**U.S. Army Corps of Engineers**
**Portland District**

# Passage Behavior of Radio-Tagged Yearling Chinook Salmon and Steelhead at Bonneville Dam Associated with the Surface Bypass Program, 1999

Annual Report

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# Executive Summary

In 1994, the U.S. Army Corps of Engineers (COE) initiated a program to develop and evaluate surface oriented juvenile salmonid bypass systems at hydroelectric dams on the Columbia and Snake Rivers. The goal of the program was to develop juvenile bypass systems that would significantly improve the passage efficiency and survival of juvenile salmonids during their downstream migration.

In 1999, the US Geological Survey (USGS) used radio telemetry to examine the movements and behavior of juvenile hatchery steelhead *Oncorhynchus mykiss* and yearling spring chinook salmon *O. tshawytscha* in the forebay of Bonneville Dam. The objectives of this research were to determine: 1) the general behavior, distribution, and approach patterns of juvenile salmonids upriver and in the forebay areas of Bonneville Dam; 2) the time and route of dam passage; 3) fish behavior associated with tests of surface bypass concepts and prototype surface bypass structures; and 4) compare these results to those observed during 1998. The following points summarize the major results of research in 1999.

*Detection of Radio-Tagged Fish*

Radio tags were implanted into 779 juvenile hatchery steelhead and 1106 yearling spring chinook salmon and released at Rock Creek (Rkm 370), John Day (Juvenile Fish Bypass Facility), and The Dalles Dam. Of these fish, we detected 73% of the juvenile hatchery steelhead and 69% of the yearling spring chinook salmon at Bonneville Dam. Of the fish released at Rock Creek, 64% of the yearling chinook salmon and 70% of the juvenile hatchery steelhead were detected at Bonneville Dam. Of the fish released at the John Day Juvenile Fish Bypass Facility, 67% of the yearling spring chinook salmon and 77% of the juvenile hatchery steelhead were detected at Bonneville Dam. Seventy nine percent of the yearling spring chinook salmon released at The Dalles Dam were detected at Bonneville Dam. In addition to the fish we radio-tagged, we also detected a total of 170 fish released from various sites above John Day Dam. These fish consisted of 2 yearling spring chinook salmon, 2 sockeye salmon, and 166 juvenile hatchery steelhead.

*Approach to Bonneville Dam*

Regardless of species and release site more fish were first detected at the spillway (37%) than at Powerhouse I (PH I) (31%) or Powerhouse II (PH II) (29%). Of the juvenile hatchery steelhead detected at PH I, 52% were first detected at the north end of the powerhouse, 31% in the area of the PSC, and 17% at the south end of the powerhouse. Of the yearling spring chinook salmon first detected at PH I, 48% were detected at the north end of the powerhouse, 35% in the area of the PSC, and 17% at the south end of the powerhouse. Overall, radio-tagged fish had longer residence times and a higher number of observations in the forebay of PH I than at PH II or the spillway. Median residence times for juvenile hatchery steelhead were 5.6 h at PH I, 3.9 h at PH II, and 0.3 h upstream of the spillway. Median residence times for yearling spring chinook salmon were 1.0 h at PH I, 0.2 h at PH II, and less than 0.1 h upstream of the spillway.

*Time and Route of Passage*

The distribution of passage among dam areas was similar for both species. Of the fish that were detected passing Bonneville Dam, 39-41% passed via the spillway, 30-40% passed through PH I, and 22-29% passed through PH II. Of the fish that passed through PH I, 53-68% passed north of the PSC, 9-21% passed in the area of the PSC (units 3, 4, under the PSC at unit 5, or 6), 4% passed via the PSC through unit 5, and 19-22% passed south of the PSC. Of the fish that passed at PH II, 34-43% passed at the north end and 57-66% passed at the south end of the powerhouse. At the spillway, a majority (67-68%) of the radio-tagged fish passed at the north end. Generally, fish from all release sites passed the dam throughout the diel period, although passage was slightly higher during nighttime (2000-0659 h).

*Surface Bypass Concepts*

The difference between the percentages of fish detected within 10 m versus 3 m in front of the PSC at unit 5 was small. Of the fish detected within 10 m of the PSC entrance at unit 5, 81% (75 of 92) were also detected within 3 m of the PSC entrance at unit 5. Entrance efficiencies at unit 5 were lower for fish that came within 10 m (19-

20%) of the PSC than fish that came within 3 m (27-30%) at a 5 ft. slot width. During a 20 ft. slot test, 21-33% of the fish that came within 10 m of the PSC at unit 5 entered. A similar percentage of fish (21-40%) that came within 3 m of the PSC at unit 5 entered during the 20 ft. slot width.

Slot efficiency, defined as the number of fish that entered unit 5 divided by the sum of fish that entered unit 5 plus the number of fish that went under the PSC at unit 5. Based on detections within 3 m, the slot efficiency during a 5 ft. slot width was 30-75%, and during a 20 ft. slot test was 55-75%. Regardless of slot width and species, the majority of the fish that were detected within 3 or 10 m in front of the PSC entrance at unit 5 (71-72%) did not enter the PSC. Radio-tagged fish either moved north or south along the PSC face, entered the PSC at unit 5, or went under the PSC into unit 5. At 10 m, 46% moved and passed south of the unit 5 PSC entrance while 26% moved and passed to the north of the PSC. Likewise at 3 m, 48% of the fish detected in front of the PSC entrance at unit 5 moved and passed south of unit 5 entrance while 23% moved and passed north.

Residence times within the PSC differed between slot widths and species. Regardless of slot width, the median residence time was 0.77 h for juvenile hatchery steelhead and less than 0.1 h for yearling spring chinook salmon. At a 5 ft. slot width, juvenile hatchery steelhead had a residence time of 0.2 h while yearling spring chinook salmon had a residence time of less than 0.01 h. During the test of the 20 ft. slot width, juvenile hatchery steelhead had a median residence time of 3.0 h and yearling spring chinook salmon had a median residence time of 1.8 h.

# 1.0 Introduction

Survival of out-migrating juvenile salmonids *Oncorhynchus* spp. in the Columbia River may be improved by successfully bypassing fish through or around hydroelectric dams. Routing fish away from turbine units may minimize delay associated with the forebay environment. In 1994, the U.S. Army Corps of Engineers (COE) initiated a prototype development program for surface collection and bypass systems (surface bypass) for the lower Snake and Columbia River dams to increase bypass efficiency for juvenile salmonids. In order to evaluate the efficiency of these systems and make recommendations to improve their performance, detailed information regarding juvenile salmonid behavior was needed. Giorgi and Stevenson (1995) reviewed existing studies describing juvenile salmonid passage behavior at Bonneville Dam and the applicability of these studies to developing surface bypass systems. They identified many deficiencies regarding juvenile salmonid behavior at Bonneville Dam and suggested that a combination of hydroacoustic and radio telemetry would be the best way to evaluate the passage efficiency of surface collection and bypass structures.

In 1999, the U.S. Geological Survey used radio telemetry to examine the movements and behavior of yearling spring chinook salmon *O. tshawytscha* and juvenile hatchery steelhead *O. mykiss* in the forebay of Bonneville Dam. The objectives of this research were to determine: 1) the general behavior, distribution, and approach patterns of juvenile salmonids upriver and in the forebay areas of Bonneville Dam; 2) the time and route of dam passage; 3) fish behavior associated with tests of surface bypass concepts and prototype surface bypass structures; and 4) compare these results to those observed during 1998.

# 2.0 Methods

*2.1 Study Site*

Bonneville Dam is located on the Columbia River at river km 233. The dam consists of two powerhouses and a single spillway, each separated by an island. PH I consists of 10 turbine units and is located at the south side of the river, spanning from the Oregon shore to Bradford Island. PH II consists of eight turbine units and is located at the north side of the river, spanning from Cascade Island to the Washington shore. The spillway lies between Cascade and Bradford islands and has 18 spill gates. A navigation lock is located at the south end of PH I (Figure 1).

*2.2 Telemetry Equipment*

*2.2.1 Transmitters*

Pulse-coded transmitters developed by Lotek Engineering (Lotek) were implanted in juvenile hatchery steelhead and yearling spring chinook salmon. Two transmitter sizes were used to accommodate the different sizes of the two species. Transmitters implanted in juvenile hatchery steelhead were 8.2 mm (diameter) x 18.9 mm and weighed 1.75 g in air, while the transmitters implanted in yearling spring chinook salmon were 7.3 mm (diameter) x 18 mm and weighed 1.4 g in air. The antenna length was 30 cm for both transmitters. The pulse rate was 2.0 s, resulting in an estimated tag life of 18 d for the steelhead transmitters and 8 d for the yearling spring chinook salmon transmitters.

*2.2.2 Fixed Receiving Equipment*

Four-element Yagi (aerial) antennas were positioned along the periphery of the forebay to detect fish within about 100 m of the dam face, defined as the near-dam area. Up to seven aerial antennas were connected to a Lotek SRX 400 receiver, which recorded the telemetry data. The SRX 400 scans all antennas combined (the master antenna), until it receives a signal. The receiver then cycles through individual aerial antennas (auxiliary antennas) to determine a more precise location of the transmitter.

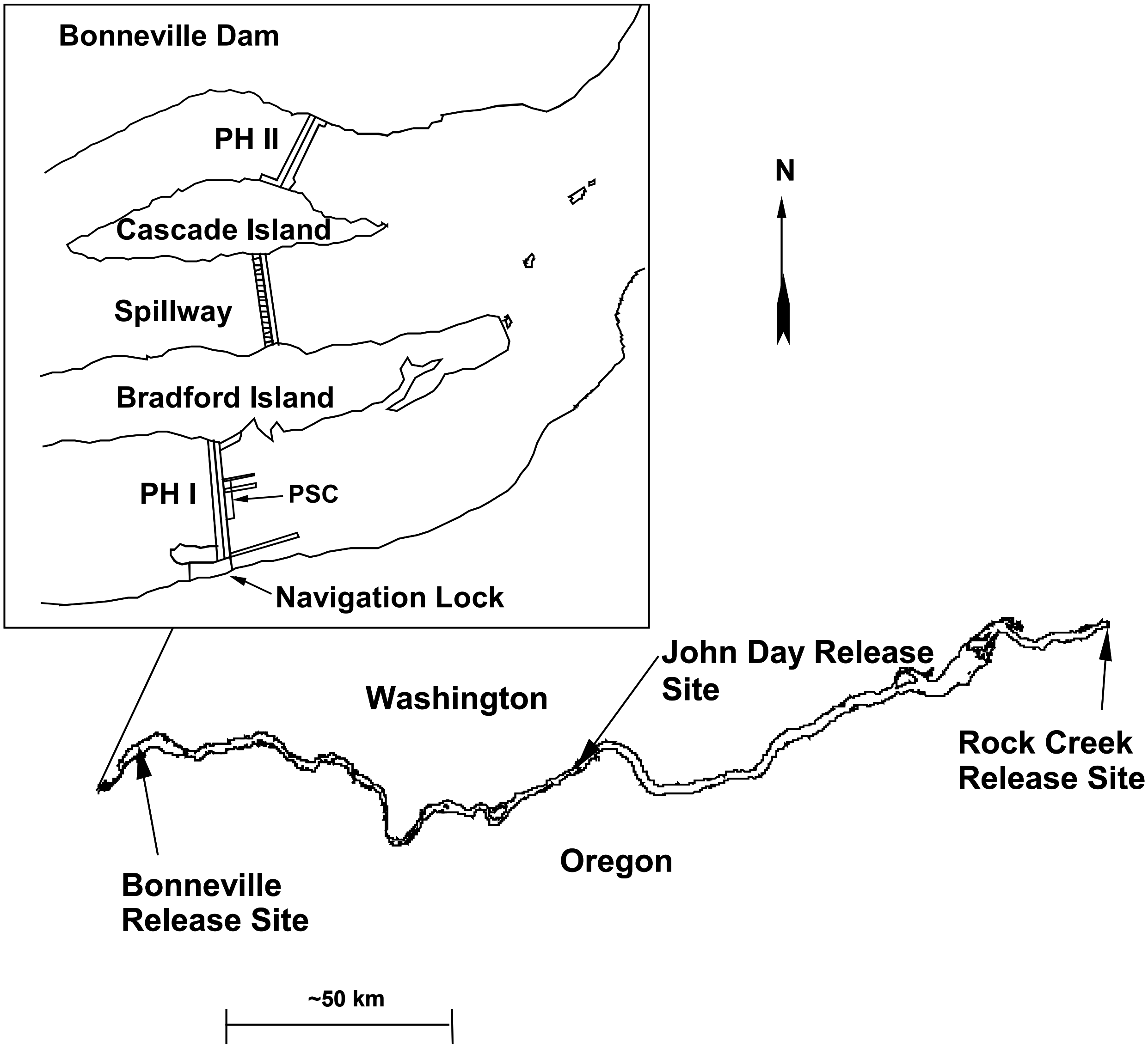


Figure 1. Columbia River from Rock Creek (Rkm 370) to Bonneville Dam (Rkm 233) showing study area and release locations. PH refers to powerhouses and PSC refers to the Prototype Surface Collector

Because the cable lengths leading from each auxiliary antenna to the receivers differed, pre-amplifiers were used to ensure the integrity of the signals transmitted to the receivers. A standard input signal was used to determine the signal strength reaching the receiver from each auxiliary antenna. Over amplified signals were then attenuated to a standard level, resulting in a balanced receiving system.

Additional aerial antennas and underwater antennas were used to detect radio-tagged fish in and around the prototype surface bypass structures and other areas of interest. Up to seven underwater antennas and/or aerial antennas were attached to a Lotek Digital Spectrum Processor (DSP) in tandem with a SRX 400. The DSP simultaneously scans 25 preset frequencies. Once the DSP receives a signal on the master antenna it immediately scans each auxiliary antenna and records the signal from the strongest antenna. On the dam, 12 V deep-cycle batteries attached to solar panels or directly to a 110 V source powered receivers and preamplifiers.

*2.2.3 System Configuration*

A total of 33 aerial antennas attached to six SRX 400 receivers monitored the near-dam area in the Boneville forebay. Four additional aerial antennas attached to three SRX 400 receivers positioned 100-500 m upstream of the dam. These sites served as our entrance stations to monitor arrival of fish into the study area. Six aerial antennas attached to twelve SRX 400 receivers positioned about 100 m downstream of the dam were to monitor fish as they left the study area.

At PH I, 33 underwater antennas connected to five DSP units were positioned along the face of the PSC, 20 underwater antennas connected to two DSP units were positioned within the PSC, and 36 underwater antennas connected to three DSP units were positioned on the trash racks at turbines 3, 5, and 6 behind and below the PSC (Figure 2). Three additional DSP units connected to 29 underwater antennas monitored the areas near the dam and trash racks at turbines 1 and 2. Monitoring fish passage through the turbine units was further enhanced with the addition of 26 underwater antennas mounted on the traveling screens in units 2, 3, 5, and 6. Four additional underwater antennas were placed within the sluiceway at PH I, and two underwater antennas were in the Downstream Migration Facility (DSM). The range of the underwater antennas was about 10 m, with the exception of three underwater antennas that were mounted on a frame in the middle of the PSC slot opening of unit 5. The additional three antennas at unit 5 were tuned so that the range was limited to within 3 m.

*2.3 Tagging, Fish Handling, and Release*

Juvenile hatchery steelhead and hatchery chinook salmon to be implanted with radio-transmitters were obtained from the juvenile collection and bypass facilities operated by the National Marine Fisheries Service at John Day Dam. Fish to be implanted with transmitters were generally held 12-24 h prior to tagging in tanks at the juvenile collection and bypass facilities. Fish were carefully screened prior to tagging and were found suitable for tagging if they were free of injuries, severe descaling, signs of gas bubble trauma, or other abnormalities. All fish were surgically implanted following the methods of Adams et al. (1998b) and Martinelli et al. (1998).

After tagging, fish were held in the river at Rock Creek, Washington, and in the juvenile bypass collection facility at John Day Dam until they were released. Fish released at Rock Creek, were checked for mortalities and then towed by boat out into the north river channel where they were released. At the John Day Juvenile Fish Bypass Facility, fish were checked for mortalities and released through the juvenile bypass system. All fish released from The Dalles were yearling spring chinook salmon and were released at either the north or south side of the forebay or into the tailrace.

We released a total of 779 juvenile hatchery steelhead and 1106 yearling spring chinook salmon. Radio tagged steelhead had a mean weight of 85.4 g and a mean fork length of 214.5 mm. Yearling spring chinook salmon had an average weight of 43.3 g and an average fork length of 162.6 mm. In addition to the fish tagged for our studies, a number of other telemetry studies operating upriver released about 1700 juvenile hatchery steelhead, yearling spring chinook salmon, and juvenile sockeye salmon.

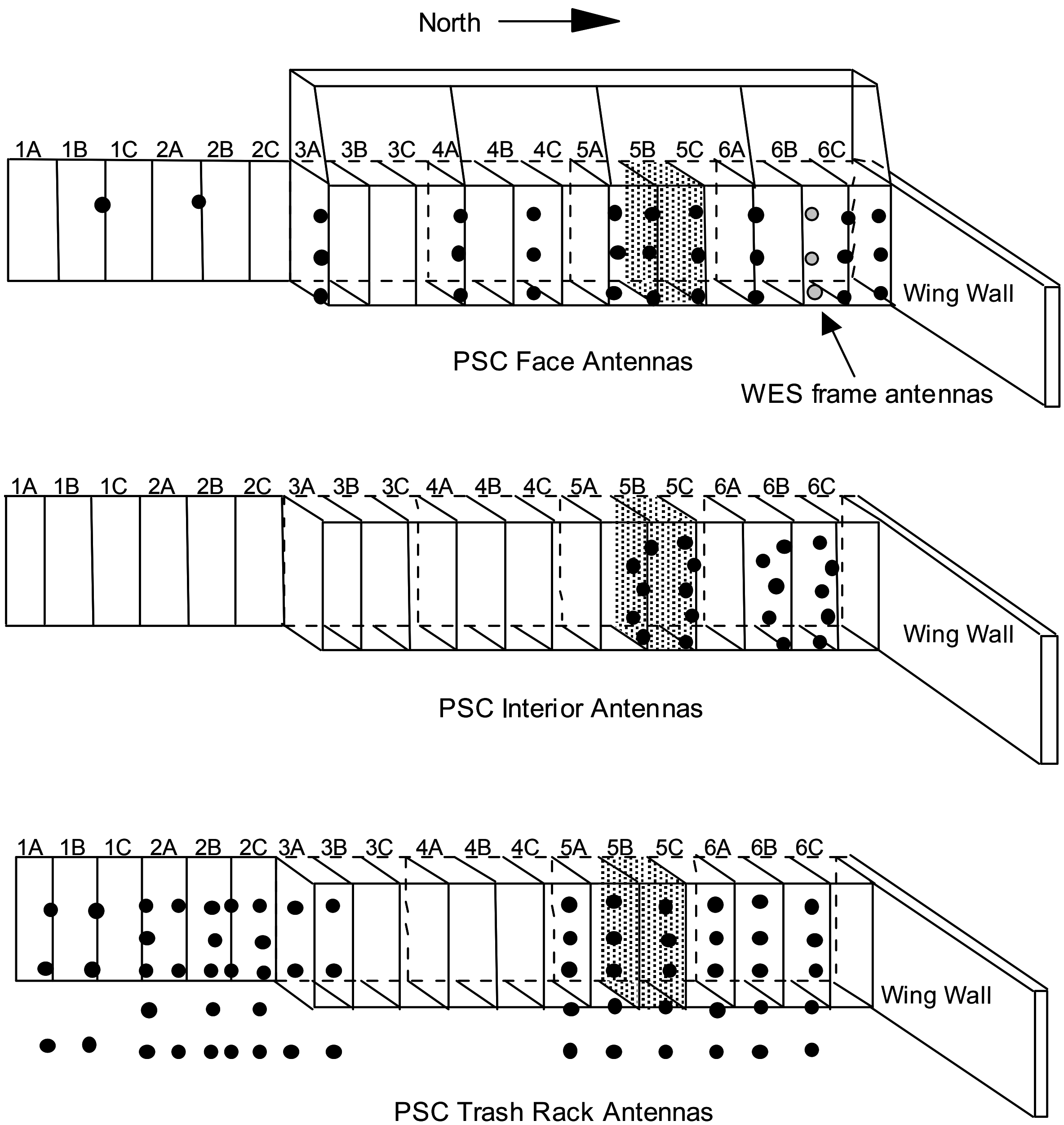


Figure 2. Schematic of Prototype Surface Collector underwater antenna arrays at Bonneville Dam Powerhouse I during spring, 1999. Black circles represent individual underwater antennas. Light colored circles represent antennas mounted on the Waterways Experiment Station's (WES) frame.

*2.4 Data Management and Analysis*

Fixed receivers were typically downloaded every other day and imported into SAS (version 7; SAS Institute Inc., Cary, N.C., USA) for subsequent proofing and analyses. These data were proofed to eliminate invalid records including background noise, single records of a particular channel and code, records that were collected prior to the known release date and time, and records known to be fish that were predated by avian or aquatic predators. Generally, the minimum number of records required to consider a contact with a radio-tagged fish valid was a combination of two master antenna contacts and one auxiliary antenna contact, or three master antenna contacts, within 1 min of each other.

The location and time an individual fish was first detected by fixed-receivers on the dam face was considered the route and time of entrance into the near-dam area. Similarly, the last contact of an individual fish on the fixed-receivers on the dam face was considered to be the route and time of passage through the dam. Manual tracking on the dams has verified that the last contact by the fixed-receiving stations is typically a good estimate of passage (Sheer et al.; 1997; Holmberg et al.; 1998; Hensleigh et al.; 1999). Data collected from tailrace exit stations were used to assign general passage among dam areas (i.e., PH I, PH II, or spillway) for fish not detected in the forebay, but were excluded from analyses of more specific passage locations (e.g., North PH I or PSC).

Residence time in the near-dam area, defined as the amount of time between the first and last contacts in the forebay, was calculated for each radio-tagged fish detected in the near the dam (residence times were not calculated for fish that were only detected at the entrance and exit stations). These residence times were a minimum estimate of the actual time that radio-tagged fish spent in the near-dam area because of receiver limitations (fish may have been in the near-dam area prior to their first contact and following their last contact) and detection probabilities (fish that approached very deep may have short residence times or passed the dam undetected).

Radio-tagged fish were often detected on multiple auxiliary antennas where zones of coverage overlapped, making data reduction necessary. Fish detected by more than one aerial auxiliary antenna within a 2 min time period were assigned to a single location corresponding to the antenna where the highest signal strength was recorded and all other records were excluded. Detections with underwater antennas were not included in the data analysis because they typically had more detections than aerial antennas and would bias the data, making comparisons with previous years useless. A 2 min interval was selected because fish could easily move from one antenna location to another during this time, and it approximately coincided with the upper boundary of time needed to complete a scan cycle if several fish were present at any given time. The assigned location was considered an observation and was used in the analyses of the distribution of observations and lateral movements.

To evaluate the PSC, we calculated two indices associated with PSC efficiency. The first was "entrance efficiency", which was the number of fish that entered the PSC at unit 5 divided by the number of fish that were detected within 3 m of the PSC entrance. Secondly, we calculated "slot efficiency" for unit 5, which is defined as the number of fish that entered the PSC at unit 5 divided by the total number of fish entering the PSC at unit 5 and the number of fish that went under the PSC at unit 5. In order to more accurately compare entrance efficiencies to 1998, we calculated entrance efficiencies based on detections within 10 m in addition to the detections within 3 m. Both of these measures were comparable to the estimates of PSC efficiency reported by researchers using hydroacoustic techniques.

# 3.0 Results

*3.1 Project Operations*

Total discharge at Bonneville Dam from 1 May through 10 June ranged from 252 to 384 kcfs. During 1998, total discharge at Bonneville Dam from 19 April to 6 June ranged from 138 to 419 kcfs (Table 1). During both years, discharge at PH I remained fairly constant, and discharge at PH II and the spillway increased (Figure 3).

Table 1. Daily average discharge (Kcfs) at Bonneville Dam during spring for 1998 and 1999. All values have been rounded to the nearest whole number. Summary statistics are based on a 49 d period for 1998 and a 41 d period for 1999. Data was obtained from the Fish Passage Center Website (www.fpc.org; 1999).

| | **1999** | May 1 through June 10 | | | **1998** | April 19 through June 6 | | |
|---|---|---|---|---|---|---|---|---|
| Discharge | Mean | Median | Min | Max | Mean | Median | Min | Max |
| Total | 317 | 309 | 252 | 384 | 309 | 324 | 138 | 419 |
| Powerhouse I | 81 | 81 | 73 | 86 | 75 | 76 | 52 | 94 |
| Powerhouse II | 115 | 122 | 73 | 136 | 103 | 21 | 3 | 135 |
| Spillway | 112 | 97 | 92 | 156 | 122 | 110 | <1 | 210 |

*3.2 Number of Fish Detected*

At Bonneville Dam, we detected 73% (567 of 779) of the juvenile hatchery steelhead and 69% (764 of 1106) of the yearling spring chinook salmon that were released from Rock Creek, John Day Dam, and The Dalles Dam. Of the fish released at Rock Creek, we detected 70% (335 of 479) of the juvenile hatchery steelhead and 64% (299 of 470) of the yearling spring chinook salmon. Of the fish released at the John Day Juvenile Fish Bypass Facility, 77% (232 of 300) of the juvenile hatchery steelhead and 67% (200 of 297) of the yearling spring chinook salmon were detected. Seventy-eight percent (265 of 339) of the yearling spring chinook salmon released from the The Dalles were detected at Bonneville Dam.

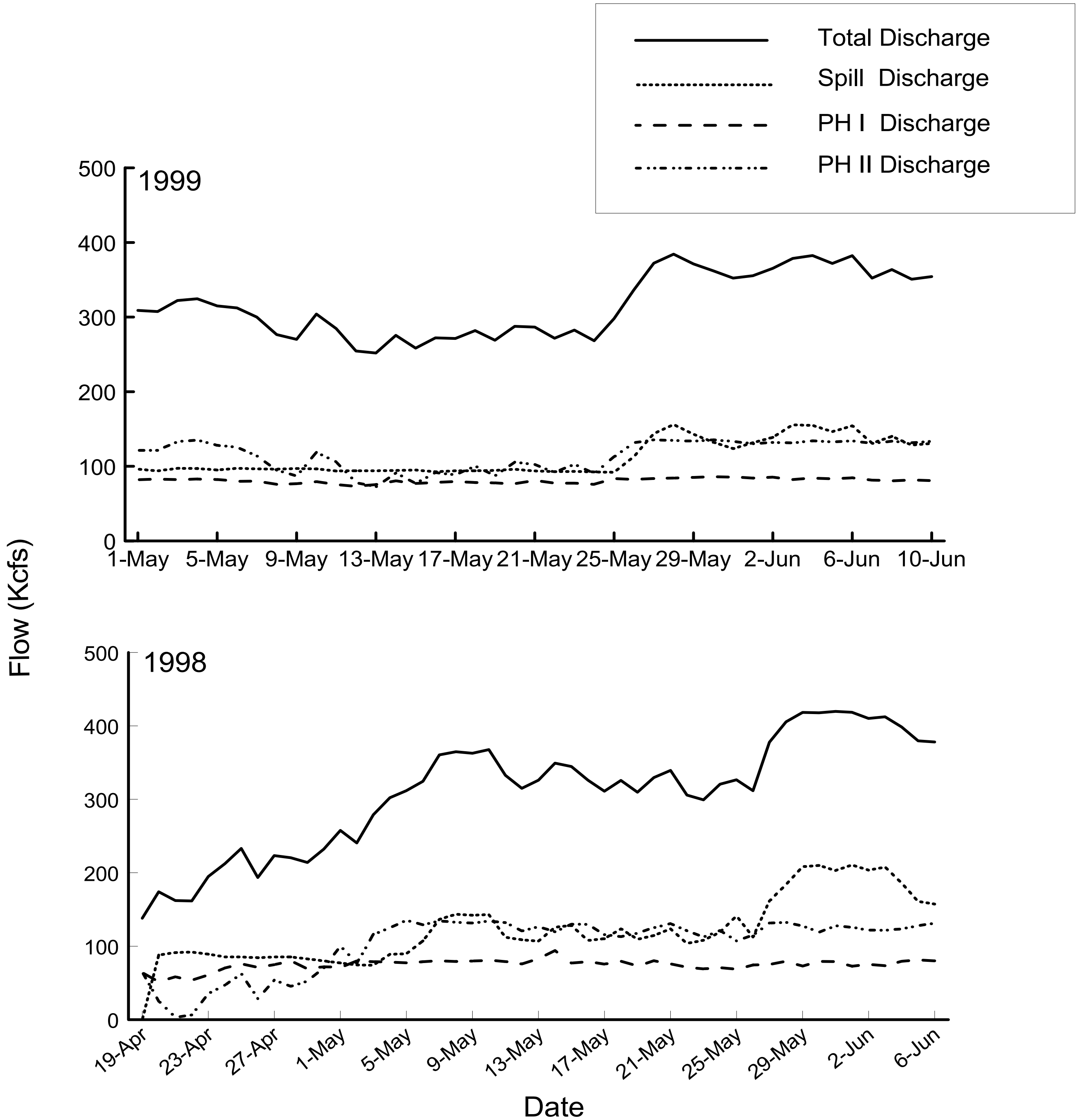


Figure 3. Total discharge for powerhouse I (PH I), powerhouse II (PH II), and spillway at Bonneville Dam during 1999 and 1998 spring sampling periods. Data was obtained from the Fish Passage Center web site (1999).

*3.3 Travel Times*

In general, travel times increased from release site to Bonneville Dam as the distance increased from the release site to Bonneville Dam. Of the fish released at Rock Creek, the juvenile hatchery steelhead had a higher median travel time (3.20 d) to Bonneville Dam than the yearling spring chinook salmon (2.84 d). Of the fish released at the John Day Dam Juvenile Fish Bypass Facility, the juvenile hatchery steelhead had a shorter median travel time (1.65 d) to Bonneville Dam than the yearling spring chinook salmon (1.92 d). The median travel time for the yearling spring chinook salmon released at The Dalles was 1.2 d (Table 2).

Table 2. Descriptive statistics for radio-tagged juvenile hatchery steelhead and yearling spring chinook salmon travel times (h) from release to Bonneville Dam, during 1999.

| Release Site | Species | N | Mean | Median | Min | Max |
|---|---|---|---|---|---|---|
| Rock Creek | STH | 316 | 3.6 | 3.2 | 1.3 | 11.2 |
| | CHN | 285 | 3.1 | 2.8 | 1.5 | 8.5 |
| John Day Dam | STH | 210 | 1.9 | 1.7 | 1.1 | 10.8 |
| | CHN | 186 | 2.1 | 1.9 | 1.3 | 9.7 |
| The Dalles Dam | CHN | 239 | 1.4 | 1.2 | 0.8 | 13.8 |

*3.4 Approach to Bonneville Dam*

During 1999, the percent of fish contacted between dam areas was 29-38% at PH I, 26-32% at PH II, and 39-35% at the spillway. At PH I, 52% of the juvenile hatchery steelhead were detected at the north end, 31% were first detected in the area of the PSC, and 17% were detected at the south end of the powerhouse. Of the yearling spring chinook salmon detected at PH I, 48% were first detected at the north end, 35% were first detected in the area of the PSC, and 17% were first detected at the south end of the powerhouse. At PH II, 67% of juvenile hatchery steelhead and 66% of yearling spring chinook salmon were first detected at the north end of the powerhouse. Fish first detected at the north end of the spillway comprised of 89% of the juvenile hatchery steelhead released, and 87% of the yearling spring chinook salmon released (Tables 3 and 4).

Table 3. Summary of first and last detections for radio-tagged juvenile hatchery steelhead (STH) recorded by fixed stations at Bonneville Dam in 1998 and in 1999. Numbers of observations were based on detections by auxiliary antennas only. First and last detections include auxiliary and master antennas, but not fish detected at the entrance and exit stations (PH I=Powerhouse I, PH II=Powerhouse II).

| 1999 | Location | Area | Numbers of Observations | | First detections | | Last detections | |
|---|---|---|---|---|---|---|---|---|
| | | | N | % | N | % | N | % |
| | PHI | North | 127,381 | 68 | 137 | 52 | 179 | 68 |
| | | PSC | 23,021 | 12 | 80 | 31 | 36 | 14 |
| | | South | 36,317 | 20 | 45 | 17 | 50 | 19 |
| | | Total: | 186,719 | | 262 | | 265 | |
| | PHII | North | 47,282 | 32 | 60 | 33 | 51 | 34 |
| | | South | 99,118 | 68 | 122 | 67 | 101 | 66 |
| | | Total: | 146,400 | | 182 | | 152 | |
| | Spill | North | 25,205 | 54 | 216 | 89 | 167 | 67 |
| | | South | 21,243 | 46 | 27 | 11 | 83 | 33 |
| | | Total: | 46,448 | | 243 | | 250 | |

| 1998 | Location | Area | Numbers of Observations | | First detections | | Last detections | |
|---|---|---|---|---|---|---|---|---|
| | | | N | % | N | % | N | % |
| | PHI | North | 23,358 | 62 | 68 | 40 | 112 | 64 |
| | | PSC | 4,256 | 11 | 21 | 12 | 27 | 16 |
| | | South | 9,951 | 27 | 83 | 48 | 35 | 20 |
| | | Total: | 37,565 | | 172 | | 174 | |
| | PHII | North | 3,442 | 25 | 101 | 68 | 43 | 30 |
| | | South | 10,144 | 75 | 48 | 32 | 98 | 70 |
| | | Total: | 13,586 | | 149 | | 141 | |
| | Spill | North | 1,989 | 41 | 128 | 62 | 118 | 56 |
| | | South | 2,869 | 59 | 77 | 38 | 93 | 44 |
| | | Total: | 4,858 | | 205 | | 211 | |

Table 4. Summary of first and last detections for radio-tagged yearling spring chinook salmon (CHN) recorded by fixed stations at Bonneville Dam in 1998 and in 1999. Numbers of observations were based on detections by auxiliary antennas only. First and last contacts include auxiliary and master antennas, but not fish detected at the entrance and exit stations (PH I=Powerhouse I, PH II=Powerhouse II).

| 1999 | Location | Area | Numbers of Observations | | First detections | | Last detections | |
|---|---|---|---|---|---|---|---|---|
| | | | N | % | N | % | N | % |
| | PHI | North | 29,604 | 51 | 98 | 48 | 106 | 53 |
| | | PSC | 4,567 | 8 | 71 | 35 | 50 | 25 |
| | | South | 23,292 | 41 | 35 | 17 | 44 | 22 |
| | | Total: | 57,463 | | 204 | | 200 | |
| | PHII | North | 18,860 | 35 | 79 | 34 | 88 | 43 |
| | | South | 35,423 | 65 | 150 | 66 | 116 | 57 |
| | | Total: | 54,283 | | 229 | | 204 | |
| | Spill | North | 9,689 | 47 | 242 | 87 | 194 | 68 |
| | | South | 10,903 | 53 | 37 | 13 | 90 | 32 |
| | | Total: | 20,592 | | 279 | | 284 | |

| 1998 | Location | Area | Numbers of Observations | | First detections | | Last detections | |
|---|---|---|---|---|---|---|---|---|
| | | | N | % | N | % | N | % |
| | PHI | North | 5,253 | 32 | 82 | 57 | 81 | 56 |
| | | PSC | 948 | 6 | 15 | 10 | 23 | 16 |
| | | South | 10,088 | 62 | 47 | 33 | 40 | 28 |
| | | Total: | 16,289 | | 144 | | 144 | |
| | PHII | North | 1,120 | 3 | 67 | 48 | 48 | 35 |
| | | South | 3,947 | 97 | 72 | 52 | 90 | 65 |
| | | Total: | 5,067 | | 139 | | 138 | |
| | Spill | North | 452 | 55 | 119 | 60 | 105 | 52 |
| | | South | 364 | 45 | 81 | 40 | 96 | 48 |
| | | Total: | 816 | | 200 | | 201 | |

*3.5 Distribution of Observations*

The number of detections is a general indicator of where and how much time fish spent in the near-dam area. The largest numbers of detections regardless of species were at PH I, and the least amount of detections were at the spillway. These differences in the number of detections reflect the differences in residence times among the three dam areas. At PH I, 68% of the juvenile hatchery steelhead and 51% of the yearling spring chinook salmon observations were located at the north end, 8-12% of the observations were in the area of the PSC, and 20% of the juvenile hatchery steelhead and 41% of the yearling spring chinook salmon observations were at the south end of the powerhouse (Tables 3 and 4). At PH II, 65-68% of the observations were at the south end of the powerhouse. At the spillway, about an equal number of observations occurred on either the north or south end (Tables 3 and 4).

*3.6 Residence Time in the Near-dam Area*

Generally, steelhead had longer median residence times (1.9 d) compared to yearling spring chinook salmon (0.09 d). Fish that entered PH I had the longest median residence times, 5.6 d for juvenile hatchery steelhead and 1.1 d for yearling spring chinook salmon. Residence times at PH II were 3.8 d for juvenile hatchery steelhead and 0.2 d for yearling spring chinook salmon. Median residence times for fish that entered the spillway were 0.3 d for juvenile hatchery steelhead and less than 0.1 d for yearling spring chinook salmon (Table 5).

Regardless of slot width, the median residence times within the PSC at unit 5 were higher for juvenile hatchery steelhead (0.77 h) than for yearling spring chinook salmon (<0.1 h). During tests of a 5 ft. slot width, juvenile hatchery steelhead had a residence time of 0.2 h while yearling spring chinook salmon had a residence time of less than 0.01 h. During tests of a 20 ft. slot width, residence times for both species were higher. At a 20 ft. slot width, the median residence time for juvenile hatchery steelhead was 3.0 h and for yearling spring chinook salmon was 1.8 h (Table 6). Residence times for fish that were present during both slot conditions were excluded from this analysis.

Table 5. Sample size (N), mean, median, minimum (Min), and maximum (Max) residence times (hours) of radio-tagged juvenile hatchery steelhead and yearling spring chinook salmon by area of first contact at Bonneville Dam.

| First Location | Species | N | Mean | Median | Min | Max |
|---|---|---|---|---|---|---|
| 1999 | | | | | | |
| Powerhouse I | STH | 203 | 15.0 | 5.6 | <0.1 | 212.7 |
| | CHN | 127 | 7.5 | 1.1 | <0.1 | 152.7 |
| Powerhouse II | STH | 150 | 10.5 | 3.9 | <0.1 | 120.6 |
| | CHN | 200 | 5.5 | 0.2 | <0.1 | 86.0 |
| Spillway | STH | 251 | 2.0 | 0.3 | <0.1 | 78.3 |
| | CHN | 284 | 0.2 | 0.1 | <0.1 | 5.2 |

| First Location | Species | N | Mean | Median | Min | Max |
|---|---|---|---|---|---|---|
| 1998 | | | | | | |
| Powerhouse I | STH | 170 | 11.8 | 4.4 | <0.1 | 177.7 |
| | CHN | 142 | 8.1 | 1.3 | <0.1 | 138.7 |
| Powerhouse II | STH | 142 | 6.3 | 1.9 | <0.1 | 189.9 |
| | CHN | 134 | 2.3 | 0.3 | <0.1 | 69.1 |
| Spillway | STH | 190 | 3.1 | 0.2 | <0.1 | 187.1 |
| | CHN | 194 | 1.0 | <0.1 | <0.1 | 149.9 |

Table 6. Sample size (N), mean, median, minimum (Min), and maximum (Max) residence times (hours) in the PSC of radio-tagged juvenile hatchery steelhead and yearling spring chinook salmon at Bonneville Dam.

| Species | Slot Width (ft.) | N | Mean | Median | Min | Max |
|---|---|---|---|---|---|---|
| STH | 5 | 5 | 0.4 | 0.2 | <0.1 | 0.8 |
| | 20 | 5 | 9.1 | 2.9 | 0.6 | 33.4 |
| | pooled | 12 | 15.2 | 0.8 | <0.1 | 75.9 |
| CHN | 5 | 2 | 0.005 | 0.005 | <0.1 | 0.01 |
| | 20 | 6 | 3.9 | 1.8 | <0.1 | 13.6 |
| | pooled | 9 | 3.7 | 0.03 | <0.1 | 13.6 |

*3.7 Route and Time of Passage*

The location of the last detection by the fixed gear at the dam was our best estimate of passage route. Of the juvenile hatchery steelhead that passed Bonneville Dam, 40% passed through PH I, 39% passed via the spillway, and 22% passed through PH II. Of the yearling spring chinook salmon that passed Bonneville Dam, 41% passed via the spillway, 30% passed through PH I, and 29% passed through PH II (Table 7).

At PH I, 68% (179 of 265) of the juvenile hatchery steelhead and 53% (106 of 200) of the yearling spring chinook salmon passed the dam at the north end, while 19% (50 of 265) of the juvenile hatchery steelhead and 22% (44 of 200) of the yearling spring chinook salmon passed south of the PSC. Nine percent (24 of 265) of the juvenile hatchery steelhead and 21% (41 of 200) of the yearling spring chinook salmon passed in the area of the PSC (units 3, 4, under the PSC at unit 5, or 6), and 4% (12 of 265; 9 of 200) of both species passed via the PSC through unit 5. At PH II, 66% (101 of 152) of the juvenile hatchery steelhead and 57% (116 of 204) of the yearling spring chinook salmon passed at the south end of the powerhouse. Passage at the spillway was similar among species, with 67% of the juvenile hatchery steelhead and 68% of the yearling spring chinook salmon passing at the northern half. During 1998, the majority (56-64%) of fish passed at the north end of PH I, about 16% of the fish passed at the PSC, and 20-28% passed south of the PSC (Tables 3 and 4).

Table 7. Summary of detections between radio-tagged juvenile hatchery steelhead (STH) and yearling spring chinook salmon (CHN) at fixed-receiving stations at Bonneville Dam by dam area, spring 1999 and 1998. Numbers of observations are based on contacts by auxiliary antennas only. First and last contacts include auxiliary, master antennas, and fish contacted only at entrance and exit stations.

| Location | | Number of Observations | | First Contact | | Last Contact | |
|---|---|---|---|---|---|---|---|
| Species | Area | N | % | N | % | N | % |
| 1999 | | | | | | | |
| STH | PH I | 186,719 | 49 | 262 | 38 | 287 | 40 |
| | PHII | 146,400 | 39 | 182 | 26 | 159 | 22 |
| | Spill | 46,448 | 12 | 243 | 35 | 280 | 39 |
| | Total: | 379,567 | | 687 | | 726 | |
| CHN | PHI | 57,463 | 43 | 204 | 29 | 229 | 30 |
| | PHII | 54,283 | 41 | 229 | 32 | 219 | 29 |
| | Spill | 20,592 | 16 | 279 | 39 | 313 | 41 |
| | Total: | 132,338 | | 712 | | 761 | |

| Location | | Number of Observations | | First Contact | | Last Contact | |
|---|---|---|---|---|---|---|---|
| Species | Area | N | % | N | % | N | % |
| 1998 | | | | | | | |
| STH | PH I | 37,565 | 24 | 178 | 32 | 179 | 32 |
| | PHII | 13,586 | 9 | 167 | 30 | 143 | 36 |
| | Spill | 4,858 | 67 | 208 | 38 | 231 | 42 |
| . | Total: | 56,009 | | 553 | | 553 | |
| CHN | PHI | 16,289 | 23 | 161 | 28 | 161 | 30 |
| | PHII | 5,067 | 4 | 148 | 42 | 140 | 26 |
| | Spill | 816 | 73 | 224 | 30 | 232 | 44 |
| | Total: | 22,172 | | 533 | | 533 | |

Radio-tagged fish generally passed throughout the diel cycle with slightly more juvenile hatchery steelhead passing between 2100 hours and midnight. Yearling spring chinook salmon showed a slight increase in passage around 2000-0000 hours and 0400 - 0800 hours (Figure 4). The diel distribution of passage for radio-tagged juvenile salmonids in 1998 and 1999, showed a higher number fish passing from 1500 hours to midnight during 1998.

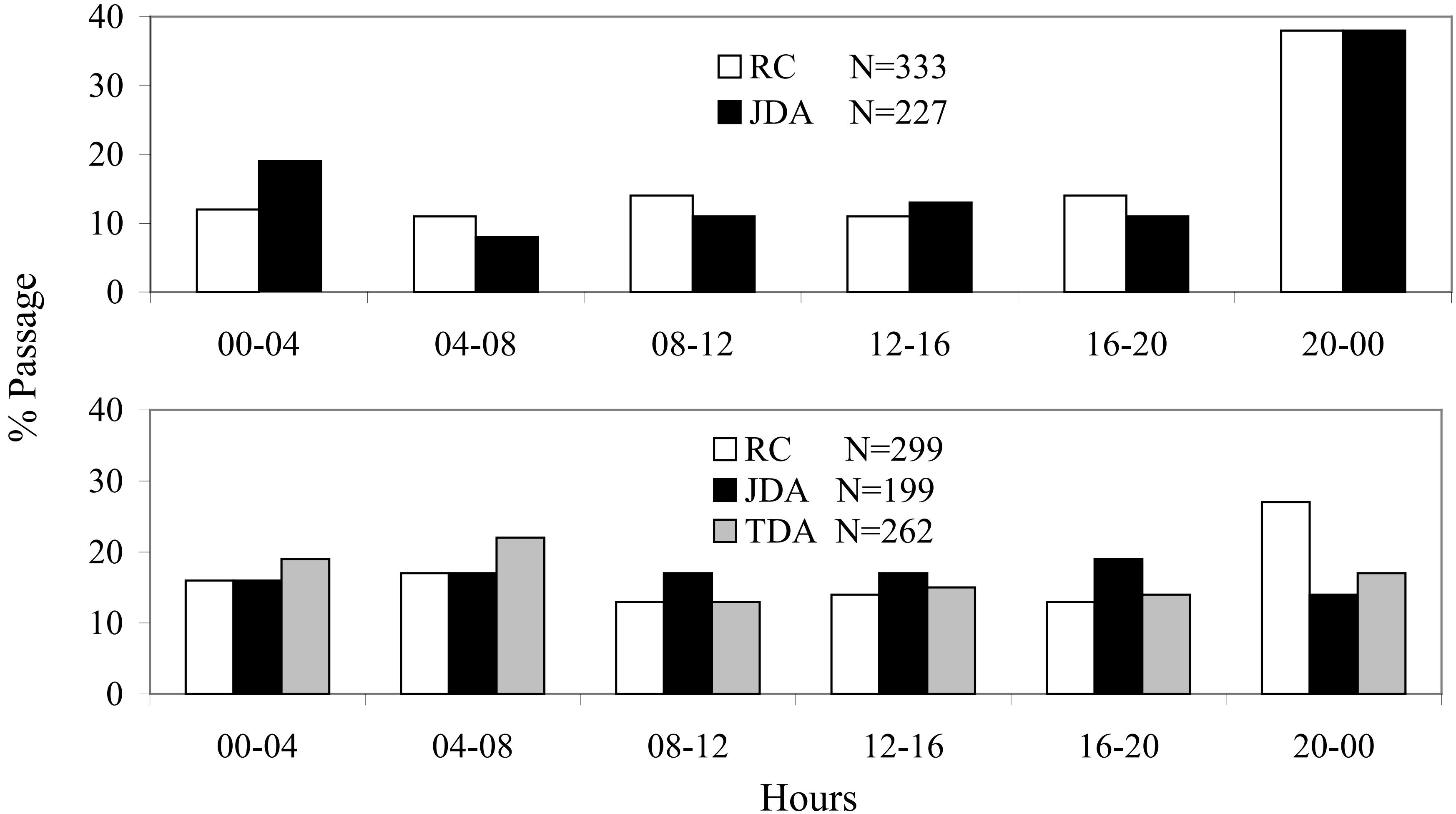


Figure 4. Percent passage through Bonneville dam by hour of day for radio-tagged juvenile hatchery steelhead (STH) and yearling spring chinook salmon (CHN) released from Rock Creek (RC), John Day Juvenile Bypass (JDA), and The Dalles Dam (TDA) at 4 hour time intervals during 1999

*3.8 Tests of the Prototype Surface Collector at Powerhouse I*

The percentages of steelhead and chinook salmon that entered the PSC were similar. Eighty-five percent (50 of 59) of juvenile hatchery steelhead and 76% (25 of 33) of yearling spring chinook salmon that were detected within 10 m of the PSC were also detected within 3 m. Of the fish that were detected within 3 m of the PSC entrance at unit 5, 44% (22 of 50) of juvenile hatchery steelhead and 40% (10 of 25) yearling spring chinook salmon were detected during a 5 ft. slot width. About 56% (28 of 50) of the juvenile hatchery steelhead and 60% (15 of 25) of the yearling spring chinook salmon were detected during tests of a 20 ft. slot width.

Of the fish that were detected within 10 m of the PSC entrance at unit 5, 53% (31 of 59) of the juvenile hatchery steelhead and 45% (15 of 33) of the yearling spring chinook salmon were detected during the tests of a 5 ft. slot width. About 47% (28 of 59) of juvenile hatchery steelhead and 55% (18 of 33) of the yearling spring chinook salmon were detected during a 20 ft. slot test (Figure 5).

Entrance efficiency, the number of fish entering the PSC at unit 5 divided by the total number of fish that were detected at the PSC entrance (reported as percent), based on the number of fish detected within 3 or 10 m from the PSC varied slightly by slot width. Of the fish detected within 10 m during a 5 ft. slot width, 19% (6 of 31) of the juvenile hatchery steelhead and 20% (3 of 15) of the yearling spring chinook salmon entered the PSC at unit 5. Twenty-seven percent (6 of 22) of the juvenile hatchery steelhead and 30% (3 of 10) of the yearling spring chinook salmon that were detected within 3 m during a 5 ft. slot width entered the PSC at unit 5. Within a 10 m distance during a 20 ft. slot width, 21% (6 of 28) of the juvenile hatchery steelhead and 33% (6 of 18) of the yearling spring chinook salmon entered the PSC at unit 5. Within a 3 m distance at a 20 ft. slot width, 21% (6 of 28) of the juvenile hatchery steelhead and 40% (6 of 15) of the yearling spring chinook salmon that detected the entrance entered the PSC at unit 5 (Figure 6). During 1998, a greater proportion of fish were also found to have passed at unit 5 (based on 10 m contacts) during an entrance width of 20 ft. (Figure 7).

Regardless of species or slot width, a substantial proportion of fish detected within 3 m (48%) or 10 m (46%) from the PSC entrance at unit 5 moved south along the PSC frame. We estimated 23% of the fish detected within 3 m and 26% of the fish detected within 10 m in front of the PSC entrance at unit 5 traveled and passed north of unit 5.

Slot efficiency is reported as a percentage and defined as the number of fish that entered the PSC at unit 5 divided by the sum of fish that entered unit 5 and the number of fish that entered the powerhouse at unit 5 multiplied by 100. Based on detections within 3 m, slot efficiency during tests of a 5 ft. slot width was 75% (6 of 8) for juvenile hatchery steelhead and 30% (3 of 10) for yearling spring chinook salmon. Similarly, slot efficiency during tests of a 20 ft. slot width was 75% (6 of 8) for juvenile hatchery steelhead and 55% (6 of 11) for yearling spring chinook salmon (Figure 8).

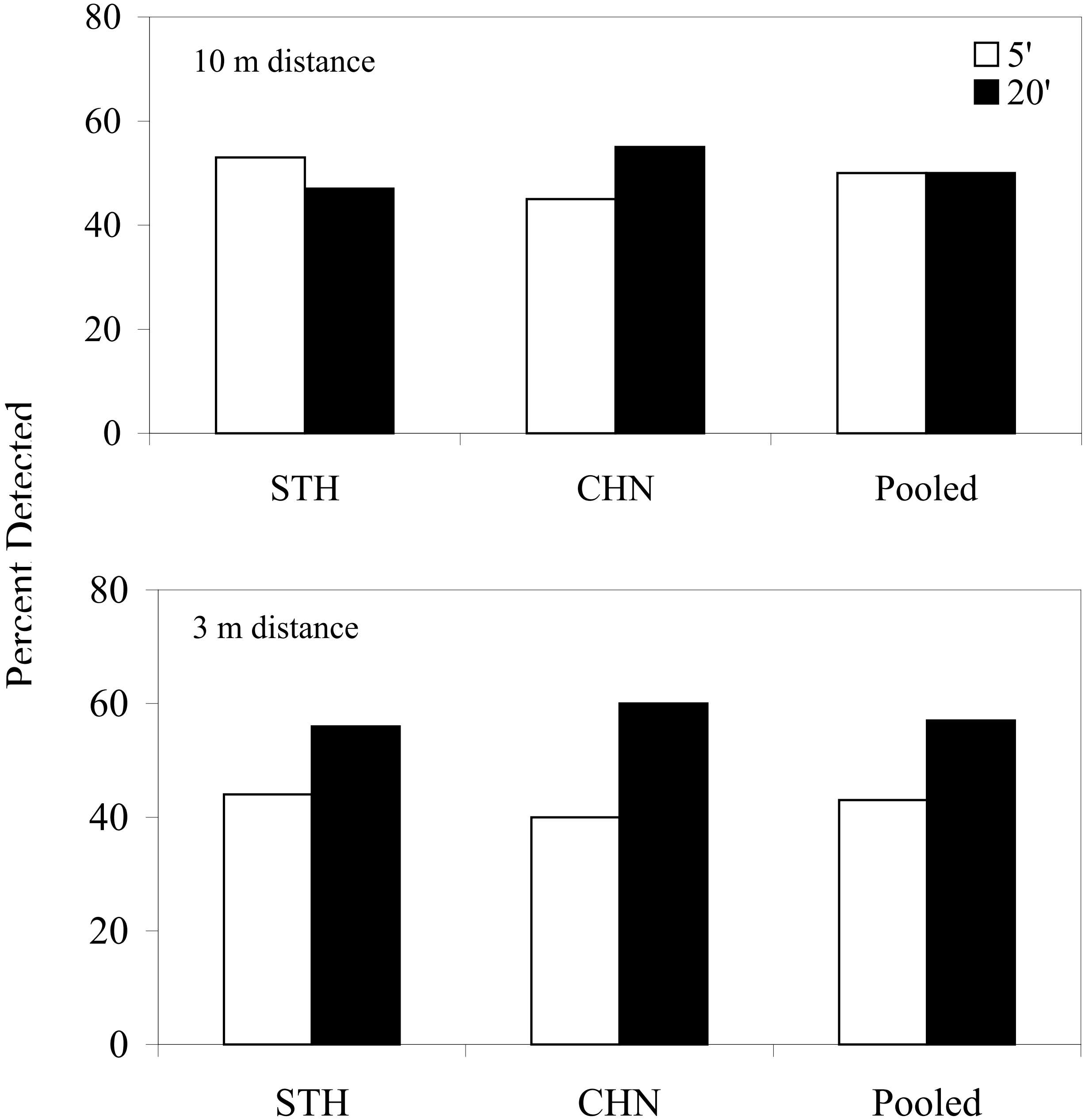


Figure 5. The percentage of radio-tagged juvenile hatchery steelhead (STH) and yearling spring chinook salmon (CHN) detected within 10 and 3 meters of the PSC for 5 and 20 ft slot widths, at Bonneville Dam Powerhouse I during 1999.

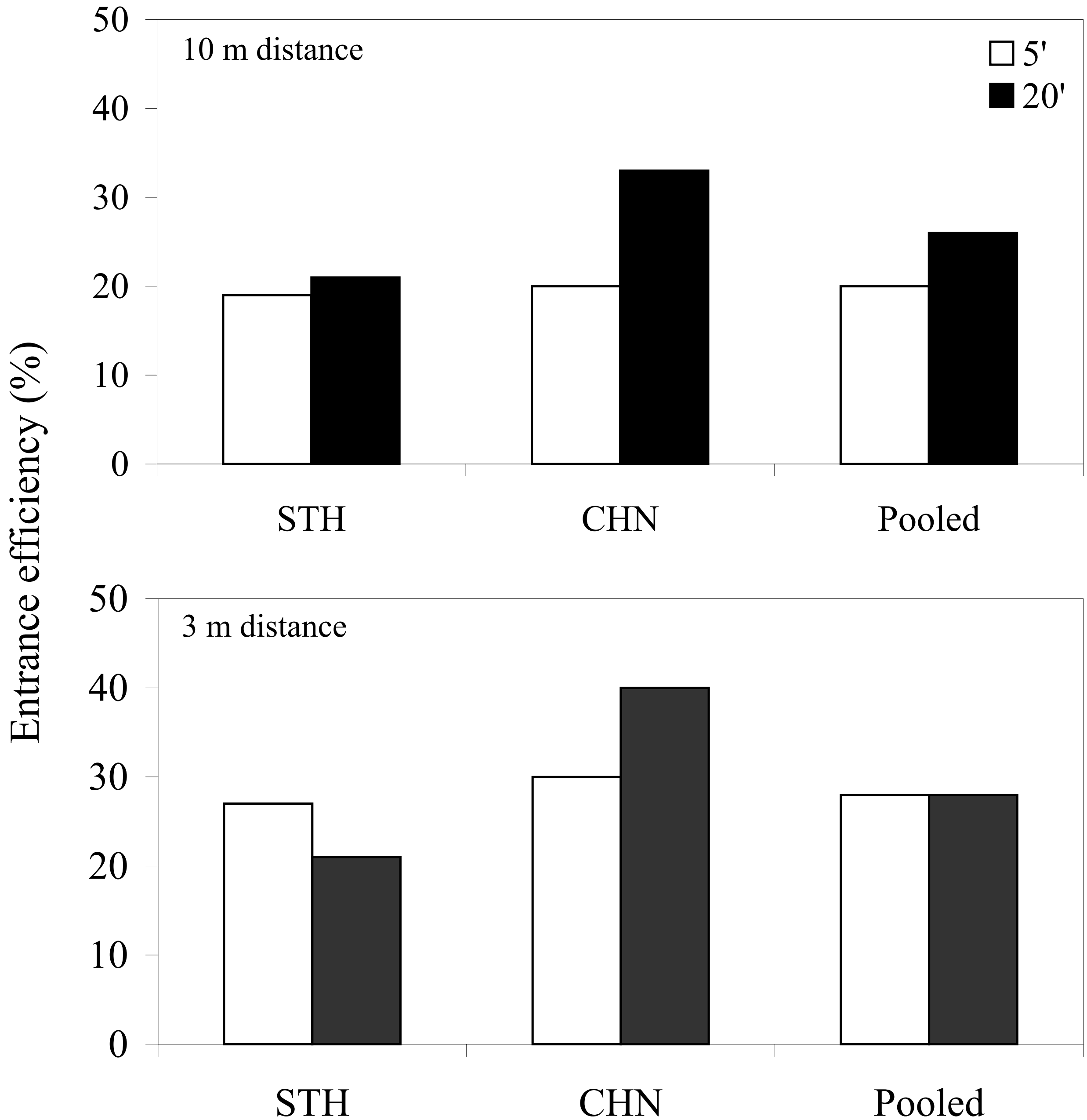


Figure 6. Entrance efficiencies for 5 and 20 ft slot widths for radio-tagged juvenile hatchery steelhead (STH) and yearling spring chinook salmon (CHN) that came within 10 and 3 m of the PSC at unit 5 in the forebay of powerhouse I at Bonneville Dam during 1999.

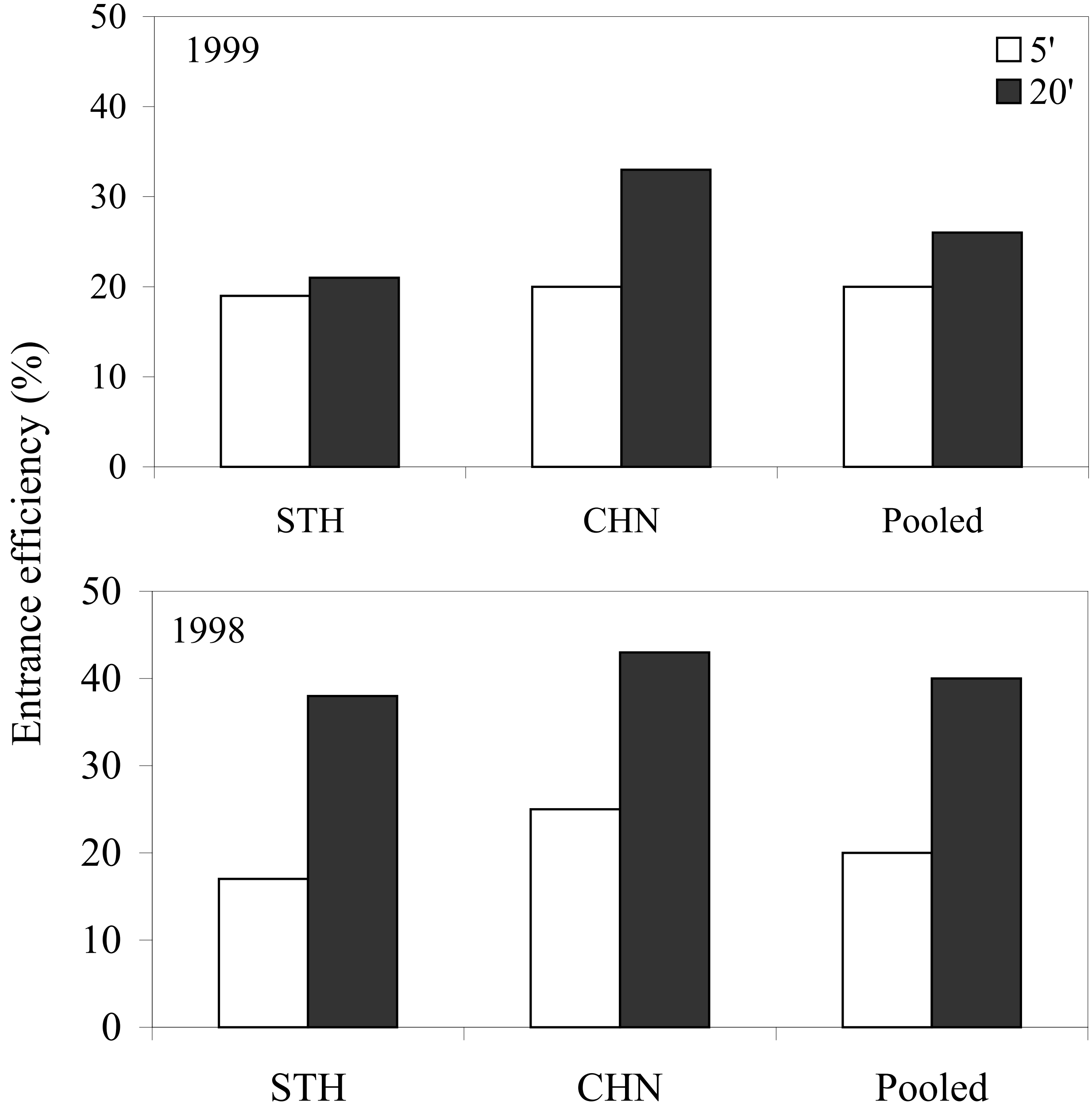


Figure 7. Entrance efficiencies at 5 and 20 ft slot widths for radio-tagged juvenile hatchery steelhead (STH) and yearling spring chinook salmon (CHN) detected within 10 meters of the PSC at Unit 5 in the forebay of powerhouse I at Bonneville Dam during 1998 and 1999.

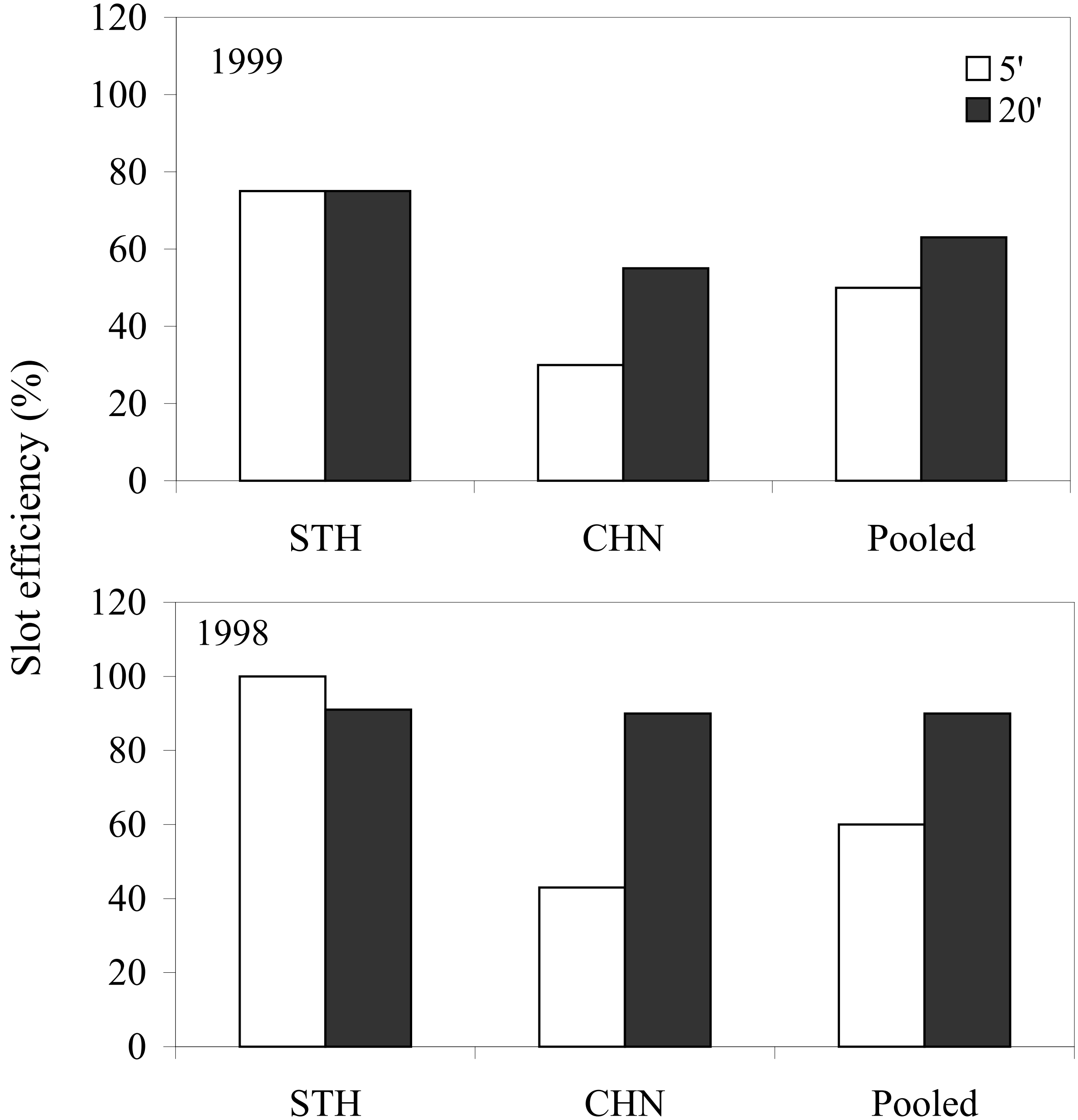


Figure 8. Prototype Surface Collector (PSC) slot efficiencies for 5 and 20 ft slot widths at unit 5 for radio-tagged juvenile hatchery steelhead (STH) and yearling spring chinook salmon (CHN) in the forebay of powerhouse I at Bonneville Dam during 1998 and 1999.

# 4.0 Discussion

*4.1 Approach, Distribution of Observations, and Forebay Residence Times*

During 1999, seventy-one percent of the juvenile salmonids released from Rock Creek, John Day Juvenile Fish Bypass Facility, and The Dalles were detected at Bonneville Dam. The total number of fish detected from each release site, regardless of species, decreased as the distance between Bonneville Dam and the release site increased.

The proportion of fish that were first detected at the spillway was slightly higher than the proportion of fish that were first detected at PH I or PH II. This was very similar to the results observed during 1998 where 10% more fish were first detected at the spillway (Hansel et al. 1999). The approach paths to the dam were indicative of where fish passed. For instance, 26% of the juvenile hatchery steelhead and 32% of the juvenile spring chinook salmon were first detected at PH II, and similarly 22% of the juvenile hatchery steelhead and 29% of the juvenile spring chinook salmon passed at PH II. This relation between the proportions of first contacts and route of passage indicated that little travel occurred between areas of the dam.

In 1998 and 1999, the highest number of observations were located within the forebay of PH I and the lowest number of observations were at the spillway for both species of juvenile salmonids. Juvenile salmonids that entered the forebay of PH I had longer residence times than those juvenile salmonids that entered PH II or the spillway. During 1998, the same assocation between the number of observations and residence time was observed. Shorter residence times within the forebay of PH II and the spillway were most likely due to higher discharges and/or the differences in hydraulic conditions within each dam area.

*4.2 Route of Passage and Time of Passage*

At PH I, juvenile salmonids passed predominately at the north end of the powerhouse while the fewest passed in the area of the PSC (units 3 through 6). At PH II, the majority of the juvenile salmonids passed at the south end of the powerhouse. At the spillway, the majority of juvenile salmonids passed at the north end. Passage routes among dam areas are most likely dependent on hydraulic flows and where a fish entered each dam area.  Passage occurred throughout the diel cycle with the most fish passing between 2000 and midnight.  Comparing species, regardless of release site, juvenile hatchery steelhead showed the highest numbers within this time period.

### *4.3 Tests Related to the PH I Prototype Surface Collector*

Eighty one percent (75 of 92) of the radio-tagged juvenile salmonids detected at a distance within 3 m in front of the unit 5 PSC entrance were also detected within 10 m. Fish that were detected upstream of the unit 5 PSC entrance, either passed at unit 5 or moved laterally to pass either north or south of unit 5.  The majority of these fish, regardless of slot width, moved south along the PSC frame.  This is likely due to the southerly direction of the flows in front of the PSC.

Overall, fish that were detected within 3 m of the PSC entrance at unit 5 had higher entrance efficiencies than the fish detected at 10 m in front of the PSC at unit 5.  This suggests that the probability of a fish entering the PSC will be higher for a fish that is closer to the PSC entrance than a fish at greater distances from the PSC entrance. Therefore, an objective should be to create a current upstream of the PSC that will attract or entrain fish swimming at greater distances from the PSC.

When data were compared between 3 m and 10 m detections in front of the unit 5 entrance, the results showed that fish detected within 10 m had a greater entrance efficiency at a 20’ slot width, yet for fish detected within 3 m in front of the unit 5 entrance both slot widths produced the same results.  This suggests that within a distance of 3 m upstream of the PSC fish were more likely to be entrained into the flow provided by the PSC and the width of the entrance had little effect.  However, at a distance within 10 m from the PSC the width of the entrance may have a greater influence on whether fish will be entrained into the PSC or not.  In addition to these results observed in 1999, a 20 ft. slot width was also observed to be more effective in our 1998 telemetry study (Hansel et al. 1999).  Also, water velocity data collected in 1999 determined that at a 20 ft slot width, the flow going into the PSC entrance at unit 5 was greater at 10 m in front of the PSC as compared to the in-flow during a 5 ft slot width (Faber et al. 1999).  This suggests that flows leading into the PSC during tests of a 20 ft slot width may have guided fish more effectively than the flow produced from a 5 ft slot width.

Slot efficiencies for juvenile hatchery steelhead were the same whether slot widths were at 5 ft (75%) or 20 ft (75%). In contrast, a greater proportion of yearling spring chinook salmon entered the PSC at unit 5 during tests of a 20 ft (55%) slot width than during tests of a 5 ft (30%) slot width. When compared to 1998, slot efficiencies were considerably lower at unit 5 during 1999 (Hansel et al. 1999) than 1998 (89-100%; Hansel et al. 1998). It is possible that the operation of the PSC at both units 3 and 5 during 1998 may have accounted for the increased performance during 1998 as compared to the single entrance available during 1999.

In 1999, hydroacoustic studies conducted by the Waterways Experiment Station determined that slot efficiencies were 69% during tests of a 5 ft slot width and 84% during tests of a 20 ft slot width. When we pooled the data from radio-tagged juvenile hatchery steelhead and yearling spring chinook salmon the slot efficiency was 50% for a 5 ft slot width and 63% for a 20 ft slot width. The higher slot efficiencies observed using hydroacoustic tests are most likely due to the larger sample sizes. However, both radio telemetry and hydoacoustic techniques indicated higher efficiencies when a 20 ft slot width was tested than a 5 ft slot width.

## 5.0 Acknowledgements

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