22% via unmonitored spillbays or through the turbines. The distribution of the 53 radio-tagged fish entering the sluiceway was comprised of 2 (4%) via Unit 4B, 5 (9%) via Unit 1A, 30 (57%) via Unit 2B, and 16 (30%) via undetermined routes. Median travel time was <1 hour for mid-river and south-side release sites 1.6 km upstream from the dam, 3 hours for those released on the north side 1.6 km upstream from the dam, and 4 hours for those released at mid-river 5 km upstream from the dam. The majority (65%) were first detected at the powerhouse rather than the spillway. The average depth of entry into Slots 1A and 4B was 6.1 m and 5.5 m, respectively. Few fish passed through Slot 1A under the high and low velocity conditions; therefore, a preference for either condition was not detectable. Similarly, a preference between the wide slot (4B) and the narrow slot (1A) was not detectable. Surface or shallow draw conditions for both the spillway and vertical slot surface collectors produced notably higher passage than deep draw conditions. Seventeen fish exhibited lateral forebay movement following initial detection at the dam. These movements were random except for 11 fish which passed through Unit 2B after prior detection at either Unit 1A or 4B.

Run-of-the-river hatchery juvenile steelhead were collected at Lower Monumental Dam, radio tagged, and released upstream from Ice Harbor Dam. Sixteen were detected at Ice Harbor Dam. Of these 16, 8 passed via the sluiceway and 3 via the spillway. Passage in relation to the operations of the surface collectors could not be evaluated because releases occurred when either the slots were closed or just prior to when the slots were closed.

Based on the results of our radio-telemetry study at Ice Harbor Dam in 1995, radio-tagged juvenile salmonids preferred a surface collector design which utilized a surface skim rather than a deep draw. Also, spillway passage efficiency was significantly higher for surface skim compared to a deep draw under the tainter gates.

INTRODUCTION

In 1995, the U. S. Army Corps of Engineers (COE), Walla Walla District, evaluated fish passage effectiveness of three types of experimental surface collectors at Ice Harbor Dam on the Snake River (River Kilometer (RKm) 15.6) (Fig. 1). The surface collector types were: 1) vertical slots mounted on the trash racks of Turbine Units 1-A and 4-B (Figs. 2 and 3), 2) a sluiceway surface-skimming gate at Turbine Unit 2-B (Fig. 3), and 3) a spillway surface skimmer utilizing stop logs that allowed surface spill in Spillbays 8 or 9 (Fig. 4). A concurrent hydroacoustic study dictated the operating conditions of the surface collectors. At the request of the COE, the National Marine Fisheries Service (NMFS) conducted a radio-telemetry study to supplement hydroacoustic data[1] by determining critical aspects of juvenile fish behavior in relation to the effectiveness of the experimental surface collectors.

OBJECTIVES

The primary objective of the radio-telemetry research was to determine behavior of juvenile salmonids in relation to the experimental surface collectors. Specific tasks within the radio-telemetry study were:

Task 1. Determine behavior of radio-tagged juvenile salmonids in relation to the vertical surface collector slots at Ice Harbor Dam.

Task 1.1. Determine approach direction to the surface collectors in the immediate vicinity of the powerhouse face.

---

[1] Hydroacoustic monitoring was conducted by a separate contractor (BioSonics, 3670 Stoneway N., Seattle, WA 98103).

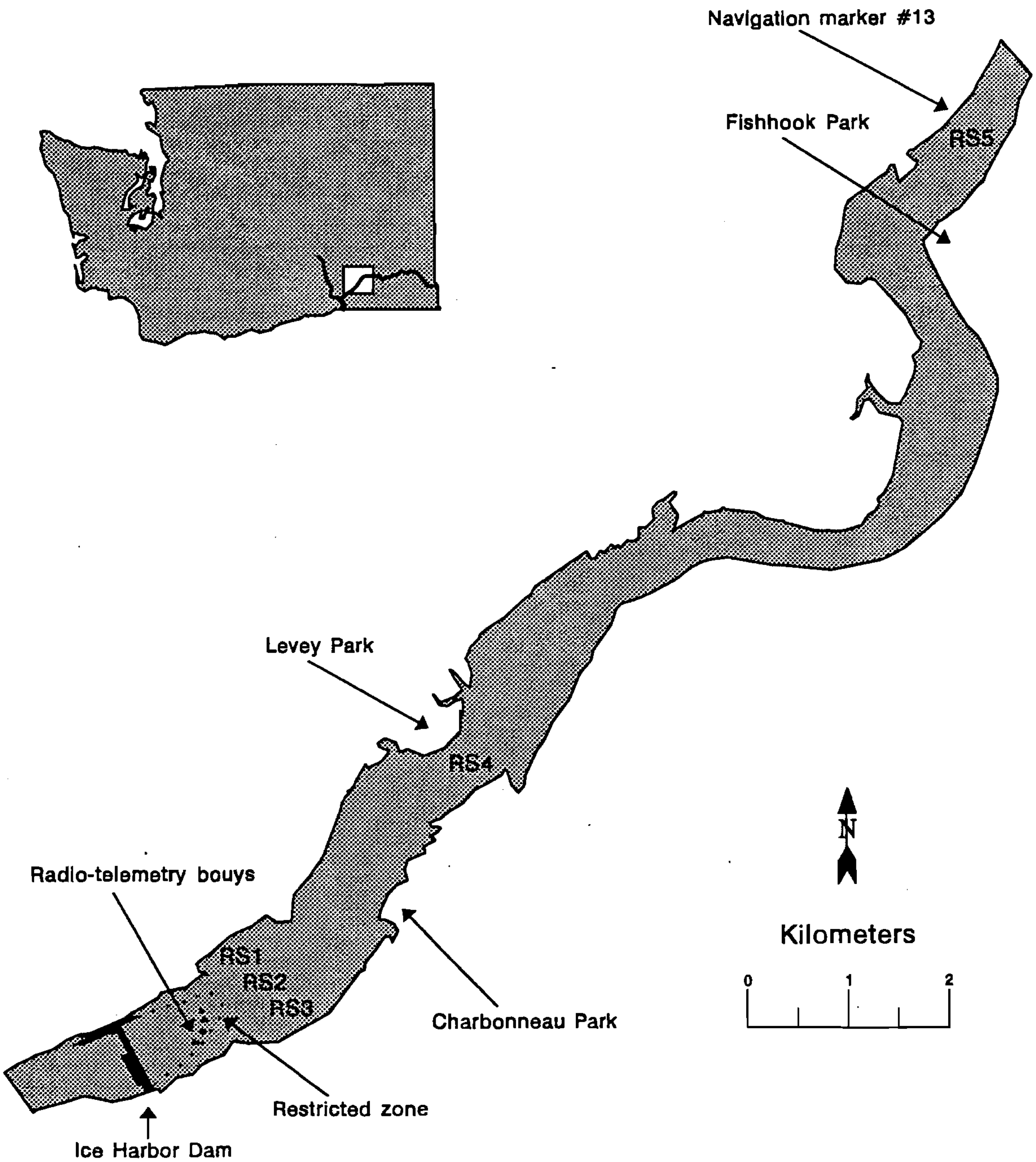


Figure 1. Study area showing release sites for the Ice Harbor Dam radio-telemetry study, 1995.

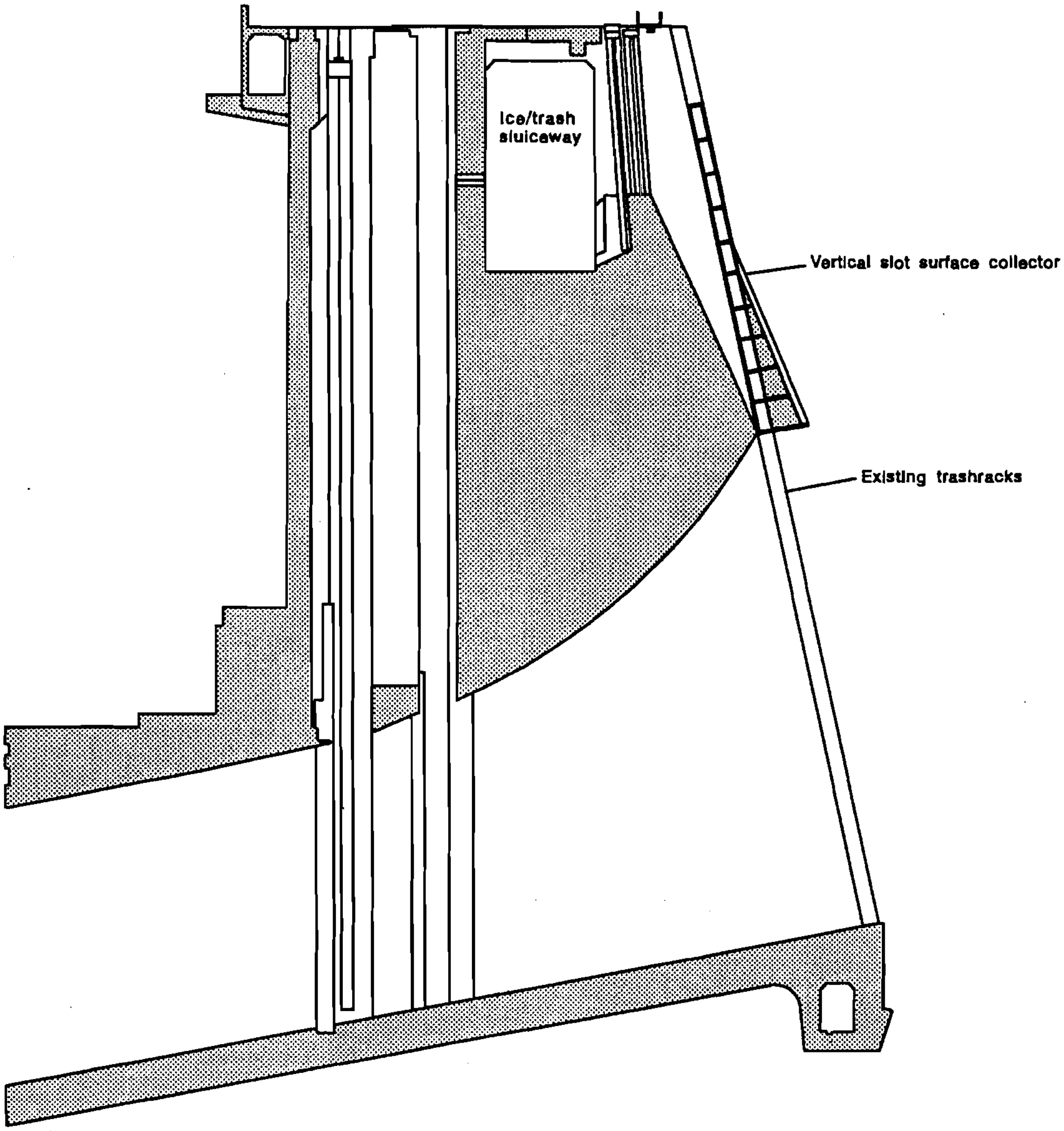


Figure 2. Cross section of a turbine intake at Ice Harbor Dam showing the vertical slot surface collector installed for testing, 1995.

Surface skimming operation

Surface collecting operation

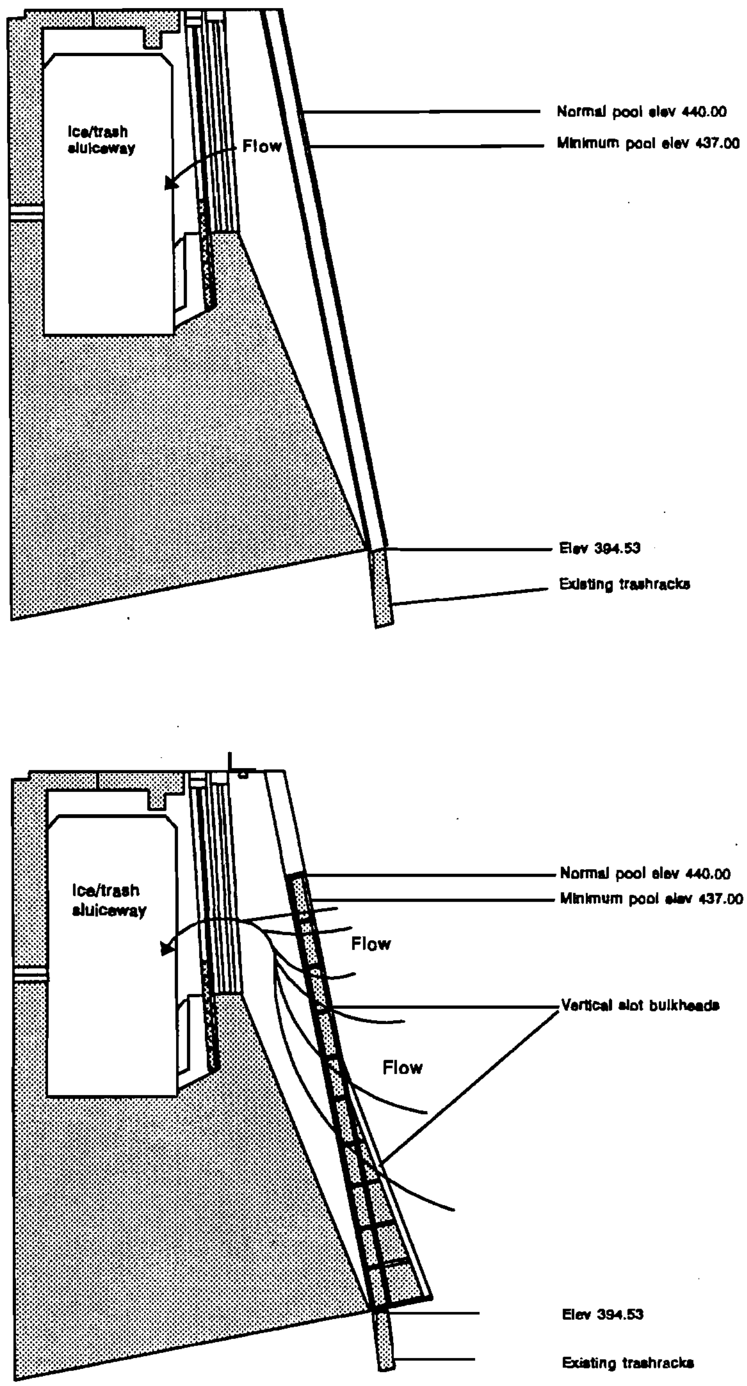


Figure 3. Cross section of the ice\trash sluiceway at Ice Harbor Dam showing a comparison of the surface skimming operation (top), and the surface collecting operation utilizing the vertical slot surface collector (bottom).

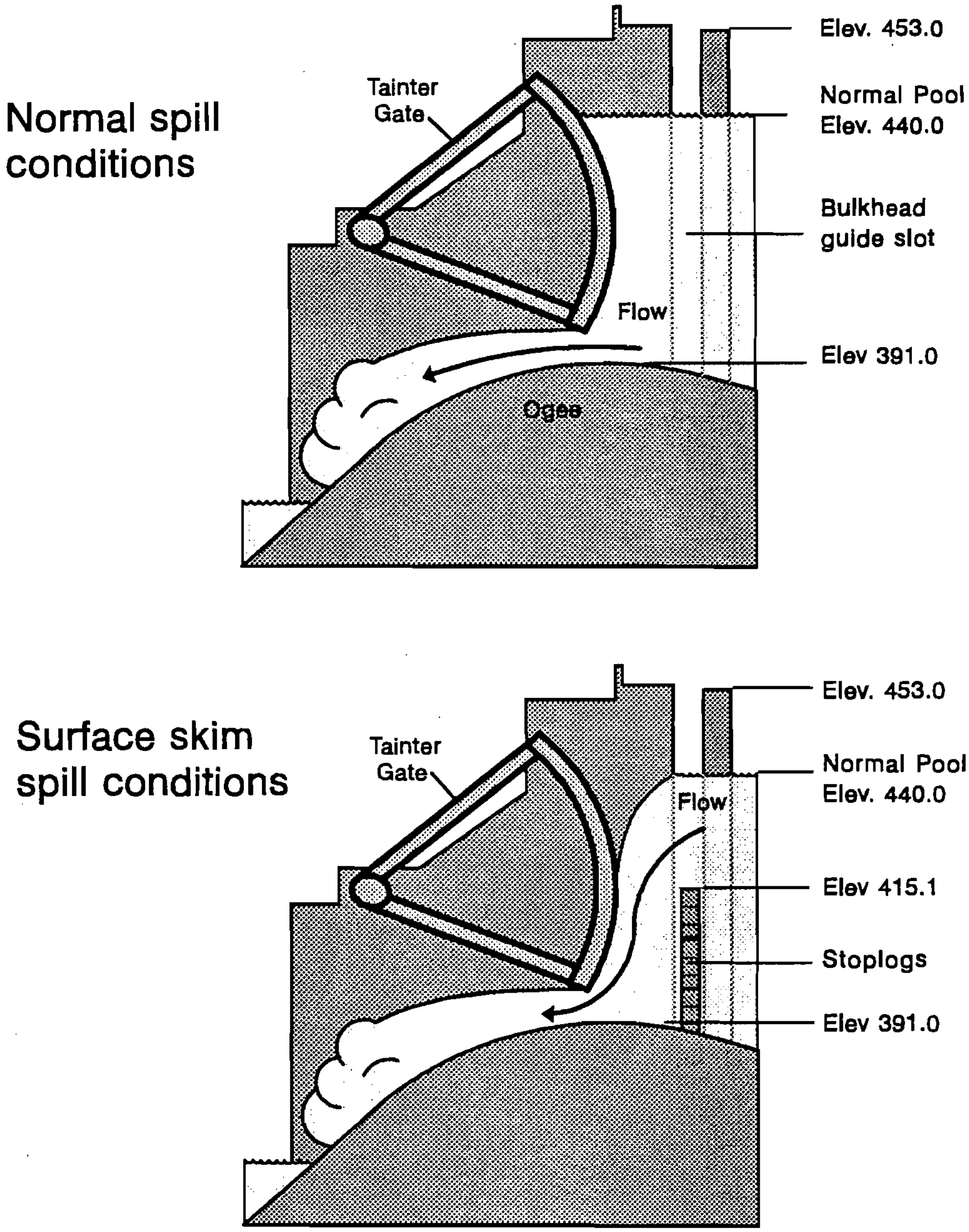


Figure 4. Cross section of a spillbay at Ice Harbor Dam showing normal spilling conditions (top) causing a deep draw and surface skimming spill conditions (bottom) with stop logs installed to provide a shallow draw.

Task 1.2. Determine elapsed time from arrival at the dam to time of passage through the surface collector.

Task 1.3. Determine depth of passage through the surface collector.

Task 1.4. Determine proportion of radio-tagged juvenile salmonids passing through the sluiceway surface collectors versus submerged traveling screens (STS).

Task 2. Determine behavior of radio-tagged juvenile salmonids in relation to the experimental spillway surface skim condition at Ice Harbor Dam.

Task 2.1. Determine approach direction in the immediate vicinity of the dam face.

Task 2.2. Determine proportion of radio-tagged juvenile salmonids passing over the spillway skimmer compared to normal deep release of spilled water through the tainter gates.

Task 3. Evaluate radio-tracking buoys.

MATERIALS AND METHODS

Juvenile chinook salmon (*Oncorhynchus tshawytscha*) were tagged with radio transmitters purchased from Advanced Telemetry Systems Inc. (ATS)[2] (Fig. 5). Each ATS tag was sealed in an epoxy capsule measuring about 1.8 cm in length, 0.5 cm in diameter, and weighed 1.4 g in air and was equipped with a 30 cm flexible external whip antenna. In addition, juvenile hatchery steelhead (*O. mykiss*) were tagged with radio tags manufactured by NMFS and described by Giorgi et. al. (1988). The NMFS tags were 2.8 cm in length, 0.95 cm in diameter, and weighed 3.5 grams in the air and were equipped with 18-cm flexible external whip antennas. The effective range of both the ATS and the NMFS transmitters was estimated to be about 50-60 m by air antennas and 6 m by underwater

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

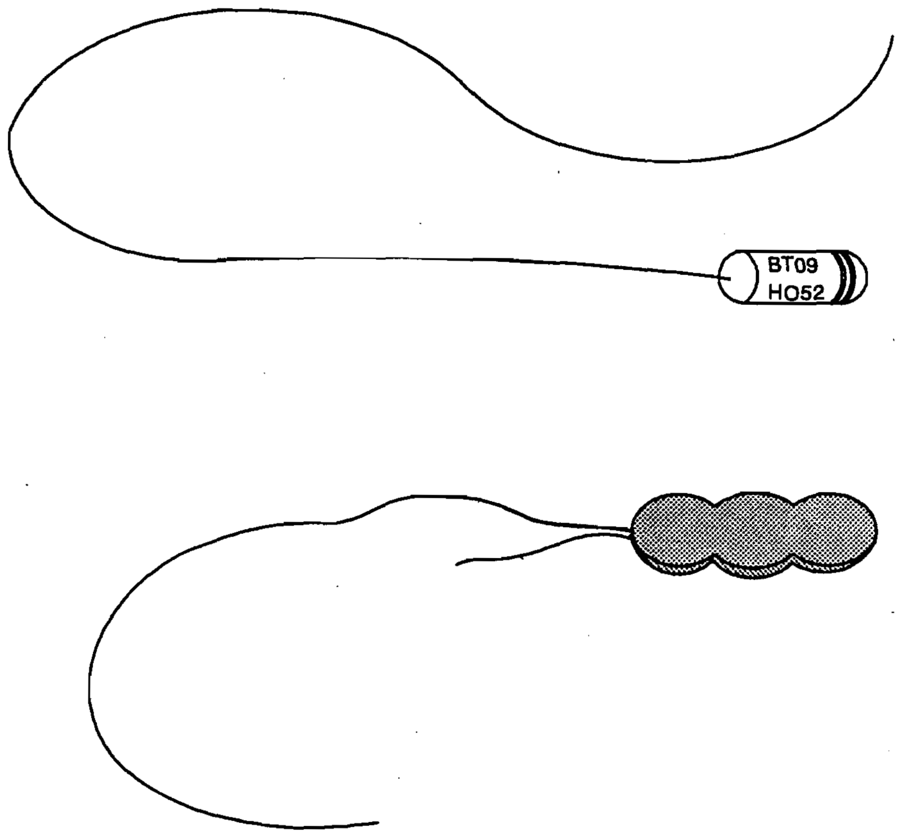


Figure 5. Demonstration of the difference between the smaller commercial radio tag used with hatchery yearling chinook salmon and the larger NMFS radio tag used in hatchery yearling steelhead (actual size).

antennas. The average life span of each tag was about 5-7 days. All tags used in this study transmitted on one of nine frequencies spaced 10 KHz apart (30.170 MHZ to 30.250 MHZ); however, frequency 30.220 MHZ was not utilized due to excessive radio interference. Each tag produced a unique identification code every second.

Self-contained, fixed-site monitors were strategically installed to record the presence of radio-tagged fish in relation to collector/skimmer locations. Specifically monitored areas of the dam included Spillbays 8 and 9, the sluiceway exit, the powerhouse tailrace, and the surface collectors (sluiceway gates) with and without the vertical slots (Fig. 6 and Table 1). Two types of telemetry receivers were used to monitor movement and behavior of radio-tagged juveniles during the study. The first type of telemetry receiver, model SRX-400, was purchased from Lotek Engineering Inc., Newmarket, Ontario, Canada and was used at fixed sites and on buoys in the forebay. The second type of receiver was developed and assembled by the NMFS electronics shop and was used in areas of higher water velocities such as in the vertical slots, the surface skimmer, and spillway monitoring.

Receivers were equipped with either air or underwater antennas. Air antennas consisted of a directional tuned-loop, and were used at fixed sites for general area tracking and fish passage where underwater antennas were not effective. Underwater antennas consisted of coaxial cable with the shielding and protective cover stripped back 10 cm from the distal end and were used to isolate an area of reception. The tuned loop antennas were further tested, in different configurations, on radio-telemetry buoys in the forebay.

Underwater antennas identified radio-tagged fish that approached a surface collector and determined their depth (within about 2 m) during passage through the vertical slots (Fig. 7). The antennas mounted in the vertical slots were numbered 1 through 4 from the

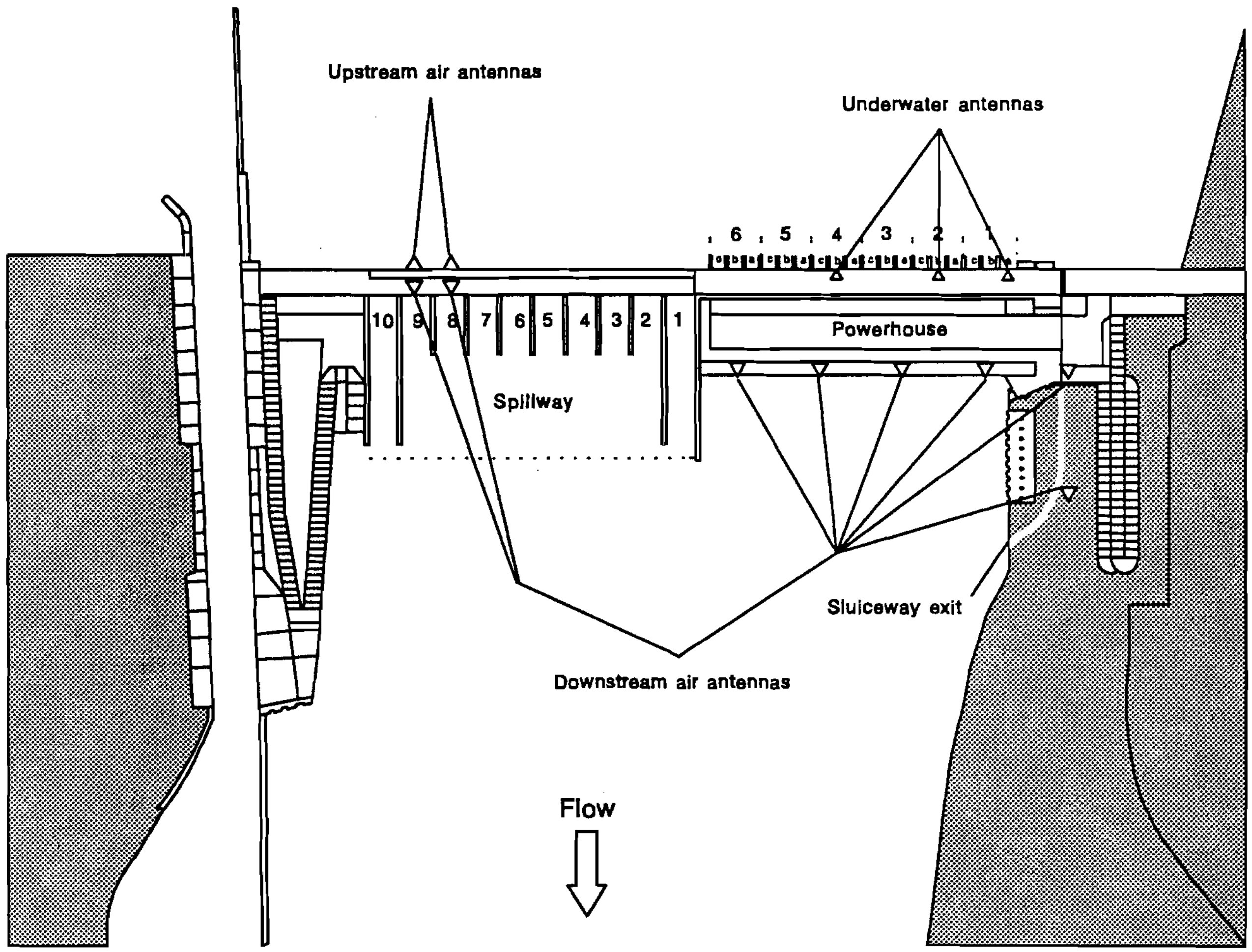


Figure 6. Plan view of Ice Harbor Dam showing the position of fixed-site receiver antennas for the 1995 radio-telemetry study.

Table 1. Fixed-site telemetry monitors and antennas used during the 1995 hatchery yearling spring and fall chinook salmon and steelhead radio-telemetry study at Ice Harbor Dam.

Monitor number	Monitor Location (upstream progression)	Number of antennas	Antenna type
1	Sluiceway (tailrace deck level)	2	Loop (air)
2	Powerhouse (tailrace deck)	1	Loop (air)
3	Powerhouse (tailrace deck)	1	Loop (air)
4	Powerhouse (tailrace deck)	1	Loop (air)
5	Powerhouse (tailrace deck)	1	Loop (air)
6	Spillbay No. 8 (forebay)	2	Loop (air)
7	Spillbay No. 9 (forebay)	2	Loop (air)
8	Spillbay No. 8 (spillway)	2	Loop (air)
9	Spillbay No. 9 (spillway)	2	Loop (air)
10	Unit 4B, vertical slot (forebay)	2 (1 and 3)[1]	Underwater coaxial cable
11	Unit 4B, vertical slot (forebay)	2 (2 and 4)[1]	Underwater coaxial cable
12	Unit 2B, surface skim	1	Underwater coaxial cable
13	Unit 1A, vertical slot (forebay)	2 (1 and 3)[1]	Underwater coaxial cable
14	Unit 1A, vertical slot (forebay)	2 (2 and 4)[1]	Underwater coaxial cable

[1] Numbered 1 through 4 from deepest to shallowest and placed at depths of 1.5, 4.9, 8.2, and 11.6 m.

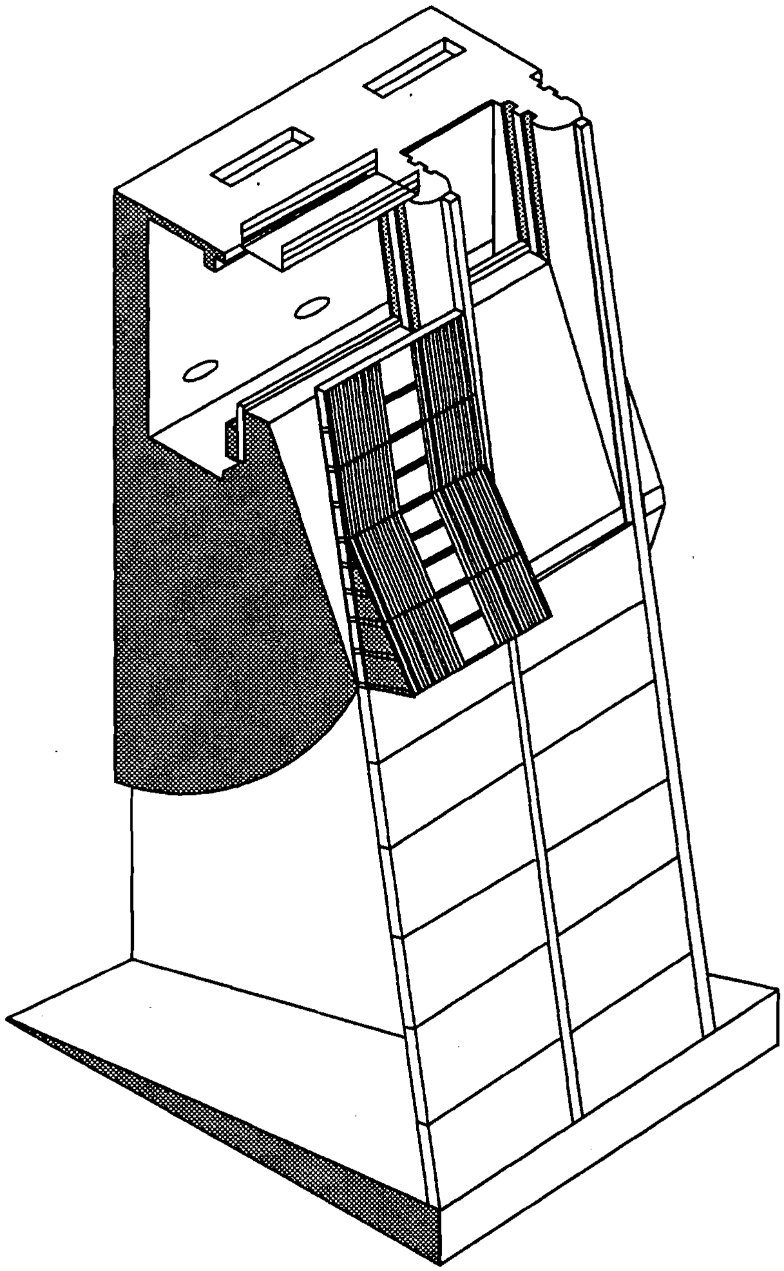


Figure 7. Three dimensional view of turbine intake units with and without the vertical slot surface collector.

deepest to the shallowest and placed at depths of 1.5, 4.9, 8.2, and 11.6 m (Table 1). A single underwater antenna immersed in the overflow to the sluiceway recorded tagged fish passing through the surface skimmer.

Two successive air antennas were mounted over the lower portion of the sluiceway to verify passage of fish through the surface collector or over the surface skimmer (Fig. 1). In addition, tagged fish exiting gatewells through the orifices were recorded by a receiver in the sluiceway. Six air antennas were mounted on the tailrace deck to detect radio-tagged fish not guided by the traveling screens, but which passed through the turbines. Two air antennas mounted on the forebay side of each test spillbay recorded the approach of tagged fish (Fig. 6). Two air antennas mounted on the downstream side of the test spillbays recorded passage of radio-tagged fish. In addition, we evaluated prototype radio-tracking buoys equipped with both air and underwater antennas in the forebay of the dam (Fig. 8 and Table 2).

Test Fish

Juvenile chinook salmon and steelhead were used for this study. Due to the late inception of this project, an ESA Section 10 permit prior to the juvenile chinook salmon outmigration in 1995 could not be obtained. Therefore, yearling fall chinook salmon from Lyons Ferry Hatchery and yearling spring chinook salmon from Dworshak National Fish Hatchery were used as test fish. A group of fish from each hatchery was transported to Ice Harbor Dam and held in floating net-pens in the forebay until tagging. Eighty-eight Dworshak fish and 82 Lyons Ferry fish were radio-tagged and released at 4 sites (RS-1 - RS-4) 1.6 to 4.8 km upstream from Ice Harbor Dam (Fig. 1) (Tables 3 and 4). Because test

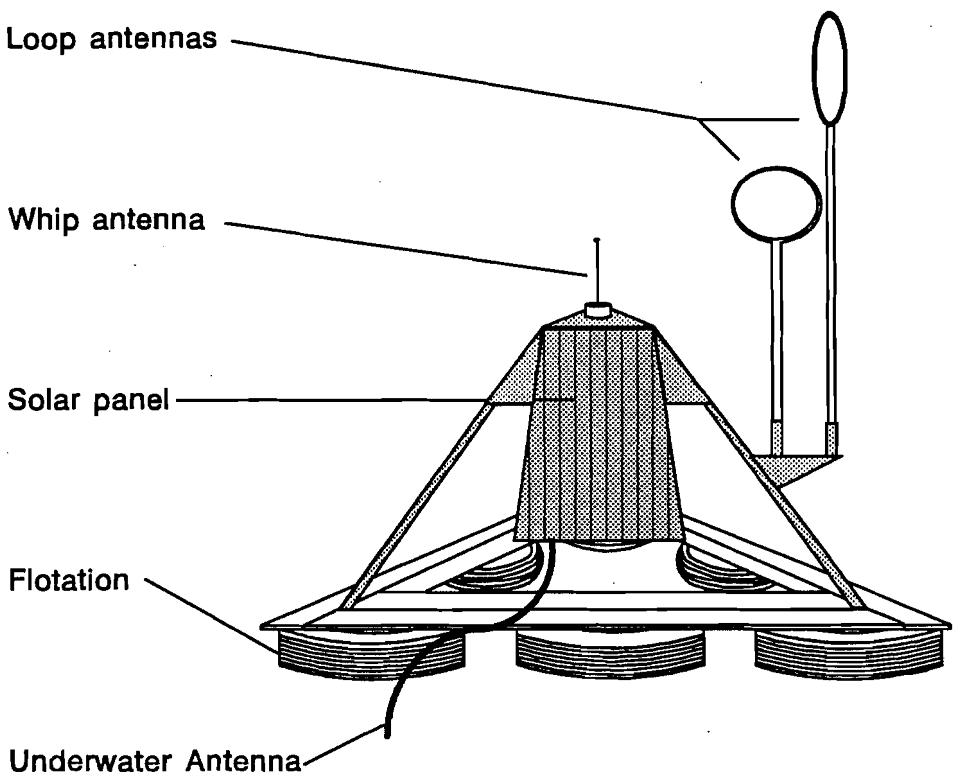


Figure 8. Prototype radio-telemetry buoy tested as a floating fixed-site receiving station at Ice Harbor Dam, 1995.

Table 2. Buoy-mounted[1] telemetry monitors and antennas used during the 1995 hatchery yearling spring and fall chinook salmon and steelhead radio-telemetry study at Ice Harbor Dam.

Monitor number	Bouy-mounted monitor location	Number of antennas	Antenna types
15	Forebay (north)	2	Underwater coaxial cable
		2	Loop (air)
16	Forebay (mid-river)	2	Underwater coaxial cable
		1	Whip (air)
17	Forebay (mid-river)	2	Underwater coaxial cable
		2	Loop (air)
18	Forebay (south)	2	Underwater coaxial cable
		1	Loop (air)

[1] See Figure 8.

Table 3. Release sites in Lake Sacajawea for radio-tagged yearling hatchery spring and fall chinook salmon and steelhead at Ice Harbor Dam, 1995.

Release site number	Release site location	River segment	Distance upstream from dam (Km)
1	Forebay	North half	1.6
2	Forebay	Mid-river	1.6
3	Forebay	South half	1.6
4	Levey Landing Park	Mid-river	4.8
5	Navigation marker No. 13	Mid-river	16.1

Table 4. Percent detection of radio-tagged hatchery yearling spring and fall chinook salmon at Ice Harbor Dam after release upstream, 1995.

Release site	Spring chinook salmon			Fall chinook salmon			Combined		
	Number released (%)	Number detected	Percent detected	Number released (%)	Number detected	Percent detected	Number released (%)	Number detected	Percent detected
1	17	10	58.8	13	7	53.8	30	17	56.7
2	38	24	63.2	41	28	68.3	79	52	65.8
3	27	14	51.9	23	11	47.8	50	25	50.0
4	6	5	83.3	5	1	20.0	11	6	54.5
Total	88	53	60.2	82	47	57.3	170	100	58.8

fish were not run-of-the-river, they were naive to riverine conditions; therefore, their behavior may not have been representative of in-river juvenile chinook salmon.

Run-of-the-river juvenile hatchery steelhead were collected from the juvenile separator at Lower Monumental Dam and transported to Ice Harbor Dam during early June. Steelhead were radio tagged and released on the day of transport (Table 5). While the behavior of chinook salmon and steelhead cannot be directly compared, the radio-tagged hatchery steelhead were expected to exhibit behavior more typical of naturally migrating fish. Release sites for radio-tagged steelhead were the same as for chinook salmon with the exception that none were released at RS-4 and steelhead were released at RS-5, located at RKm 16.1 near navigation marker "13".

Test Conditions

The hydroacoustic evaluations of the surface collectors at Ice Harbor Dam were conducted with surface bypass test conditions randomized over 3-day blocks, and spillway test conditions changed each Friday. All radio-telemetry receivers were monitored throughout the duration of the study. Test conditions and passage locations were identified for each radio-tagged fish recorded at the dam.

The test conditions of the experimental vertical slots collectors compared two velocities through a narrow slot and one velocity through a wide slot. The vertical slot conditions were: 1) Slot 1A - 1.2 m wide (narrow slot) with a water velocity of 0.6 m/s, 2) Slot 1A - 1.2 m wide (narrow slot) with a water velocity of 1.5 m/s, and 3) Slot 4B - 1.8 m wide (wide slot) with a water velocity of about 1.2 m/s. The vertical slots passed water into the sluiceway from the surface to a depth of 12.2 m at normal forebay levels.

Table 5. Summary of release and detection numbers for radio-tagged river-run juvenile hatchery steelhead released in the forebay of Ice Harbor Dam, 1995.

Release date	Release site	Number released	Number detected	Percent detected (%)
01 June	2	12	9	75.0
07 June	2	8	3	37.5
08 June	2	17	0	0.0
13 June	1	2	1	50.0
13 June	3	2	1	50.0
13 June	5	3	2	66.6
Total		44	16	36.4

Spillway test conditions compared surface skimming over stop logs to a deep draw of water under tainter gates. Spillway test conditions were alternated weekly between Spillbays 8 and 9 from 17 April to 2 June.

RESULTS AND DISCUSSION

Spill occurred through Spillbays 1-7 and 10 at Ice Harbor Dam throughout the season, ranging from 29.4 to 50.2 Kcfs with an average of 42.0 Kcfs on days that radio-tagged fish were released.

Due to the small numbers of test fish, the results of both radio-tagged spring and fall chinook salmon were combined. A total of 100 (58.8%) radio-tagged chinook salmon were detected at the dam after release. Seventy (41.2%) radio-tagged chinook salmon were not detected at Ice Harbor Dam. Seventy-eight (45.9%) radio-tagged hatchery yearling chinook salmon were detected at the upstream side of the dam and passed the dam through monitored sites (Table 6).

Travel time from release to initial detection at the dam for chinook salmon ranged from 0.5 to 19.0 hours (median of 1.0 hours). For radio-tagged fish released at RS 2 and 3 (mid-river and south-side of the forebay, respectively), median travel time was <1 hour. For those fish released on the north side (RS 1), median travel time was 3 hours. Median travel time for those released at RS 4, mid-river, 4.8 km upstream of the dam was 4 hours (Table 7).

Radio-tagged steelhead were released on 4 separate days. Three were released when all vertical slots and sluiceway flows were closed (treatment "0"), and the fourth was released in the afternoon before a treatment "0" day. Therefore approach times, movement

Table 6. Number released and passage distribution of radio-tagged hatchery yearling chinook salmon during surface collectortesting at Ice Harbor Dam, 1995.

Test scenario	Surface collector settings: Slot 1A[1]	Slot 2B[2]	Slot 4B[3]	Number released	Passage distribution (%): Overall passage	Powerhouse (sluiceway): Entry Slot 1A unknown	Slot 2B	Slot 4B		Spillway: Surface draw	Deep draw
Treatment 0	closed	closed	closed	9	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Treatment 1	low	open	low	134	64 (47.8)	3 (4.7)	25 (39.1)	2 (3.1)	16 (25.0)	14 (21.9)	4 (6.3)
Treatment 2	high	open	low	27	14 (51.9)	2 (14.3)	5 (35.7)	0 (0.0)	0 (0.0)	7 (50.0)	0 (0.0)
All treatments				170	78 (45.9)	5 (6.4)	30 (38.5)	2 (2.6)	16 (20.5)	21 (26.9)	4 (5.1)

[1] Slot 1A was set at 1.2 m wide with a low velocity of 0.6 m/s or at 1.2 m with a high velocity of 1.5 m/s.
[2] Slot 2B used existing sluice gates for surface collection.
[3] Slot 4B was set at 1.8 m wide with a low velocity of 1.2 m/s.

Table 7. Travel times of radio-tagged yearling hatchery spring and fall chinook salmon from release sites in the forebay to initial detection at Ice Harbor Dam, 1995.

Release site number	Release site location	Distance upstream form dam (km)	Median travel time to dam (hour)
1	North	1.6	3.0
2	Mid-river	1.6	<1.0
3	South	1.6	<1.0
4	Mid-river	4.8	4.0

patterns at the dam, and passage times through the dam for steelhead may be of limited value.

Of the 44 steelhead released, 16 (36%) were detected at the dam (Table 5). Three steelhead released at RS 4, near Levey Park (RKm 32.8, RM 20.4) were recorded at the buoys or dam 4 hours later (Table 8). Steelhead released closer to the dam at RS 1 were recorded at the buoys within minutes after release. Two steelhead were recorded on the buoys but not at the dam.

Results for the specific research elements were:

Task 1. Determine behavior of radio-tagged juvenile salmonids in relation to the vertical surface collector slots at Ice Harbor Dam.

One hundred radio-tagged fish were detected at the dam. Twenty-five passed via the monitored spillways; 53 passed via the bypass sluiceway; and 22 were detected at the dam but route of passage was undetermined (Fig. 9).

We released 12 groups of radio-tagged hatchery yearling chinook salmon (a total of 170 fish) at the various release sites. Eight releases (a total of 134 fish) were during surface collection conditions at Slots 1A and 4B with low water velocities, two releases (a total of 27 fish) occurred when Slot 1A had a high velocity and Slot 4B a low velocity, and two releases (a total of 9 fish) were with the slots closed (Table 6). The distribution of 53 radio-tagged hatchery yearling chinook salmon entering the sluiceway was comprised of 2 via Slot 4B, 5 via Slot 1A, 30 via Slot 2B, and 16 via undetermined routes. Few fish passed through Slot 1A under the high and low velocity; therefore, a preference for either condition was not detectable. Similarly, a preference between the wide slot (4B) and the narrow slot (1A) was not detectable. Surface or shallow draw conditions in the vertical slot

Table 8. Travel times of radio-tagged river-run juvenile hatchery steelhead from release sites in the forebay to initial detection at Ice Harbor Dam.

Release site number	Release site location	Distance upstream from dam (km)	Median travel time to dam (hour)
2	Mid-river	1.6	<1.0
4	Levey Park	4.8	4.0

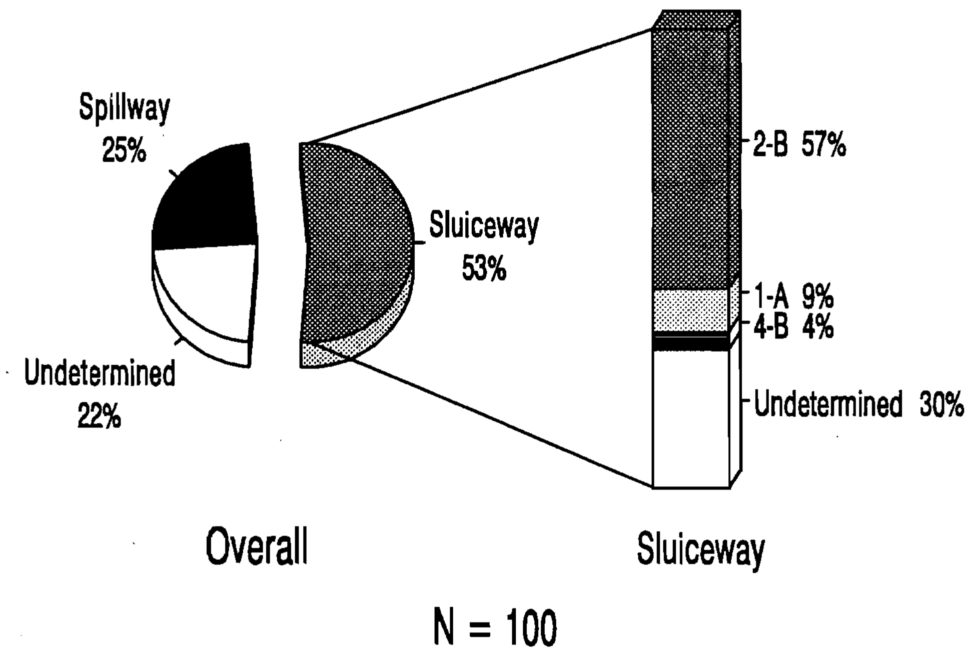


Figure 9. Passage routes for radio-tagged hatchery yearling chinook salmon at Ice Harbor Dam, 1995.

collectors had notably higher passage for radio-tagged hatchery yearling chinook salmon than did deep draw conditions.

Sixteen (36%) of the 44 radio-tagged steelhead were detected at Ice Harbor Dam and 11 were recorded as passing the dam. Of the 16 detected fish, 8 passed via the sluiceway and 3 via the spillway. Passage in relation to the operations of the surface collectors could not be evaluated because releases occurred when either the slots were closed or just prior to when the slots were closed.

Task 1.1. Determine approach direction to the surface collectors in the immediate vicinity of the powerhouse face.

Of the 100 radio-tagged hatchery yearling chinook salmon detected at the dam, 63 were initially detected at the powerhouse and 37 were detected at the spillway (Table 9).

Seventeen radio-tagged hatchery yearling chinook salmon exhibited lateral movement in the near-forebay following initial detection at the dam. Fifteen of these were initially recorded at either vertical slots 1A or 4B, and passed elsewhere. Eleven of the 15 fish passed through Slot 2B (powerhouse surface skimmer), while four passed from Slot 4B to either Slot 1A or the spillway. Numbers of radio-tagged hatchery steelhead detected at dam monitors were too few for analyses.

Task 1.2. Determine elapsed time from arrival at the dam to time of passage through surface collector.

Approximately one-third (17 of 53) of the chinook salmon that passed the dam through the sluiceway were initially detected at Slot 2B (Tables 6 and 9) with a median passage time of 1 minute. Fish with initial detections at Slot 1A, Slot 4B, and the spillways had median passage times of 62, 12, and 78 minutes, respectively. Travel times associated with Slot 2B reflected passage over the sluice gate and through the sluiceway

Table 9. Number released and number and percent initial detection at Ice Harbor Dam by release site for radio-tagged hatchery yearling chinook salmon, 1995.

Release site	Number released	Spillway		Powerhouse				Total detected
		Spillbay 8	Spillbay 9	Slot 1A Sluiceway	Slot 2B	Slot 4B		
1	30	6 (20.0)	1 (3.3)	2 (6.7)	3 (10.0)	4 (13.3)	1 (3.3)	17 (56.7)
2	79	13 (16.5)	5 (6.3)	14 (17.7)	10 (12.7)	3 (3.8)	7 (8.9)	52 (65.8)
3	50	8 (16.0)	2 (4.0)	1 (2.0)	3 (6.0)	2 (4.0)	9 (18.0)	25 (50.0)
4	11	2 (18.2)	0 (0.0)	1 (9.1)	1 (9.1)	0 (0.0)	2 (18.2)	6 (54.5)
Total	170	29 (17.1)	8 (4.7)	18 (10.6)	17 (10.0)	9 (5.3)	19 (11.2)	100 (58.8)

while the others reflect forebay movement following initial detection plus sluiceway passage.

Task 1.3. Determine depth of passage through the surface collector.

The depth of approach for 14 radio-tagged chinook salmon recorded at the wide vertical slot installed in Unit 4B was somewhat uniform over the 4 antenna depths (Table 10). Average depth of approach was similar for fall chinook salmon and spring chinook salmon. Seventeen (85%) of the 20 radio-tagged hatchery yearling chinook salmon approaching the narrow vertical slot in Unit 1A were concentrated between depths of 6.5 m to 20.2 m, and 3 (15%) were recorded between the depths of 0 m to 6.5 m. Average depth of entry into Slot 1A and Slot 4B for radio-tagged hatchery yearling spring and fall chinook salmon combined was 6.1 m and 5.5 m, respectively.

Task 1.4. Determine proportion of radio-tagged juvenile salmonids passing through the sluiceway surface collectors versus submerged traveling screens (STS).

Of the 53 chinook salmon recorded when passing through the sluiceway, 5 (9%) passed through Slot 1A, 30 (57%) passed via Slot 2B, 2 (4%) passed via Slot 4B, and 16 (30%) passed through the sluiceway via undetermined routes (Fig. 9 and Table 6).

Thirty-one (58%) radio-tagged hatchery yearling spring chinook salmon passed Ice Harbor Dam via the sluiceway. One (3%) fish passed via Slot 4B, 21 (68%) passed via Slot 2B, 2 (6%) passed via Slot 1A, and 7 (23%) into the sluiceway by an undetermined route (Table 11). Twenty-two (46%) of the radio-tagged hatchery yearling fall chinook salmon passed via the sluiceway. Of the 22, one (5%) entered via Slot 4B, 9 (41%) entered via Slot 2B, 3 (14%) entered via Slot 1A, and 9 (41%) entered the sluiceway through an unknown route.

Table 10. Depth at which individual radio-tagged hatchery yearling chinook salmon approached the vertical slots in Units 1A and 4B.

Depth range (m)	Unit 1A Number of fish (%)	Percent	Unit 4B Number of fish	Percent (%)
0.0 - 6.5	3	15.0	5	35.7
6.5 - 13.4	8	40.0	3	21.4
13.5 - 20.2	9	45.0	4	28.6
20.3 - 27.0	0	0.0	2	14.3
Total	20	100.0	14	100.0

Table 11. Passage route selection to the sluiceway by radio-tagged hatchery yearling spring and fall chinook salmon at Ice Harbor Dam, 1995.

Passage route	Spring chinook	Fall chinook	Total	Spring chinook	Fall chinook	Total
Unit 1A	2	3	5	6.5	13.6	9.4
Unit 2B	21	9	30	67.7	40.9	56.6
Unit 4B	1	1	2	3.2	4.5	3.8
Undetermined	7	9	16	22.6	40.9	30.2
Total	31	22	53	100.0	100.0	100.0

The median travel time for fall chinook salmon from release to detection on the sluiceway monitors (9 fish) was 2.8 hrs with a maximum of 19.0 h. The median travel time for vertical slot-passed fall chinook salmon (13 fish) was 2.9 hours with a maximum of 8.1 hours. The median travel time for spring chinook salmon detected only in the sluiceway (7 fish) was 2.1 h with a maximum of 13.7 h while the median travel time for vertical slot-passed fall chinook salmon (24 fish) was 2.0 h with a maximum of 12.1 h.

Task 2. Determine behavior of radio-tagged juvenile salmonids in relation to the experimental spillway surface skim condition at Ice Harbor Dam.

Twenty-five radio-tagged hatchery yearling chinook salmon passed Ice Harbor Dam via monitored spillbays (Table 6). The majority of these (84%) passed during surface or shallow draw conditions compared to deep draw conditions.

The majority of fish that passed via the spillway were initially recorded in Spillbay 8 (Table 9). Median time from initial detection to spillway passage for these fish was 4 minutes. Two fish were first detected at Slot 4B and then passed over Spillbay 8, 39 and 49 minutes later, respectively.

Task 2.1. Determine approach direction in the immediate vicinity of the dam face.

Sixty-three (37%) of the radio-tagged hatchery yearling chinook salmon released in the forebay were initially detected at the powerhouse while only 37 (22%) were initially detected at the spillway. Ten (22.7%) of the radio-tagged steelhead were initially detected at the powerhouse, whereas only 6 (13.6%) were initially recorded at the spillway.

A comparison of percent initial detection at the monitored intake slots versus release sites for radio-tagged juvenile chinook salmon indicated that about 43% of the fish released in the middle of the forebay at RS 2 were initially detected in one of the three powerhouse test slots or sluiceway. Nearly as high percent detection occurred for the other release groups.

Task 2.2. Determine proportion of radio-tagged juvenile salmonids passing over the spillway skimmer compared to normal deep release of spilled water through the tainter gates.

About 78% of the radio-tagged hatchery yearling chinook salmon initially detected at the spillway were specifically recorded at Spillbay 8. Virtually all 25 of the chinook salmon passing over the monitored spillbays did so when the surface skimming spill condition was in effect.

Task 3. Evaluate radio-tracking buoys.

Our initial evaluation of radio-tracking buoys provided encouraging results. Prototype radio-tracking buoys were completed and deployed in the forebay midway through the study. Despite only four buoys in the forebay, the high river flow conditions, and the limited detection range of radio tags for juvenile fish, we were still able to detect both radio-tagged juvenile chinook salmon and steelhead.

Thirty-six percent of the radio-tagged hatchery yearling chinook salmon and 34% of the radio-tagged hatchery steelhead were detected by the buoy monitors, primarily on the underwater antennas. Of the fish detected by the buoy monitors, 89% and 100% of the chinook salmon and steelhead, respectively, were subsequently detected at the dam.

Radio-telemetry receivers mounted on buoys anchored in strategic locations or grid patterns could provide valuable successive data for fish movement patterns and for areas beyond signal range of the fixed-site receivers located on shore. Radio-tracking buoys can also reduce mobile tracking time and effort and decrease safety hazards associated with operating boats within the boat restricted zone of the forebay.

SUMMARY

1. Monitoring the entry and passage behavior, relative to individual surface collection devices, of radio-tagged juvenile salmonids at collection and bypass facilities of hydroelectric dams is feasible.
2. Radio-tagged hatchery yearling chinook salmon in this study showed a preference for surface skimming operations over the relatively deeper drawing surface collection operations as a means of passage at both the powerhouse and spillway at Ice Harbor Dam.
3. It was not possible with our limited data to determine the passage routes into the powerhouse of the fish detected only on the sluiceway monitors.
4. The 30 MHZ telemetry system developed by NMFS which utilizes a combination of individually coded, 1-second pulse-rate tags, and fast scanning receivers allowed monitoring of tagged fish passing through short dimensional openings under high velocity flows.

ACKNOWLEDGMENTS

We thank the many COE personnel who provided information and assistance: Rick Jones, Teri Barila, Dan Kenney, and Martin Ahmann from the Walla Walla District office; Donald Phillips, Steve Voss, Scott Sutliff, Dave Easley, Ford Shockman, Randy Reynolds, Buddy Black, Lester Maier, Gordon Gann, Dolores Owen, David Woodland, and Pat Slape from Ice Harbor Dam; and Bill Spurgeon from Lower Monumental/Ice Harbor Dam fish facilities.

We thank the personnel of BioSonics (especially Jim Dawson, John Hedgepeth, Randy Holeman, and Chuck Ebel) for their cooperative coordination of research efforts during a busy test schedule and in a crowded work site.

We thank hatchery managers Bill Miller of Dworshak National Fish Hatchery and Rob Allen of Lyons Ferry Hatchery.

Last, but of equal importance, we acknowledge the help of the following NMFS personnel: Brad Peterson, Jim Simonson, Scott Davidson, Ron Marr, Thomas Ruehle, and Penny Smith.

REFERENCES

Giorgi, A. E., L. Stuehrenberg, and J. Wilson. 1988. Juvenile Radio-tag study: Lower Granite Dam, 1985-86. Report to Bonneville Power Administration, Contract DE-A179-85BP21237, 50 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98122-2097.)