Technical Report 2004-7

MIGRATION BEHAVIOR OF ADULT CHINOOK SALMON AND STEELHEAD RELEASED IN THE FOREBAY OF BONNEVILLE DAM, 2000-2001

C. T. Boggs, M. L. Keefer, K. R. Tolotti, C. A. Peery and T.C. Bjornn

U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit
University of Idaho, Moscow, Idaho 83844-1141

and

M.L. Moser and L.C. Stuehrenberg

National Marine Fisheries Service
2725 Montlake Blvd, East, Seattle, Washington 98112

for

U.S. Army Corps of Engineers

Portland and Walla Walla Districts

2004

Preface

We began radio telemetry studies of adult salmon and steelhead passage through the lower Columbia River with fish being tagged and released at Bonneville Dam in 1996. The objectives included observing behavior and assessing potential sources of delay and mortality for adult salmon and steelhead during their upstream migration. This report summarizes our investigation of alternate locations for the exit of the Bradford Island fishway at Bonneville Dam to reduce fallback associated with this fishway.

This and related reports from this project can be downloaded from:
http://www.cnr.uidaho.edu/uiferl/

Acknowledgements

Many people assisted in the field work and data compilation for this project. Notable among them were Rudy Ringe and Steve Lee who supervised fish tagging , Ken Tolotti, Kevin Traylor and Travis Dick who maintained and downloaded the receivers, Megan Heinrich who handled all the recaptured tag information and Michael Jepson who supervised the coding of the data and Alicia Matter for database management.

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Abstract

In 2000 and 2001, we evaluated the efficacy of potential sites for a new or modified Bradford Island fishway exit to reduce fallback of adult salmon and steelhead at Bonneville Dam. Radio-tagged salmon and steelhead were released on the Oregon shore just upstream from the navigation lock, on the north and south (2000 only) sides of the downstream end of the navigation lock guidewall and at the upstream end (2001 only) of the navigation lock guidewall. Telemetry records were used to determine migration routes through the forebay and the number and type of fallback events by fish released at these sites, we also documented the fallback behavior of radio-tagged fish released downstream from the dam that passed the Bradford Island fishway.

In 2000, forebay migration routes were determined for 131 spring–summer Chinook, 253 fall Chinook and 260 steelhead released in the forebay and 462 spring–summer, 330 fall Chinook and 328 steelhead released downstream from the dam that passed the Bradford Island fishway. Most (72-82%) fish released at the three forebay sites were *only* recorded by telemetry receivers located on the Oregon shore or the south side of Bradford Island (south shore migrants) as they migrated out of the forebay. The remaining 18-28% of forebay-released fish were recorded in the forebay of the spillway or along the Washington shore. By comparison, significantly higher proportions (50-61%) of downstream-released fish that exited the Bradford Island fishway were recorded in the spillway forebay or along the Washington shore. Fallback rates for spring–summer Chinook and steelhead released in the forebay were significantly lower than rates of fish that exited the Bradford Island fishway. Fall Chinook released in the forebay fell back at significantly higher rates than those that passed the Bradford Island fishway; most fallbacks by forebay-released fall Chinook were through the navigation lock.

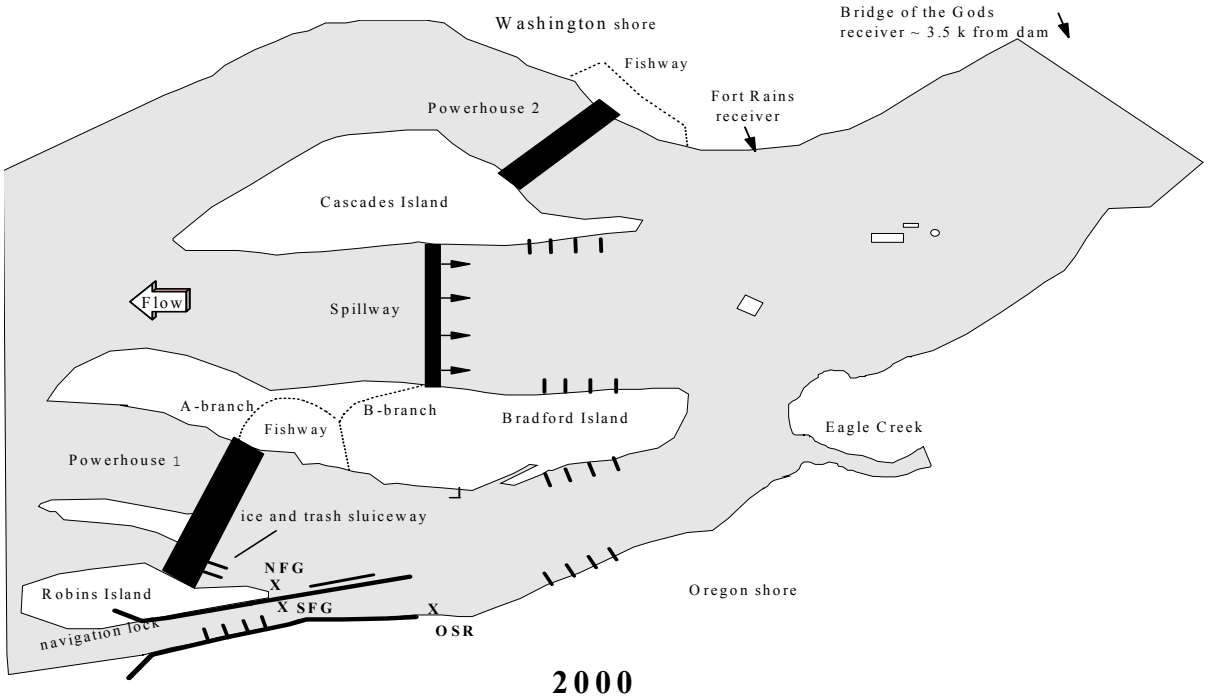
In 2001, forebay migration routes were determined for 297 spring–summer Chinook, 360 fall Chinook and 297 steelhead released in the forebay and 307 spring–summer, 170 fall Chinook and 265 steelhead released downstream from the dam that passed the Bradford Island fishway. Most (59-68%) fish released at the three forebay sites were determined to be south shore migrants; the remaining 32-41% were recorded in the spillway forebay or along the Washington shore. Between 48 and 70% of downstream-released fish that exited the Bradford Island fishway were recorded in the forebay of the spillway or along the Washington shore. These proportions were significantly lower for spring–summer Chinook released at all three forebay release sites and for steelhead released at one of three sites. Fallback rates for forebay-released fish were in all cases significantly higher than rates for fish that passed the dam via the Bradford Island fishway; most fallbacks by forebay-released fish occurred through the navigation lock.

Introduction

Adult steelhead *Oncorhynchus mykiss* and Chinook salmon *O. tshawytscha* returning to the Columbia and Snake River drainages encounter up to nine mainstem dams on their upstream migration to spawning grounds and hatcheries. Researchers (Bjornn et al. 1999) have reported that most adult salmonids migrate relatively close to shore in the mainstem Columbia and Snake rivers. Entrances and exits of fishways and fish ladders at most dams were built adjacent to the shorelines and telemetry data indicate that fish exiting from the tops of ladders tend to follow shoreline routes out of dam forebays.

Bonneville Dam on the lower Columbia River is unique among mainstem dams, consisting of two powerhouses, a spillway and a navigation lock separated by Cascades, Bradford and Robins Islands (Figure 1). Fish using the Bradford Island fishway exit on the southern shore of the island and have exhibited a tendency to follow the shoreline around the upstream tip of the island and into the forebay of the spillway where they are subject to fallback during periods of spill (Bjornn et al. 1999, 2000; Reischel and Bjornn 2003). Previous adult passage studies showed that Bonneville Dam often had a higher rate of fallback than other Columbia and Snake River dams and that the majority of these fallbacks were by fish that had exited the Bradford Island fishway (Young et al. 1975). Bjornn et al. (2000) reported fallback rates from 16-20% for radio-tagged spring–summer Chinook salmon that passed Bonneville Dam in 1996-1998; in all years more than 94% of these fallback events were by fish that had exited the Bradford Island fishway. Fish that fall back at dams escape to spawning areas and hatcheries at lower rates than fish that do not fall back (Bjornn et al. 2000, Boggs et al. 2004). Fallback also causes positively biased fish counts and may lead to significant delays in fish migration (Horton and Wallace 1966; Monan and Liscom 1975, 1979).

Researchers have suggested that the addition of a fishway on the Oregon shore at Bonneville Dam would lower rates of fallback by decreasing the number of fish that cross the upstream face of the Bonneville Dam spillway. The location and design of the navigation lock along the Oregon shore precludes construction of a typical fishway at that location so efforts were made to evaluate moving the Bradford Island fishway exit to a location nearer the navigation lock floating guidewall (Figure 1). In 2000 and 2001, we released radio-tagged Chinook salmon and steelhead at four sites in the forebay of Bonneville Dam and monitored their movements and fallback behavior as they migrated out of the forebay. Concurrently, we monitored the forebay movements and fallback behavior of radio-tagged Chinook salmon and steelhead released downstream from Bonneville Dam that had passed the dam via the two fishways. We used a chi-square test of independence to identify differences in forebay migration routes and fallback behavior by fish released at the four sites in the forebay and those to pass the dam via the fishways.



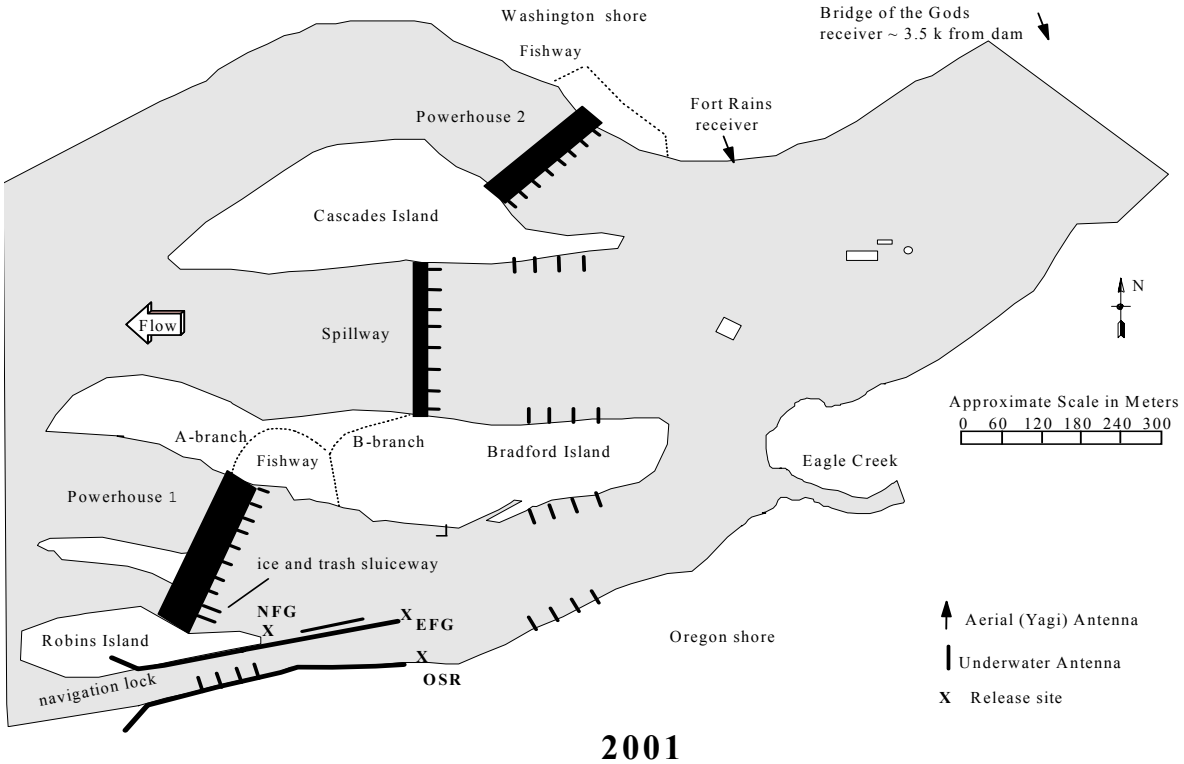


Figure 1. Configurations of aerial (Yagi) and underwater (dipole) antennas and locations of release sites in the forebay of Bonneville Dam in 2000 and 2001.

Methods

Fish trapping, tagging and releases

Adult Chinook salmon and steelhead were collected, tagged with radio-transmitters and released near Bonneville Dam from April to October. Fish were collected using the trap facility adjacent to the Washington-shore ladder. During trapping operations, a picketed-lead weir was dropped into the ladder and adult migrants were diverted into a collection pool. Fish then passed a false weir and selected fish were diverted into an anesthetic tank (tricaine methanesulphonate or clove oil) using electronically controlled guide gates. Anesthetized fish were moved to a smaller tagging tank where fish were measured, sexed, examined for injuries and fin clips, and tagged. In 2000, each fish received a coded wire tag injected into the dorsal sinus, a uniquely numbered visual-implant (VI) tag injected under the clear tissue posterior to the eye (usually left) and a PIT tag was inserted into the pelvic girdle. In 2001, an ISO PIT tag was the only secondary tag used. An 80-mm long, 7-V or a 45-mm long 3-V Lotek (Newmarket, Ont.) radio transmitter (149 Mhz) was disinfected and lubricated with glycerine and inserted through the esophagus and into the stomach. Fish were then placed in a 600-gallon aerated hauling tank and allowed to recover.

Up to twelve fish were tagged and placed in the hauling tank before being transported for release, fish were usually held for less than 3 h. In 2000, fish were released directly from the hauling tank into the forebay. Release sites included the Oregon shore (OSR) just upstream from the navigation lock and two release sites located on the north (NFG) and south (SFG) sides of the navigation lock floating guidewall near its connection to Robbins Island (Figure 1).

In 2000, all spring–summer Chinook salmon were released at the OSR site while fall Chinook and steelhead were released at the NFG, SFG and OSR sites. In 2001, fish were conveyed via a 12-inch diameter flexible pipe from the hauling tank to a 16-foot pontoon boat that had been retrofitted with a 130 ft^3 submersible holding pen located between the pontoons, then transported to the release sites. Release sites included the Oregon shore (OSR), north floating guidewall (NFG) and the upstream end of the floating guidewall (EFG) (Figure 1). In 2001, all runs and both species were released at the three release sites.

Receiver coverage and antenna configurations

Migratory behavior in the forebay and fallback events of salmon and steelhead were monitored using Lotek SRX and SRX/DSP telemetry receivers. Fish movements in the forebay directly upstream from the dam were monitored by receivers with submerged antennas located along the Oregon shore, the south and north shores of Bradford Island and the south shore of Cascades Island (Figure 1). As migrants proceeded upstream from the dam, a receiver with an aerial antenna located between Bonneville Dam and the Fort Rains in-lieu site (WA shore) and a similar receiver/antenna fixed site located at the Bridge of the Gods (WA shore) were used to collect data on forebay passage rates and migration routes used. During 2000, two receivers with aerial antennas oriented upstream were located above the spillway; in 2001 this area was monitored with submerged dipole antennas mounted to

spillbay pier noses. In 2001, submerged antennas mounted to the traveling screens of the turbine intakes of both powerhouses monitored fish movements and fallbacks in these areas; turbine intakes were not monitored in 2000. In both years, receivers with aerial antennas oriented perpendicular to the river flow were located approximately 2 km downstream from Bonneville Dam on opposite shores, a receiver with submerged antennas located on the north side of the navigation lock monitored fish that passed through the navigation lock, and the ice and trash sluiceway of Powerhouse 1 was monitored (Figure 1).

Data analysis

In both years, the forebay telemetry records of all fish released upstream and downstream from the dam were examined individually and one of three routes was assigned to fish with adequate telemetry records. Fish that were recorded *only* on receivers located along the Oregon shore of the forebay and/or on the south side of Bradford Island before being recorded at upriver sites (the Bridge of the Gods or further upriver) were considered "south shore" migrants. Migrants not included in this first category were separated into those fish that were detected near the Washington shore by the Fort Rains receiver and those that were detected near the spillway by receivers and antennas attached to the spillway structure, the north side of Bradford Island and the south side of Cascades Island (Figure 2). A chi-square test of independence was used to identify differences in the proportions of fish from each release group assigned to these routes and also to identify differences in fallback for fish from each release site.

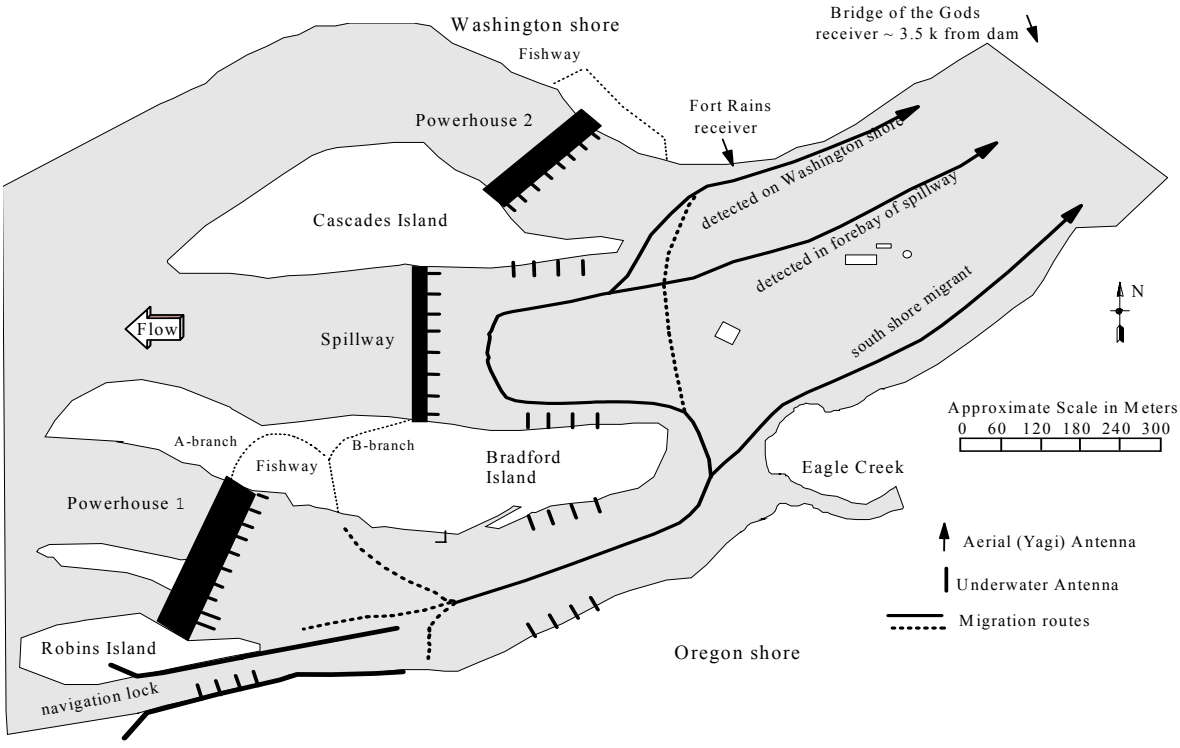


Figure 2. The forebay of Bonneville Dam with the three forebay migration routes to which downstream and forebay released salmon and steelhead were assigned in 2000 and 2001. Shown with 2001 antenna configuration.

Results

In the sections that follow, we present information on the routes salmon and steelhead took through the Bonneville Dam forebay after release in the forebay and after exiting the two fishways or passing through the navigation lock in 2000 and 2001. We also present information on the number of fish that fell back over the dam and related fallback behavior to release location and spill when fish were in the forebay. We did not include in the fallback analyses the fish that migrated upstream after release or exit from the fishway that were recorded at an upstream site (The Bridge of the Gods or further upriver), and then returned and fell back over the dam. We believe their behavior was not related to location of release into the forebay or environmental conditions in the forebay at the time of release.

In 2000, 973 adult spring and summer, 745 fall Chinook salmon and 844 steelhead were trapped at the Bonneville Dam Adult Fish Facility, outfitted with radio-transmitters and released downstream from the dam and 153 spring and summer, 352 fall Chinook salmon and 313 steelhead were released at three sites in the forebay. In 2001, 884 spring and summer, 561 fall Chinook salmon and 804 steelhead were released with transmitters downstream from the dam and 356 spring and summer, 431 fall Chinook salmon and 347 steelhead were released in the forebay. Telemetry receivers located in the forebay, in the fishways and at sites upstream from Bonneville Dam (Figure 1) were used to determine the forebay migration routes of fish released at these locations. Fish routes, their times to migrate out of the forebay and fallback behavior associated with each release site (including those that exited the Bradford Island fishway) were compared.

Environmental conditions at Bonneville Dam differed substantially between 2000 and 2001. River flows during the 2000 migration season (April through October), were 96% of the 10-year average (1990-1999), versus 58% of the 10-year average during the 2001 migration season (Figure 3). Spill volume during the 2000 migration season was 93% of the 10-year average, compared to 20% of average in 2001. Spill typically begins at Bonneville Dam in mid April and continues until mid to late August with a 10-year mean of 136 spill days. During this study period, spill occurred on 147 days during the 2000 migration season and 70 days during the 2001 season (Figure 3). Dissolved gas levels were higher in 2000 than in 2001 (Figure 4). Secchi disk readings averaged over one foot more visibility in 2001 than in 2000 (Figure 4). Mean water temperatures were slightly higher (0.3 C) during the 2001 migration season and the water stayed warmer later into the fall (Figure 4).

Discharges from Bonneville Dam's two powerhouses also differed between 2000 and 2001 (Figure 5) as did the proportion of fish to pass each fishway (Figure 6). In 2000, discharges through the two powerhouses were similar until the end of May when priority was given to Powerhouse 1, located adjacent to the navigation lock and the Oregon shore. Starting in September, priority shifted to Powerhouse 2, adjacent to the Washington shore. This coincided with the end of spill. During the entire 2001 migration season, Powerhouse 2 had priority and Powerhouse 1 discharged very little flow. Given the low river flows and reduced periods of spill in 2001, this resulted in about 75% of the available river flow passing through Powerhouse 2 during the migration season.

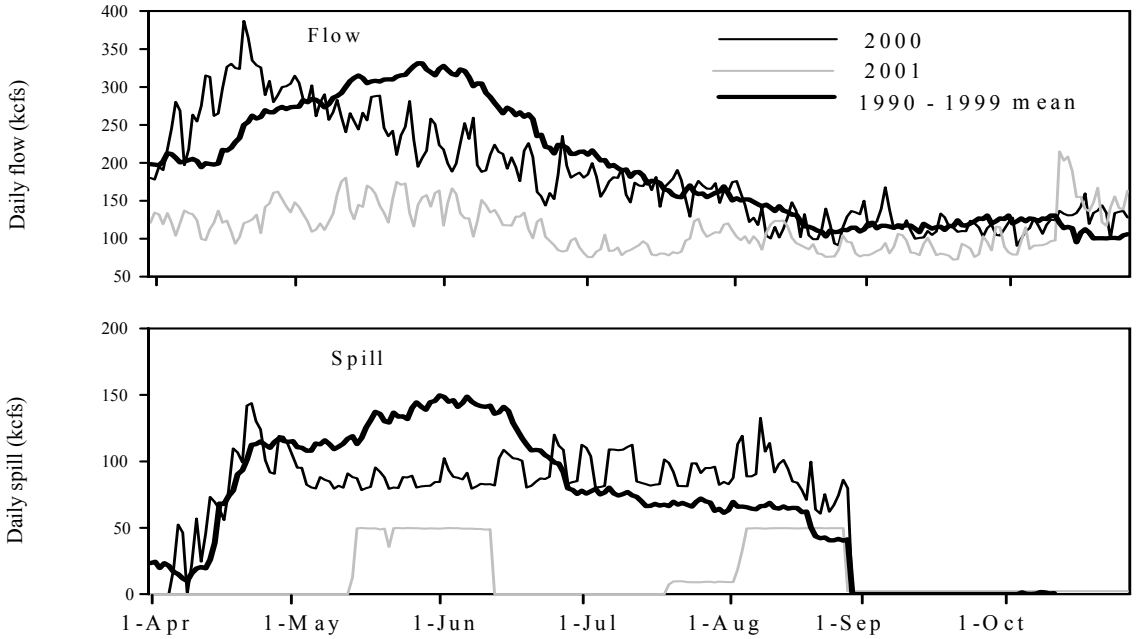


Figure 3. River flow and spill at Bonneville Dam in 2000 and 2001 with ten year average.

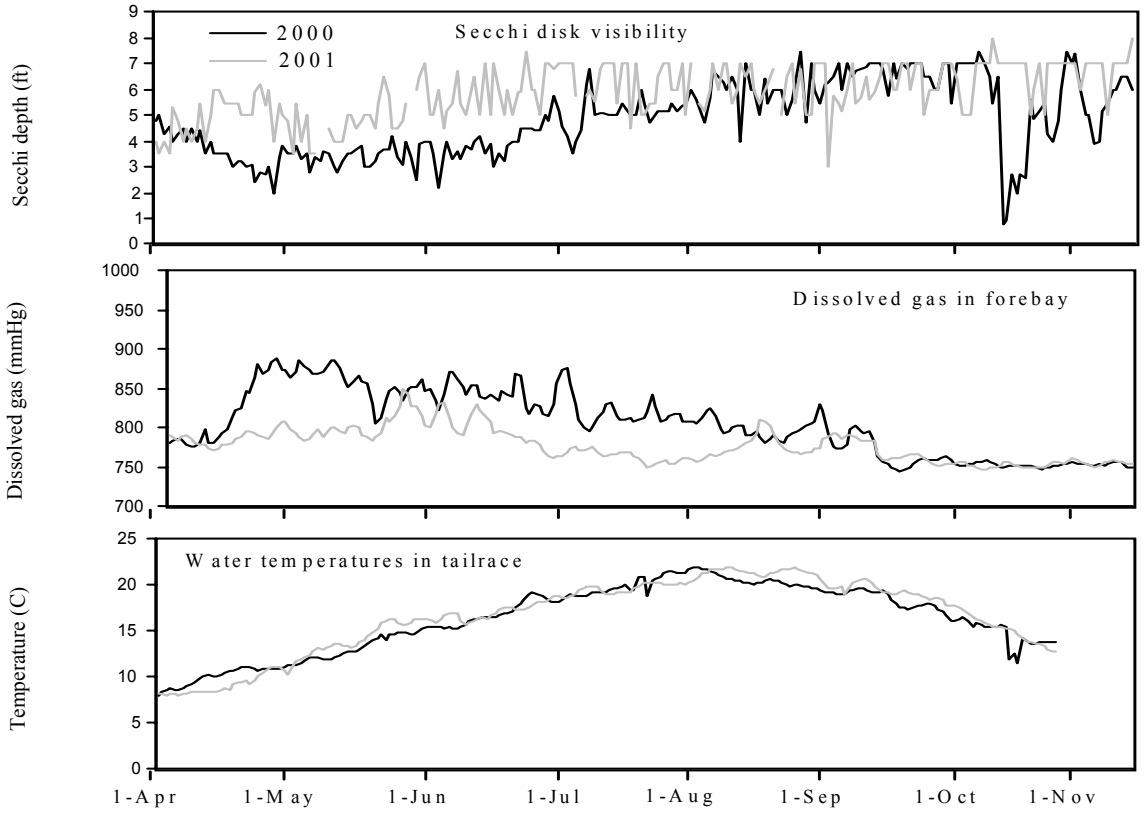


Figure 4. Daily Secchi visibility and dissolved gas levels in the forebay, and water temperature in the tailrace of Bonneville Dam during the migration seasons of 2000 and 2001.

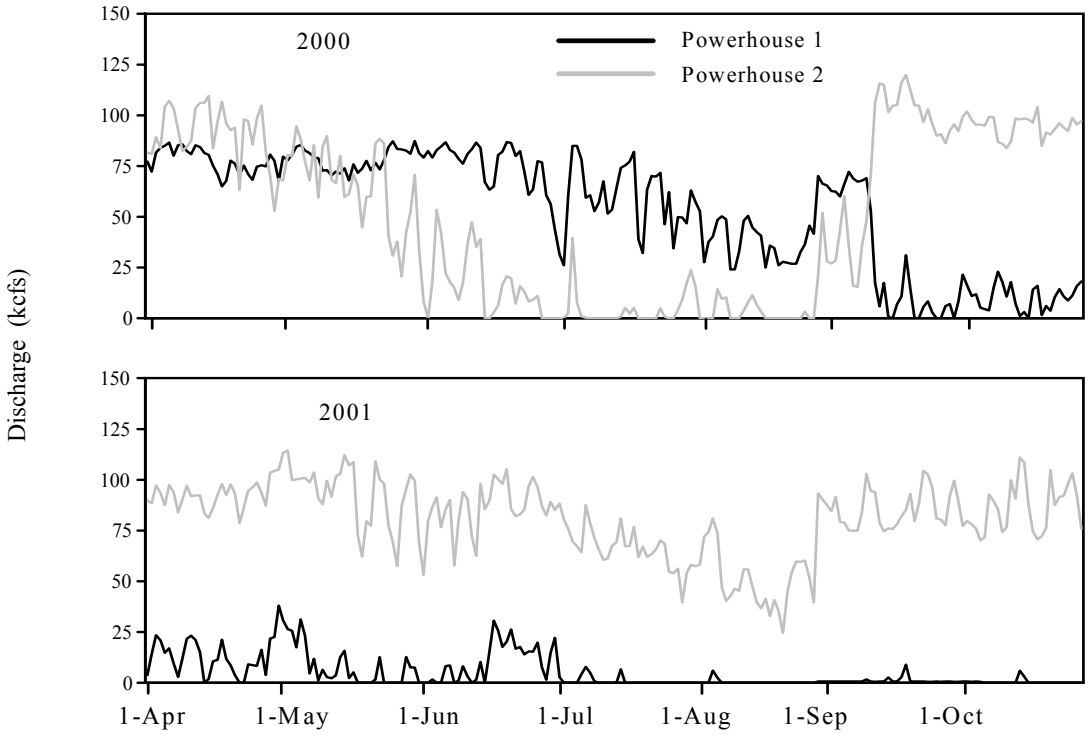


Figure 5. Discharge (kcfs) from Powerhouses 1 and 2 during the migration seasons of 2000 and 2001.

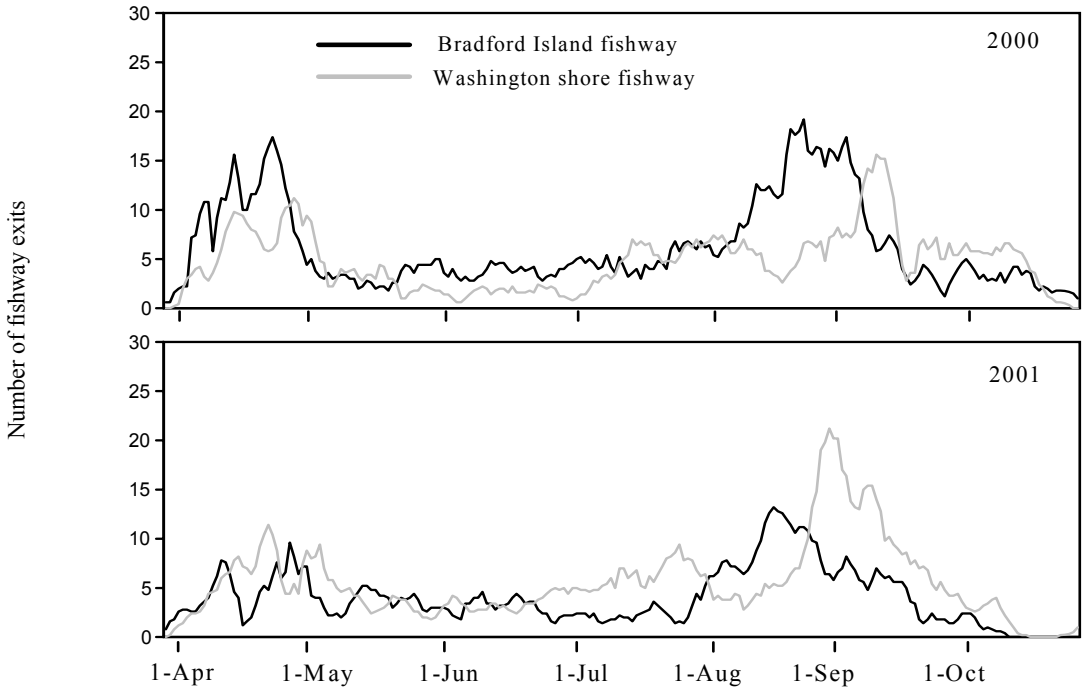


Figure 6 Five-day moving average of all radio-tagged spring–summer and fall Chinook and steelhead that exited the Bradford Island and Washington shore fishways in 2000 and 2001.

Timing of the spring–summer Chinook salmon run in 2000 was similar to average (1990-1999) with the peak of the spring run occurring in mid April. The run size, however, was nearly three times the 10-year mean (88,258 salmon) with 243,731 spring and summer Chinook counted passing Bonneville Dam. The 2001 spring and summer Chinook run was one of the largest recorded since construction of the Columbia River dams with 496,418 spring and summer Chinook counted passing Bonneville Dam. The 2001 run started approximately one week earlier than average but also peaked in mid April (Figure 7). The 2000 steelhead run (275,178) was slightly larger than the 10-year mean as was the 2000 fall Chinook run (248,174). Both the 2001 steelhead run (633,073) and the 2001 fall Chinook run (474,701) were nearly three times the 10-year mean fish counts for those runs (Figure 7) (USACE 2000,2001).

2000 Releases

Forebay Migration Routes of Spring and Summer Chinook

We outfitted spring–summer Chinook with radio transmitters from early May through July of 2000 (Figure 8). All of the spring–summer Chinook salmon released with transmitters that passed through the Bonneville Dam forebay did so when there was spill at the dam (Figure 3). Spill levels ranged from 19.2 to 143.8 kcfs with a mean of 84.6 kcfs.

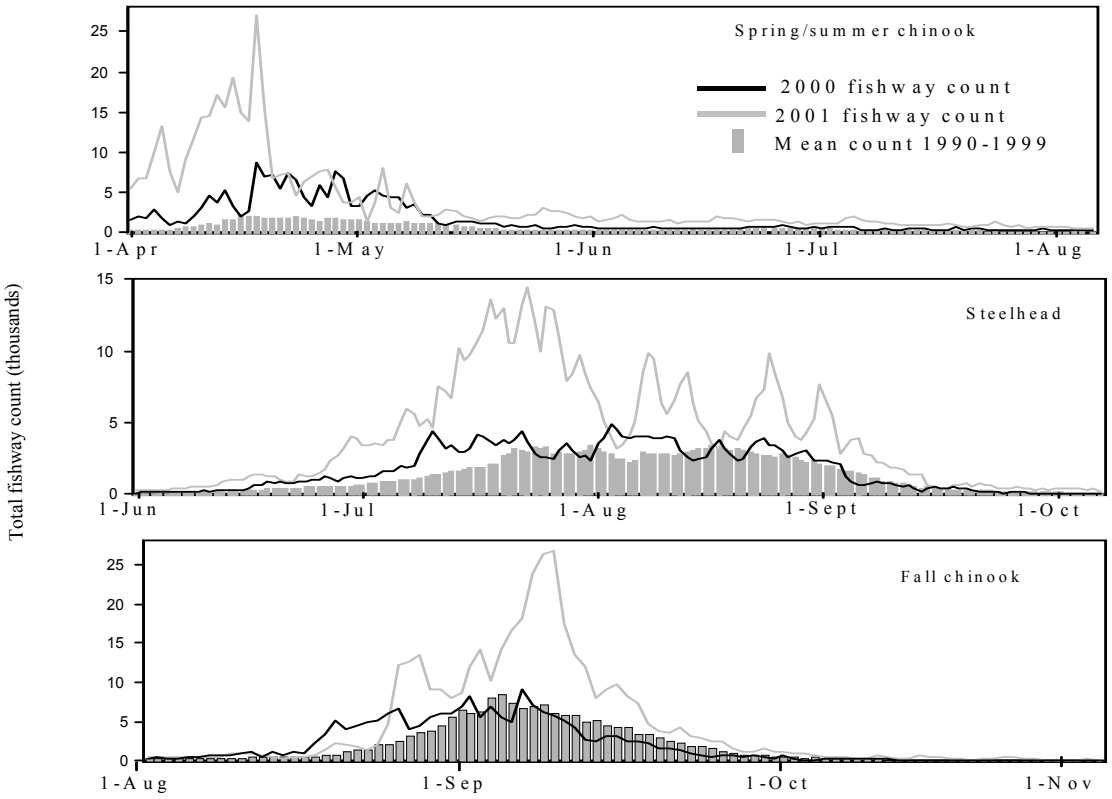


Figure 7 Daily spring–summer and fall Chinook and steelhead counts at Bonneville Dam in 2000 and 2001 with mean counts for 1990-1999.

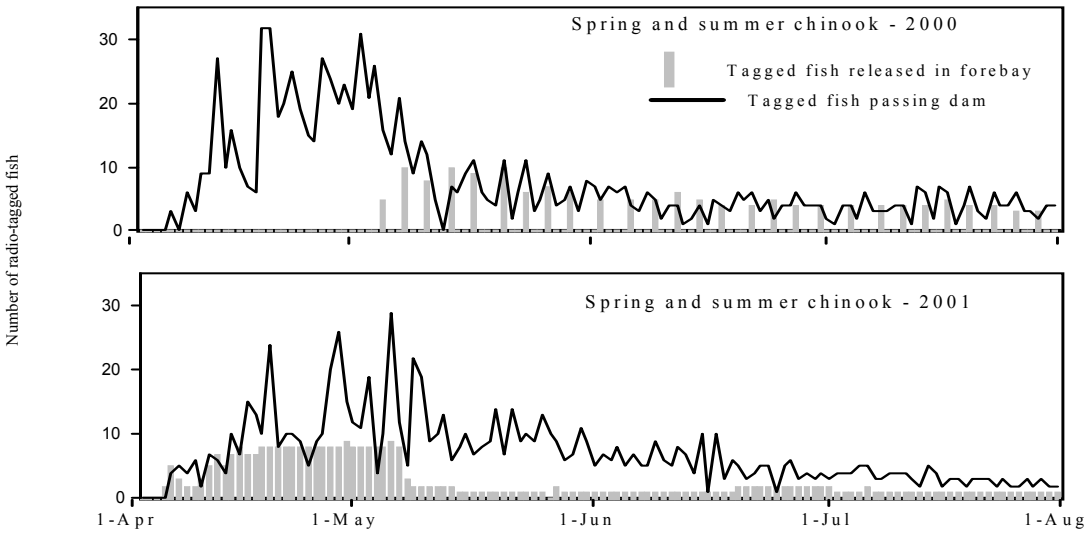


Figure 8 Numbers of radio-tagged spring–summer Chinook released in the forebay and released downstream of Bonneville Dam that passed through the fishways.

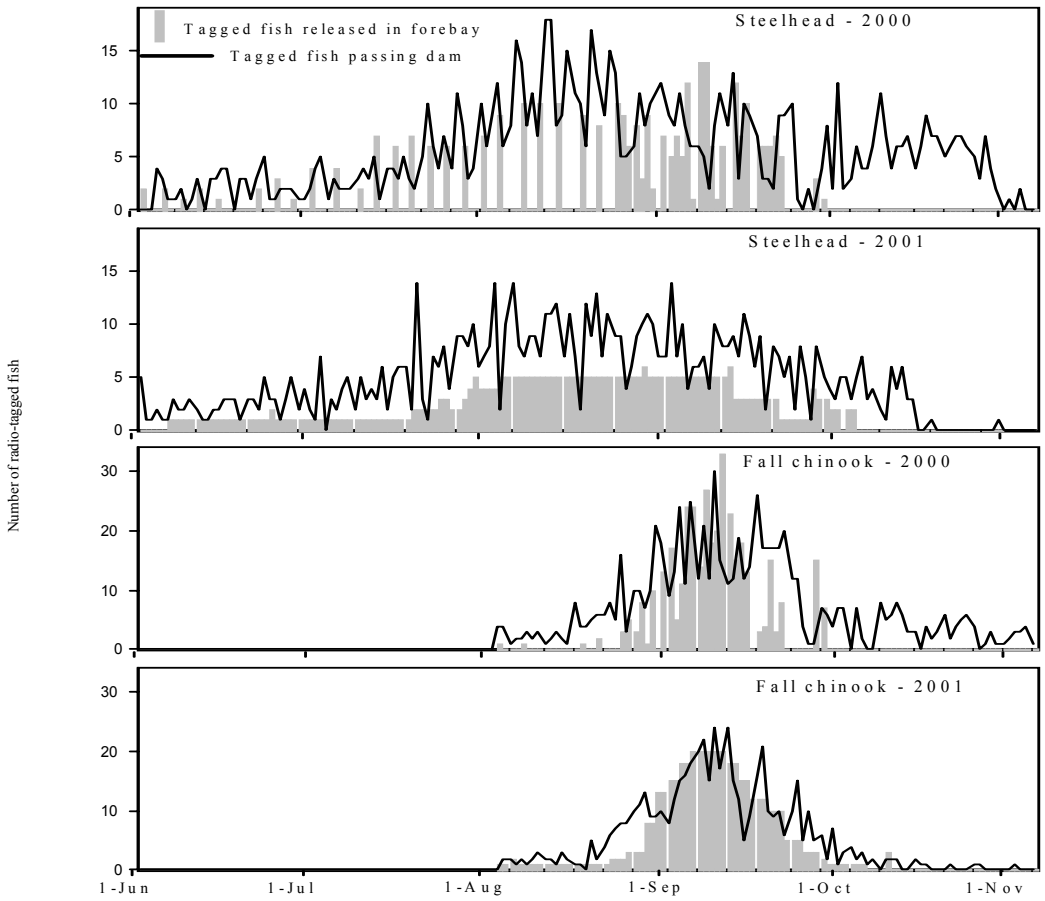


Figure 9 Numbers of radio-tagged steelhead and fall Chinook released in the forebay and released downstream of Bonneville Dam that passed through the fishways.

Downstream releases

About 40% (376) of downstream-released spring–summer Chinook passed the dam via the Washington-shore fishway. Of the 376 fish, almost all (98%) were detected exclusively on the Washington shore as they left the forebay and only one (0.3%) fish entered the spillway and fell back over the dam (Table 1). Median time for spring–summer Chinook that exited the Washington-shore fishway to migrate upstream to the Bridge of the Gods receiver was 1.2 h (n = 175). The median rate of forebay migration (distance from fishway exit to the Bridge of the Gods divided by the median travel time) was 2.7 km/h (Table 2).

Table 1. Number of spring–summer and fall Chinook and steelhead that passed Bonneville Dam via the Washington shore fishway or the navigation lock, the number assigned a forebay migration route, number (%) to migrate along south shore, detected on the Washington shore or detected in the spillway forebay and number, route and percentage of fallback in 2000. All spring–summer Chinook passed the dam during spill conditions.

	Spring–summer Chinook		Steelhead		Fall Chinook	
	WA shore	Nav lock	WA shore	Nav lock	WA shore	Nav lock
Exited	376	16	403	25	245	29
Assigned migration route	374	15	400	25	244	25
during spill	374	15	209	20	42	3
no spill	-	-	191	5	202	22
South shore migrants (%)	1 (0.3)	14 (93.3)	1 (0.3)	16 (64.0)	0	24 (96.0)
during spill	1 (0.3)	14 (93.3)	0	12 (60.0)	0	3 (100)
no spill	-	-	1 (0.5)	4 (80.0)	0	21 (95.5)
Detected on Wa. shore (%)	367 (98.1)	1 (6.6)	390 (97.5)	7 (28.0)	242 (99.2)	0
during spill	367 (98.1)	1 (6.6)	204 (97.6)	6 (30.0)	41 (97.6)	0
no spill	-	-	186 (97.4)	1 (20.0)	201 (99.5)	0
Detected near spillway (%)	6 (1.6)	0	9 (2.3)	2 (8.0)	2 (0.8)	1 (4.0)
during spill	6	0	5	2	1	0
no spill	-	-	4	0	1	1 (4.5)
All fallbacks	1	1	0	0	1	0
during spill	1	1	0	0	1	0
no spill	-	-	0	0	0	0
Via spillway	1	1	0	0	1	0
Via nav lock	0	0	0	0	0	0
Undetermined	0	0	0	0	0	0
% fallback	0.3	6.3	0	0	0.4	0
% nav lock fallback	0	0	0	0	0	0

Relatively few spring–summer Chinook salmon (16, 1.7% of those that passed the dam) passed via the navigation lock and one of those fish (6.3%) fell back over the spillway. Most (93%) Chinook were detected only along the Oregon shore or south side of Bradford Island receivers (south shore migrants) after exiting the navigation lock (Table 1). Median time for 14 Chinook that passed the dam via the navigation lock to migrate upstream to the Bridge of the Gods receiver was 1.7 h (median rate = 2.7 km/h) (Table 2).

Table 2. Number of spring–summer and fall Chinook and steelhead that had adequate telemetry records to calculate a time to migrate from fishway exit or forebay release site to the Bridge of the Gods receiver site, median and mean times to travel this distance and migration rates in 2000. Migration rates calculated using median times.

	Dam passage			Forebay Release		
	Wa. shore	Nav lock	Bradford Is.	Oregon shore	N. guidewall	S. guidewall
Sp/su Chinook						
N	175	14	304	122	-	-
Median time (h)	1.2	1.7	2.2	3.4	-	-
Mean time (h)	2.1	1.8	3.2	6.6	-	-
Rate (km/h)	2.7	2.7	2.0	1.3	-	-
Steelhead						
N	250	20	254	121	35	51
Median time (h)	1.3	2.1	2.5	3.4	3.6	2.8
Mean time (h)	2.2	2.9	4.2	4.9	8.0	3.6
Rate (km/h)	2.5	2.2	1.8	1.3	1.3	1.6
Fall Chinook						
N	60	17	147	24	60	55
Median time (h)	1.2	2.0	2.0	2.8	3.7	3.4
Mean time (h)	2.3	7.3	3.7	4.7	5.7	5.5
Rate (km/h)	2.7	2.3	2.3	1.6	1.2	1.4

Spring–summer Chinook salmon that passed the dam via the Bradford Island fishway (BIF) (559, 58.8% of all spring–summer Chinook that passed the dam) took a variety of routes through the forebay. A large proportion migrated upstream along the south side of Bradford Island before crossing over to the Oregon or Washington shores, or entering the spillway forebay where 84 (15.0% of those that exited the BIF) fell back over the dam (Table 3). Seventy-three of these fallback events occurred via the spillway and 11 were via an undetermined route. Of 462 spring–summer Chinook with adequate telemetry records to assign a migration route, 39.4% (182 fish) migrated along the south shore of the forebay while proceeding upstream (Table 3). Of the other 280 spring–summer Chinook that exited BIF, 33.5% were detected by Washington shore receivers and 27.1% were detected by receivers monitoring the spillway forebay. Median time for spring–summer Chinook that exited the BIF to migrate upstream to the Bridge of the Gods receiver was 2.2 h (n = 304) (median rate =2.0 km/h) (Table 2).

Forebay Releases

In addition to the fish that passed through the fishways and navigation lock, we released 153 spring–summer Chinook salmon along the Oregon shore (OSR) of the forebay across the navigation channel from the upstream end of the navigation lock floating guidewall. Ten of the 153 fish (6.5%) fell back over the dam; six via the spillway, two through the navigation lock, one via the ice and trash sluiceway and one via an undetermined route (Table 3). About 82% of the salmon released at the OSR site migrated along the south shore while exiting the forebay, 13.0% were recorded migrating along Bradford Island and then to the Washington shore, and 4.6% moved along Bradford Island and into the forebay of the spillway before being recorded at upstream receiver sites. Median time for 122 Chinook released at the OSR

Table 3. Number of spring–summer Chinook that exited the Bradford Island fishway or were released along the Oregon shore and assigned a forebay migration route, percentage that migrated along the south shore, detected on the Washington shore or detected in the spillway forebay and number and percentage and route of fallback in 2000. All spring–summer Chinook passed the dam or were released in the forebay during spill conditions.

Spring–summer Chinook 2000	Bradford Island fishway	Oregon shore release
Exited or released	559	153
Assigned migration route	462	131
South shore migrants (%)	182 (39.4)	108 (82.4)
Detected on Wa. shore (%)	155 (33.5)	17 (13.0)
Detected in spillway forebay (%)	125 (27.1)	6 (4.6)
All fallbacks	84	10
Via spillway	73	6
Via nav lock	0	2
Via ice and trash sluiceway	0	1
Undetermined	11	1
% fallback	15.0	6.5
% nav lock fallback	0	1.3

site to migrate upstream to the Bridge of the Gods receiver was 3.4 h (median rate = 1.3 km/h) (Table 2).

Forebay Migration Routes of Steelhead

We outfitted steelhead with radio-transmitters from June through mid October of 2000, and most of these fish passed through the Bonneville Dam forebay during August and September (Figure 9). We began releasing steelhead at the Oregon shore site in early June; releases at the north and south guidewall sites did not begin until the last week of August. There was spill at the dam from June through August (Figure 3) (60.7 to 132.8 kcfs with a mean of 64.7 kcfs) and no spill in September and October.

Downstream Releases

Nearly 98% of the 403 radio-tagged steelhead that passed the dam via the Washington-shore fishway migrated along the Washington shore when exiting the forebay; proportions were nearly identical for fish that exited during spill and no-spill conditions. There were no fallbacks by steelhead that passed the dam via this fishway (Table 1). Median time for 250 steelhead that exited the Washington-shore fishway to migrate to the Bridge of the Gods receiver was 1.3 h (median rate = 2.5 km/h) (Table 2).

Twenty-five (3% of all passages) radio-tagged steelhead passed upstream via the navigation lock. Most (64%) of these fish migrated up the south shore while exiting the forebay. About 28% crossed the river and were detected along the Washington shore and 8% were detected in the forebay of the spillway before exiting the forebay (Table 1). There were no fallbacks by steelhead that passed the dam via the navigation lock. Median time for 20

steelhead that passed the dam via the navigation lock to migrate to the Bridge of the Gods receiver was 2.1 h (median rate = 2.2 km/h) (Table 2).

Of the 386 radio-tagged steelhead that passed the dam via the Bradford Island fishway (47.7% of downstream-released steelhead that passed the dam), 266 did so during spill conditions and 120 passed the dam after spill had ceased. About 16% of the steelhead that exited the BIF during spill conditions fell back over the dam via the spillway. About 40% of steelhead that passed the BIF were detected only by receivers on the south shore of Bradford Island or Oregon shore (south shore migrants) while exiting the forebay, 37.2% were detected in the spillway forebay and 22.9% were detected by the receiver on the Washington shore. The proportions of steelhead that migrated along the south shore were similar during spill and no spill conditions (39.3 and 41.3%, respectively). Proportionally more steelhead crossed to the Washington shore during spill (28.8%) than during no-spill (11.0%) conditions (Table 4). Median time for 254 steelhead that exited the BIF to migrate to the Bridge of the Gods receiver was 2.5 h (median rate = 1.8 km/h) (Table 2).

Forebay Releases

We released 187 steelhead with transmitters at the Oregon-shore release site in 2000; 145 were released prior to September 1 during spill conditions and 42 were released after spill had ceased. Fallback percentages were low for steelhead released during spill (6.2%) and slightly higher for those released after spill had ceased (11.9%); the difference was not significant and may have been influenced by the discrepancy in sample sizes. Overall, the majority (76.8%) of steelhead released at OSR were detected only on receivers located on the Oregon shore and the south side of Bradford Island while migrating out of the forebay, 13.9% were recorded on the Washington shore and 9.3% were detected in the forebay of the spillway. These proportions were similar when only steelhead released during spill conditions were examined (75.4, 17.8 and 6.8%, respectively). During no spill conditions, 27 of 33 (81.8%) steelhead released were determined to be south shore migrants, and 6 (18.2%) were detected by receivers monitoring the spillway forebay as they migrated upstream (Table 4). Median time for 121 steelhead released at the OSR site to the Bridge of the Gods receiver was 3.4 h (median rate = 1.3 km/h) (Table 2).

A total of 52 steelhead were released at the north floating guidewall release site (NFG) in 2000. There were no fallbacks associated with the 19 fish released during spill conditions and one fallback (via ice and trash sluiceway) by the 33 steelhead released after spill had ceased. The majority (73.3%) of steelhead released at the NFG site migrated along the south shore while migrating out of the forebay, 4.4% were detected on Washington-shore receivers and 22.2% were detected in the forebay of the spillway. Proportions of steelhead that migrated along the south shore were similar during spill and no-spill conditions (78.9 and 69.2%, respectively) (Table 4). Median time for 35 steelhead released at NFG to migrate upstream to the Bridge of the Gods receiver was 3.6 h (median rate = 1.3 km/h) (Table 2).

We released 74 steelhead on the south side of the navigation lock floating guidewall (SFG) in 2000; 27 fish were released during spill conditions and 47 fish were released after spill had ceased. There were three fallbacks through the navigation lock by steelhead

Table 4. Number of steelhead that exited the Bradford Island fishway or were released at the three sites in the forebay and the number assigned a forebay migration route, number (%) that migrated along the south shore, were detected on Washington shore or were detected in spillway forebay and number, percentage and route of fallback during spill and no spill conditions in 2000.

Steelhead 2000	Bradford Island	Oregon shore	N. guidewall	S. guidewall
Exited or released	386	187	52	74
during spill	266	145	19	27
no spill	120	42	33	47
Assigned migration route	328	151	45	64
during spill	219	118	19	24
no spill	109	33	26	40
South shore migrants (%)	131 (39.9)	116 (76.8)	33 (73.3)	53 (82.8)
during spill	86 (39.3)	89 (75.4)	15 (78.9)	15 (62.5)
no spill	45 (41.3)	27 (81.8)	18 (69.2)	38 (95.0)
Detected on Wa. shore (%)	75 (22.9)	21 (13.9)	2 (4.4)	7 (10.9)
during spill	63 (28.8)	21 (17.8)	2 (10.5)	7 (29.2)
no spill	12 (11.0)	0	0	0
Detected in spillway forebay (%)	122 (37.2)	14 (9.3)	10 (22.2)	4 (6.3)
during spill	70 (32.0)	8 (6.8)	2 (10.5)	2 (8.3)
no spill	52 (47.7)	6 (18.2)	8 (30.8)	2 (5.0)
All fallbacks	45	14	1	3
during spill	44	9	0	1
no spill	1	5	1	2
Via spillway	42	5	0	0
Via nav lock	1	9	0	3
Via ice/trash sluiceway	0	0	1	0
Undetermined	2	0	0	0
% fallback	11.7	7.5	1.9	4.1
during spill	16.5	6.2	0	3.7
no spill	8.3	11.9	3.0	4.3
% nav lock fallback	0.26	4.8	0	4.1

released at SFG, one during spill and two after spill had ceased. A high proportion (82.8%) of the steelhead released at the SFG site migrated along the south shore while migrating out of the forebay, 10.9% were detected along the Washington shore and 6.3% were detected by receivers in the forebay of the spillway. A smaller proportion (62.5%) of steelhead released at SFG migrated along the south shore after exiting the forebay during spill conditions compared to fish released during no-spill (95.0%) but sample sizes were relatively small (Table 4). Median time for 51 steelhead released at SFG to migrate upstream to the Bridge of the Gods receiver was 2.8 h (median rate = 1.6 km/h) (Table 2).

Forebay Migration Routes of Fall Chinook

We outfitted fall Chinook salmon with transmitters during August, September and October. Most fish passed through the Bonneville Dam forebay during August and September (Figure 9). We began releasing fall Chinook at the Oregon shore site at the beginning of August. Releases at the north and south guidewall sites began in the last week

of August. There were spill conditions at the dam during August (60.7 to 132.8 kcfs with a mean of 88.9 kcfs) but no spill during September and October (Figure 3).

Downstream Releases

Nearly all (99%) fall Chinook salmon that exited the Washington-shore fishway (245, 37% of fish that passed the dam via fishways or navigation lock) moved upstream along the Washington shore as they left the forebay. Forty-two of the 245 fall Chinook salmon exited the fishway before 1 September when there was spill at the dam, and one of these fish (2.3%) fell back over the dam via the spillway. During no-spill conditions in September and October, 202 fall Chinook exited the fishway and none fell back. Migration routes for fall Chinook that exited the Washington shore ladder were very similar during the spill and no-spill conditions (Table 1). Median time for 60 fall Chinook exiting the Washington shore ladder to migrate upstream to the Bridge of the Gods receiver was 1.2 h (median rate = 2.7 km/h) (Table 2).

Four percent (29 fish) of all fall Chinook salmon that passed upstream via the navigation lock (Table 1). Three passed the dam before 1 September, and 26 passed after 31 August; none of these fish fell back over the dam. Nearly all (96.0%) fall Chinook that exited the navigation lock were south shore migrants; one fish (4.0%) was detected by receivers in the spillway forebay. Median time for 17 fall Chinook that passed the dam via the navigation lock to migrate upstream to the Bridge of the Gods receiver was 2.0 h (median rate = 2.3 km/h) (Table 2).

Fifty-nine percent (388 fish) of the downstream-released fall Chinook salmon with transmitters passed Bonneville Dam via the Bradford Island fishway (Table 5). Of the 131 that exited the fishway before 1 September while spill was occurring, three (2.3%) fell back over the dam over the spillway. Of the 257 fall Chinook salmon that exited the fishway after August 31 (no-spill), two fell back over the dam, one via the navigation lock and one by an undetermined route. About half (49.7%) of all fall Chinook that passed the BIF that were assigned migration routes migrated along the south shore while leaving the forebay, 17.3% crossed to the Washington shore and 33.0% were detected in the spillway forebay before migrating upstream. Again, proportions of fall Chinook assigned these routes during spill and no spill conditions were similar (Table 5). Median time for 147 fall Chinook that exited the BIF to migrate upstream to the Bridge of the Gods receiver was 2.0 h (median rate = 2.3 km/h) (Table 2).

Forebay Releases

We released 51 fall Chinook at the Oregon shore site in 2000, 25 fish during spill conditions prior to 1 September and 26 fish after 31 August when there was no spill at the dam. Two fall Chinook (8.0%) released during spill fell back over the dam, one over the spillway and one through the navigation lock; three fall Chinook (11.5%) released during no-spill conditions fell back, one via the navigation lock and two by undetermined routes. Most (83.4%) fall Chinook released at OSR were only detected by south shore of Bradford Island and Oregon shore receivers, 2.7% (1 fish) crossed to the Washington shore and 13.5% were

Table 5. Number of fall Chinook that exited the Bradford Island fishway or were released at the three sites in the forebay and the number assigned a forebay migration route, number (%) that migrated along the south shore, that were detected on the Washington shore or were detected in spillway forebay and number, percentage and route of fallback during spill and no spill conditions in 2000.

Fall Chinook 2000	Bradford Island	Oregon shore	N. guidewall	S. guidewall
Exited or released	388	51	161	140
during spill	131	25	20	18
no spill	257	26	141	122
Assigned migration route	330	37	123	107
during spill	115	20	18	14
no spill	215	17	105	93
South shore migrants (%)	164 (49.7)	31 (83.4)	91 (74.0)	70 (65.4)
during spill	60 (52.2)	18 (90.0)	17 (94.4)	10 (71.4)
no spill	104 (48.4)	13 (76.5)	74 (70.5)	60 (64.5)
Detected on Wa. shore (%)	57 (17.3)	1 (2.7)	4 (3.3)	10 (9.3)
during spill	27 (23.5)	1 (5.0)	0	2 (14.3)
no spill	30 (14.0)	0	4 (3.8)	8 (8.6)
Detected in spillway forebay (%)	109 (33.0)	5 (13.5)	28 (22.3)	27 (25.2)
during spill	28 (24.3)	1 (5.0)	1 (5.6)	2 (14.3)
no spill	81 (37.7)	4 (23.5)	27 (25.7)	25 (26.9)
All fallbacks	5	5	3	4
during spill	3	2	0	0
no spill	2	3	3	4
Via spillway	3	1	0	0
Via nav lock	1	2	3	4
Via ice/trash sluiceway	0	2	0	0
Undetermined	1	0	0	0
% fallback	1.3	9.8	1.9	2.9
during spill	2.3	8.0	0	0
no spill	0.8	11.5	2.1	3.3
% nav lock fallback	0.3	3.9	1.7	2.9

detected in the vicinity of the spillway before migrating out of the forebay. Proportions of fall Chinook assigned to the three migration routes were similar during spill and no-spill conditions given the small sample sizes (Table 5). Median time for 24 fall Chinook released at the OSR site to migrate upstream to the Bridge of the Gods receiver was 2.8 h (median rate = 1.6 km/h) (Table 2).

A total of 161 fall Chinook were released at the north floating guidewall release site. There were no fallbacks associated with the 20 fish released during spill conditions; three of 141 fall Chinook released during no-spill conditions fell back, all through the navigation lock. Seventy-four percent of the fall Chinook released at this site were detected only by south shore of Bradford Island and Oregon shore receivers, 3.3% crossed to the Washington shore and 22.3% were detected near the spillway. Proportions assigned to the three migration routes during spill and no-spill were again similar given the large discrepancy in sample sizes (Table 5). Median time for 60 fall Chinook released at NFG to migrate upstream to the Bridge of the Gods receiver was 3.7 h (median rate = 1.2 km/h) (Table 2).

We released 140 fall Chinook on the south side of the navigation lock floating guidewall in 2000; 18 fish were released during spill conditions and 122 fish were released after spill had ceased. There were no fallbacks associated with the 18 fish released during spill; four (3.3%) of the 122 released during no-spill conditions fell back through the navigation lock. Most (65.4%) of the fall Chinook released at this site migrated along the south shore while leaving the forebay, 25.2% were detected near the spillway and 9.3% crossed to the Washington shore. Median time for 55 fall Chinook released at SFG to migrate upstream to the Bridge of the Gods receiver was 3.4 h (median rate = 1.4 km/h) (Table 2).

Comparison of Routes used by Downstream- and Forebay-Released Fish

Migratory behavior of salmon and steelhead that were released in the forebay or exited the Bradford Island fishway was summarized into two categories: 1) migrants recorded *only* on receivers located on the Oregon shore and/or the south side of Bradford Island before being recorded upriver (south shore migrants) and 2) those recorded on receivers associated with the spillway, the north side of Bradford Island adjacent to the spillway, Cascades Island and/or the Washington shore before being recorded upriver (north shore migrants). The latter category represents a consolidation of the fish detected on the Washington shore and the fish detected in the spillway forebay as described in the previous sections and tables. A two-way table and χ^2 statistic were used to describe differences in the proportions of migrants that exited the Bradford Island fishway and migrated up the south or north shores and those released in the forebay that were assigned to each category. Using the same method, we compared the migratory behavior of fall Chinook and steelhead released in the forebay or that exited the Bradford Island fishway during spill and no-spill conditions. Data for fall Chinook and steelhead released at the three sites were pooled for the spill/no spill comparison. In all cases, spring–summer and fall Chinook salmon and steelhead released at all three forebay release sites migrated along the south shore and out of the forebay in higher proportions (χ^2 test, $P<0.005$) than fish that exited the Bradford Island fishway (Table 6). All spring–summer Chinook were released at the OSR site during spill conditions.

A significantly higher proportion (χ^2 test, $P<0.05$) of fall Chinook released at the OSR site migrated along the south shore compared to fall Chinook released at the SFG site although sample sizes were quite different. Differences in migration routes between fall Chinook released at the OSR site and the NFG site and between the NFG site and the SFG site were not significant (Table 6). Differences in proportions of steelhead that migrated along the south shore after release in the forebay did not differ significantly between the three forebay release sites (Table 6).

We also compared forebay migration routes of steelhead and fall Chinook during spill and no-spill conditions. Due to small sample sizes, data for the three forebay release sites were pooled for this comparison. Fall Chinook and steelhead released in the forebay migrated along the south shore in significantly higher proportions (χ^2 test, $P<0.0001$) than fish that exited the Bradford Island fishway regardless of whether or not spill was occurring (Table 7). Fall Chinook used the Oregon shore in significantly higher proportions (χ^2 test, $P<0.01$) during spill than during no spill conditions; the difference was not significant for steelhead (Table 7).

Table 6. Numbers of spring–summer and fall Chinook salmon and steelhead classified as south and north shore migrants after exiting the Bradford Island fishway or after release in the forebay and χ^2 comparisons of proportions in 2000.

Migration Route	Bradford Is. fishway	Or. shore release	N. guidewall release	S. guidewall release
Spring–Summer Chinook				
South shore migrant	182	108	-	-
North shore migrant	280	23	-	-
Steelhead				
South shore migrant	131	116	33	53
North shore migrant	197	35	12	11
Fall Chinook				
South shore migrant	164	31	91	70
North shore migrant	166	6	32	37

χ^2 comparisons of proportions of fish that migrated along south and north shores.

Release Site	Bradford Is. fishway	Oregon shore release	N. guidewall release
Spring–Summer Chinook			
Oregon shore release	P<0.0001	-	-
Steelhead			
Oregon shore release	P<0.0001	-	-
North guidewall release	P<0.0001	ns	-
South guidewall release	P<0.0001	ns	ns
Fall Chinook			
Oregon shore release	P<0.0001	-	-
North guidewall release	P<0.0001	ns	-
South guidewall release	P<0.005	P<0.05	ns

Table 7. Numbers of steelhead and fall Chinook that passed the Bradford Island fishway or were released in the forebay that were assigned south and north shore migration status during spill and no-spill conditions in 2000 and χ^2 comparisons of proportions.

	Steelhead			Fall Chinook		
	Bradford Island	Forebay Release	χ^2 P	Bradford Island	Forebay Release	χ^2 P
Spill						
South shore	86	119	<0.0001	60	45	<0.0001
North shore	133	42		55	7	
No spill						
South shore	45	83	<0.0001	104	147	<0.0001
North shore	64	16		111	68	
Spill vs. no spill						
X^2 P	ns	0.06		ns	0.009	

Fallback by Downstream- and Forebay-Released Fish

Because we were interested in the influence the release location had on fallback behavior, we did not include in this or any other analysis fallback events that took place after fish had migrated out of the forebay and been recorded at an upriver site.

Spring–summer Chinook that passed the Bradford Island fishway fell back in significantly higher proportions (χ^2 test, P=0.006) than those released along the Oregon shore. No spring–summer Chinook that passed the BIF fell back through the navigation lock, and two (1.3%) Chinook released along the Oregon shore fell back by this route (Table 3).

Similarly, a significantly higher proportion (χ^2 test, P=0.007) of steelhead that passed the Bradford Island fishway fell back compared to those released in the forebay (release sites pooled). Only one of 386 (0.3%) steelhead that passed the BIF fell back via the navigation lock, while twelve of 313 (3.8%) steelhead released in the forebay fell back via this route (P = 0.001, Z test)(Table 4). There were three releases of steelhead at the Oregon shore site from which more than one steelhead fell back through the navigation lock: one release had two of three steelhead fall back, one release had two of six fall back and one release had three of seven fall back through the navigation lock.

Low proportions of fall Chinook that passed the BIF fell back (1.3%). One fish fell back through the navigation lock. The fallback proportion for fall Chinook released in the forebay (3.4%, release sites pooled) was significantly higher (χ^2 test, P=0.05) than for those fish that passed via the BIF with nine of twelve fallbacks via the navigation lock. There were no multiple navigation lock fallbacks from a single forebay release group (Table 5).

2001 Releases

Forebay Migration Routes of Spring–Summer Chinook

We outfitted spring–summer Chinook with radiotransmitters from April through July (Figure 8). Releases at the forebay sites began in early April, fish were released every day alternately at the three sites. Spill conditions existed for 31 days, from 16 May to 15 June (Figure 3) with spill levels ranging from 12.6 to 49.9 kcfs, with a mean of 39.5 kcfs.

Downstream Releases

About 99% of spring–summer Chinook that passed Bonneville Dam via the Washington shore fishway (431, 55.5 % of those known to pass the dam) were detected only by the receiver on the Washington shore as they migrated upstream. Six (1.4%) spring–summer Chinook that passed the dam by this route were detected by receivers associated with the spillway. No fish that exited the Washington shore fishway fell back (Table 8). Median time for 317 Chinook that exited the Washington shore fishway to migrate to the Bridge of the Gods receiver was 0.9 h (median rate = 3.0 km/h) (Table 9).

Eight spring–summer Chinook (1% of all passages) passed Bonneville Dam via the navigation lock, of which seven had sufficient telemetry records to assign a migration route. Three (43%) Chinook migrated along the south shore and four (57%) were detected along the Washington shore while exiting the forebay. There were no fallbacks by Chinook that passed the dam via the navigation lock (Table 8). Median time for 8 Chinook that passed upstream via the navigation lock to migrate to the Bridge of the Gods receiver was 1.8 h (median rate = 2.6 km/h) (Table 9).

Table 8. Number of spring–summer and fall Chinook and steelhead that passed Bonneville Dam via the Washington shore fishway or the navigation lock, the number assigned a forebay migration route, number (%) that migrated along south shore, number (%) detected on the Washington shore or detected in the spillway forebay and number, route and percentage of fallback in 2001.

	Spring–summer Chinook		Steelhead		Fall Chinook	
	Wa. shore	Nav lock	Wa. shore	Nav lock	Wa. shore	Nav lock
Exited	431	8	448	18	303	12
Assigned migration route	410	7	428	14	303	12
during spill	92	1	167	9	53	1
no spill	318	6	261	5	250	11
South shore migrants (%)	0	3 (42.9)	0	7 (50.0)	0	3 (25.0)
during spill	-	0	-	4 (44.4)	-	0
no spill	-	3 (50.0)	-	3 (60.0)	-	3 (27.3)
Detected on Wa. shore (%)	404 (98.5)	4 (57.1)	424 (99.1)	5 (35.7)	302 (99.7)	9 (75.0)
during spill	92 (100)	1 (100)	165 (98.8)	4 (44.4)	53 (100)	1 (100)
no spill	312 (98.1)	3 (50.0)	259 (99.2)	1 (20.0)	249 (99.6)	8 (72.7)
Detected near spillway (%)	6 (1.4)	0	4 (0.9)	2 (14.3)	1 (0.3)	0
during spill	0	-	2 (1.2)	1 (11.1)	0	-
no spill	6 (1.9)	-	2 (0.8)	1 (20.0)	1 (0.4)	-
All fallbacks	0	0	1	0	0	0
during spill	-	-	0	-	-	-
no spill	-	-	1	-	-	-
Via spillway	-	-	0	-	-	-
Via nav lock	-	-	0	-	-	-
Via powerhouses	-	-	1	-	-	-
Undetermined	-	-	0	-	-	-
% fallback	0	0	0.2	0	0	0
% nav lock fallback	0	0	0	0	0	0

Table 9. Number of spring–summer and fall Chinook and steelhead that had adequate telemetry records to calculate a time to migrate from fishway exit or release in the forebay to the Bridge of the Gods receiver site, median and mean times to travel this distance and the migration rates in 2001. Migration rates calculated using median times.

	Dam passage			Forebay Release		
	WA shore	Nav lock	Bradford Is.	Oregon shore	N. guidewall	End of guidewall
Sp/su Chinook						
N	317	8	283	88	85	83
Median time (h)	0.9	1.8	1.6	2.8	3.1	2.7
Mean time (h)	1.1	2.4	2.2	4.8	5.0	4.3
Rate (km/h)	3.0	2.6	2.8	1.6	1.5	1.7
Steelhead						
N	335	15	258	78	91	84
Median time (h)	1.2	2.5	2.2	2.9	3.7	3.3
Mean time (h)	1.8	20.9	8.7	11.2	8.8	8.0
Rate (km/h)	2.7	1.8	2.0	1.6	1.2	1.4
Fall Chinook						
N	133	6	142	87	85	81
Median time (h)	1.0	1.6	1.8	2.9	3.2	2.7
Mean time (h)	1.3	3.9	2.7	5.1	4.5	5.1
Rate (km/h)	3.3	2.9	2.9	1.6	1.4	1.7

Of 338 radio-tagged spring–summer Chinook that passed the dam through the Bradford Island fishway (43.5% of all tagged Chinook that passed the dam), 102 did so during spill conditions and 236 passed the dam during no-spill. There was one fallback (via the spillway) by a Chinook that passed the dam via the BIF. About 30% of spring–summer Chinook that passed the BIF were detected only by south shore of Bradford Island and Oregon shore receivers (south shore migrants) while exiting the forebay, 63.8% were detected by receivers on the Washington shore and 6.2% were detected in the spillway forebay. The proportions of Chinook that migrated along the south shore were similar during spill and no-spill conditions (30.8 and 29.6%, respectively) (Table 10). Median time for 283 spring–summer Chinook that exited the BIF to migrate to the Bridge of the Gods receiver was 1.6 h (median rate = 2.8 km/h) (Table 9).

Table 10. Number of spring–summer Chinook that exited the Bradford Island fishway or were released at the three sites in the forebay and the number assigned a forebay migration route, number (%) that migrated along the south shore, that were detected along the Washington shore or were detected in the spillway forebay and number, percentage and route of fallback during spill and no-spill conditions in 2001.

Spring–summer Chinook 2001	Bradford Island	Oregon shore	N. guidewall	End of guidewall
Exited or released	338	119	122	115
during spill	102	24	24	26
no spill	236	95	98	89
Assigned migration route	307	109	94	94
during spill	91	26	13	24
no spill	216	83	81	70
South shore migrants (%)	92 (30.0)	79 (72.5)	63 (67.0)	59 (62.8)
during spill	28 (30.8)	22 (91.6)	11 (84.6)	20 (83.3)
no spill	64 (29.6)	57 (68.7)	52 (64.2)	39 (55.7)
Detected on Wa. shore (%)	196 (63.8)	25 (22.9)	25 (26.6)	31 (33.0)
during spill	60 (65.9)	2 (7.8)	0	4 (16.7)
no spill	136 (62.9)	23 (27.7)	25 (26.6)	27 (38.6)
Detected near spillway (%)	19 (6.2)	5 (4.6)	6 (6.4)	4 (4.3)
during spill	3 (3.3)	0	2 (15.4)	0
no spill	16 (7.4)	5 (6.0)	4 (4.9)	4 (5.7)
All fallbacks	1	3	4	10
during spill	1	0	2	1
no spill	0	3	2	9
Via spillway	1	0	0	1
Via nav lock	0	3	4	8
Via ice/trash sluiceway	0	0	0	1
Via powerhouse	0	0	0	0
Undetermined	0	0	0	0
% fallback	0.3	2.5	3.3	8.7
during spill	1.0	0	8.3	3.8
no spill	0	3.2	2.0	10.1
% nav lock fallback	0	2.5	3.3	7.0

Forebay Releases

We released 119 spring–summer Chinook at the Oregon shore release site; 24 during spill conditions and 95 during no-spill. Three (2.5%) Chinook fell back while no spill was occurring, all via the navigation lock. Most (72.5%) Chinook released at this site were determined to be south shore migrants, 22.9% were detected along the Washington shore and 4.6% were detected by spillway receivers. The proportion of south shore migrants was higher during spill than during no-spill (92% and 69%, respectively), however only 24 Chinook were released while spill conditions existed and this difference in proportions was not significant (Table 10). Median time for 88 Chinook released at the OSR site to migrate to the Bridge of the Gods receiver was 2.8 h (median rate = 1.6 km/h (Table 9).

A total of 122 spring–summer Chinook were released at the north guidewall site; 24 during spill conditions and 98 during no-spill. Four (3.3%) Chinook fell back through the navigation lock after release, two during spill and two during no-spill. Sixty-seven percent of the Chinook released at the NFG site that were assigned a migration route were designated south shore migrants, 26.6% were detected along the Washington shore and 6.4% were detected near the spillway. As with the Oregon shore releases, the proportion of south shore migrants was higher during spill than during no spill (84.6 and 64.2%, respectively); however, this difference was not significant (Table 10). Median time for 85 Chinook released at the NFG site to migrate to the Bridge of the Gods receiver was 3.1 h (median rate = 1.5 km/h) (Table 9).

We released 115 spring–summer Chinook near the end of the navigation lock guidewall (EFG); 26 during spill conditions and 89 during no-spill. Ten (8.7%) Chinook fell back, eight through the navigation lock, one via the spillway and one via the ice and trash sluiceway. Nine of these fallbacks occurred while no spill was occurring. Of the 94 Chinook assigned a migration route, 62.8% were south shore migrants, 33.0% were detected on the Washington shore and 4.3% were detected near the spillway. The proportion of south shore migrants was higher during spill than no-spill conditions (83.8 and 55.7%, respectively) (Table 10). This difference was significant (χ^2 test, P=0.016). Median time for 83 Chinook released at the EFG site to migrate to the Bridge of the Gods receiver was 2.7 h (median rate = 1.7 km/h) (Table 9).

Forebay Migration Routes of Steelhead

We outfitted steelhead with radio transmitters from June through mid October (Figure 9). Releases at the forebay sites began in early June, fish were released every day alternately at the three sites. Spill conditions existed for two distinct periods while steelhead were tagged and released: from 1 June to 15 June and from 24 July to 31 August (Figure 3), with spill levels ranging from 7.3 to 49.8 kcfs (mean = 32.8 kcfs). After 31 August, 2.3 kcfs was spilled from spillbays adjacent to fishway entrances as adult migrant attraction water.

Downstream Releases

Of 448 radio-tagged steelhead that passed the dam via the Washington shore fishway (57.8% of all passages), 428 had adequate telemetry records to assign a migration route and 99% of these fish were determined to have migrated along the Washington shore while exiting the forebay. Proportions were nearly identical for fish that exited during spill and no-spill conditions. There was one fallback via a Powerhouse 2 turbine intake while there was no spill (Table 8). Median time for 335 steelhead that exited the Washington shore fishway to migrate to the Bridge of the Gods receiver was 1.2 h (median rate = 2.7 km/h) (Table 9).

Eighteen (2.3% of all passages) steelhead passed the dam via the navigation lock and 14 were assigned migration routes. Half (50%) of these fish migrated up the south shore while exiting the forebay. About 36% crossed the river and were detected on the Washington shore and 14% were detected in the forebay of the spillway before exiting the forebay (Table 8). There were no fallbacks by steelhead that passed the dam via the navigation lock. Median time for 15 steelhead that passed the dam via the navigation lock to migrate to the Bridge of the Gods receiver was 2.5 h (median rate = 1.8 km/h) (Table 9).

Forty percent of the tagged steelhead that passed the dam did so via the Bradford Island fishway (309 fish). There were nine fallbacks (2.9%) associated with this group, six via the navigation lock and two via the spillway. Of the 265 steelhead for which we were able to assign a forebay migration route, about 47.5% were south shore migrants, 44.5% were detected along the Washington shore and 8% were detected by receivers in the spillway forebay. A significantly higher proportion (56.7%) of steelhead that exited the BIF during spill conditions were south shore migrants than those that exited during no-spill (34.3%) (χ^2 test, $P<0.001$) (Table 8). Median time for 258 steelhead that passed the BIF to migrate to the Bridge of the Gods receiver was 2.2 h (median rate = 2.0 km/h (Table 9).

Forebay Releases

We released 112 steelhead with transmitters at the Oregon shore release site in 2001; 65 were released during spill conditions and 47 were released when spill was not occurring. The fallback percentage was 6.2% during spill and 10.6% during no-spill with six of nine fallbacks occurring via the navigation lock. Of steelhead assigned a migration route, 57.3% released at OSR were detected only by receivers located on the Oregon shore and the south side of Bradford Island while migrating out of the forebay, 31.3% were recorded along the Washington shore and 11.5% were detected in the spillway forebay. The proportion of south shore migrants was slightly higher during spill (63.6%) than during no spill (48.8%) (Table 11). Median time for 78 steelhead released at the OSR site to migrate to the Bridge of the Gods receiver was 2.9 h (median rate = 1.6 km/h) (Table 9).

A total of 117 steelhead were released at the north floating guidewall release site in 2001. There were two fallbacks by the 62 fish released during spill conditions and five fallbacks by the 55 steelhead released during no-spill; six of the seven fallbacks were through the navigation lock. Most (57.1%) of the steelhead released at the NFG site migrated along the south shore while migrating out of the forebay, 28.6% were detected on Washington shore

Table 11. Number of steelhead that exited the Bradford Island fishway or were released at the three sites in the forebay and the number assigned a forebay migration route, number (%) that migrated along the south shore, that were detected on Washington shore or were detected in spillway forebay and number, percentage and route of fallback during spill and no spill conditions in 2001.

Steelhead 2001	Bradford Island	Oregon shore	N. guidewall	End of guidewall
Exited or released	309	112	117	118
during spill	182	65	62	62
no spill	127	47	55	54
Assigned migration route	265	96	98	103
during spill	157	55	54	59
no spill	108	41	44	44
South shore migrants (%)	126 (47.5)	55 (57.3)	56 (57.1)	70 (68.0)
during spill	89 (56.7)	35 (63.6)	30 (55.6)	42 (71.2)
no spill	37 (34.3)	20 (48.8)	26 (59.1)	28 (63.6)
Detected on Wa. shore (%)	118 (44.5)	30 (31.3)	28 (28.6)	19 (18.4)
during spill	54 (34.4)	13 (23.6)	15 (27.8)	11 (18.6)
no spill	64 (59.3)	17 (41.5)	13 (29.5)	8 (18.2)
Detected near spillway (%)	21 (7.9)	11 (11.5)	14 (14.3)	14 (13.6)
during spill	14 (8.9)	7 (12.7)	9 (16.7)	6 (10.2)
no spill	7 (6.5)	4 (9.8)	5 (11.4)	8 (18.2)
All fallbacks	9	9	7	9
during spill	6	4	2	2
no spill	3	5	5	7
Via spillway	2	1	1	0
Via nav lock	6	6	6	4
Via ice/trash sluiceway	0	1	0	4
Via powerhouse	0	0	0	0
Undetermined	1	1	0	1
% fallback	2.9	8.0	6.0	7.6
during spill	3.3	6.2	3.2	3.2
no spill	2.4	10.6	9.0	13.0
% nav lock fallback	1.9	5.4	5.1	3.4

receivers and 14.3% were detected in the spillway forebay. Proportions of steelhead that migrated along the south shore were similar during spill and no-spill conditions (55.6 and 59.1%, respectively) (Table 11). Median time for 91 steelhead released at the NFG site to migrate upstream to the Bridge of the Gods receiver was 3.7 h (median rate = 1.2 km/h) (Table 9).

We released 118 steelhead at the end of the navigation lock floating guidewall; 62 fish were released during spill conditions and 54 fish were released after spill had ceased. There were nine (7.6%) fallbacks by steelhead released at EFG, two during spill and seven when no spill was occurring. Four of the fallbacks were through the navigation lock, four were via the ice and trash sluiceway and one was by an unknown route. The majority (68.0%) of the steelhead released at the EFG site migrated along the south shore while migrating out of the forebay, 18.4% were detected along the Washington shore and 13.6% were detected by receivers in the forebay of the spillway . Proportions were similar during spill and no spill conditions (71.2 and 63.6%, respectively) (Table 11). Median time for 84 steelhead released

at the EFG site to migrate upstream to the Bridge of the Gods receiver was 3.3 h (median rate = 1.4 km/h) (Table 9).

Forebay Migration Routes of Fall Chinook

We outfitted fall Chinook with radio-tags from August through mid October (Figure 9). Releases at the forebay sites began in early August, and fish were released every day alternately at the three sites. Spill conditions existed for all of August (Figure 3) with spill levels ranging from 9.1 to 49.9 kcfs (mean = 40.0 kcfs). After 31 August, 2.3 kcfs was spilled from spillbays adjacent to fishway entrances as adult migrant attraction water.

Downstream Releases

All but one (99.7%) fall Chinook salmon that exited the Washington-shore fishway (303, 58.2% of fish that passed dam via fishways or navigation lock) moved upstream along the Washington shore as they left the forebay. Fifty-three fall Chinook salmon exited the fishway before 1 September when there was spill at the dam, 250 fall Chinook exited after spill had been reduced to 2.3 kcfs. There were no fallback events by fall Chinook that exited this fishway (Table 8). Median time for 133 fall Chinook that exited the Washington shore ladder to migrate upstream to the Bridge of the Gods receiver was 1.0 h (median rate = 3.3 km/h) (Table 9).

About two percent (12 fish) of all fall Chinook salmon passed upstream via the navigation lock. One passed the dam before 1 September, and the remaining 11 passed after 31 August; none fell back over the dam. Nine (75.0%) of these fall Chinook were detected by Washington shore receivers, the other three were south shore migrants (Table 8). Median time for 6 fall Chinook that passed the dam via the navigation lock to migrate upstream to the Bridge of the Gods receiver was 1.6 h (median rate = 2.9 km/h) (Table 9).

Forty percent (206 fish) of the fall Chinook salmon with transmitters passed Bonneville Dam via the Bradford Island fishway (Table 12). There were no fallbacks by the 93 fall Chinook that exited the fishway during spill conditions. Of the 113 fall Chinook salmon that exited the fishway after 31 August when spill had been reduced to 2.3 kcfs, three fell back through the navigation lock. About half (52.4%) of all fall Chinook that passed the BIF that were assigned migration routes were determined to have migrated along the south shore when leaving the forebay, 44.7% crossed to the Washington shore and 2.9% were detected in the spillway forebay before migrating upstream. Proportions of fall Chinook assigned these routes during spill and no-spill conditions were similar (Table 12). Median time for 142 fall Chinook that exited the BIF to migrate upstream to the Bridge of the Gods receiver was 1.8 h (median rate = 2.9 km/h) (Table 9).

Forebay Releases

We released 145 fall Chinook at the Oregon shore site in 2001, 40 during spill conditions prior to 1 September and 105 after 31 August when spill had been reduced to 2.3 kcfs. One

Table 12. Number of fall Chinook that exited the Bradford Island fishway or were released at the three sites in the forebay and the number assigned a forebay migration route, number (%) to migrate along the south shore, detected on Washington shore or detected in spillway forebay and number, percentage and route of fallback during spill and no spill conditions in 2001.

Fall Chinook 2001	Bradford Island	Oregon shore	N. guidewall	End of guidewall
Exited or released	206	145	144	142
during spill	93	40	35	32
no spill	113	105	109	110
Assigned migration route	170	127	119	114
during spill	78	38	30	23
no spill	92	89	89	91
South shore migrants (%)	89 (52.4)	72 (56.7)	70 (58.8)	71 (62.3)
during spill	40 (43.0)	27 (67.5)	16 (45.7)	19 (59.4)
no spill	49(43.4)	45 (42.8)	54 (49.5)	52 (47.3)
Detected on Wa. shore (%)	76 (44.7)	47 (37.0)	39 (32.7)	34 (29.8)
during spill	34 (43.6)	9 (22.5)	10 (28.6)	3 (13.0)
no spill	42 (45.7)	38 (36.2)	29 (26.6)	31 (34.1)
Detected near spillway (%)	5 (2.9)	8 (6.3)	10 (8.4)	9 (7.9)
during spill	4 (5.1)	2 (5.0)	4 (11.4)	1 (4.3)
no spill	1 (1.1)	6 (5.7)	6 (5.5)	8 (8.8)
All fallbacks	3	13	12	13
during spill	0	1	1	2
no spill	3	12	11	11
Via spillway	0	1	0	0
Via nav lock	3	11	12	10
Via ice/trash sluiceway	0	1	0	2
Via powerhouse	0	0	0	1
Undetermined	0	0	0	0
% fallback	1.5	9.0	8.3	9.2
during spill	0	2.5	2.9	6.3
no spill	1.5	11.4	10.1	10.0
% nav lock fallback	1.5	7.6	8.3	7.0

fall Chinook (2.5%) released during spill fell back via the spillway and twelve (11.4%) released during reduced spill fell back, eleven of them through the navigation lock. Most (56.7%) fall Chinook released at OSR were only detected by south shore of Bradford Island and/or Oregon shore receivers, 37.0% were detected on the Washington shore and 6.3% were detected in the vicinity of the spillway before migrating out of the forebay. Fall Chinook released during spill migrated along the south shore in significantly higher proportions than those released after spill had ceased (67.5 and 42.8%, respectively) (χ^2 test, P=0.03) (Table 12). Median time for 87 fall Chinook released at the OSR site to migrate upstream to the Bridge of the Gods receiver was 2.9 h (median rate = 1.6 km/h) (Table 9).

A total of 144 fall Chinook were released at the north floating guidewall release site. There was one fallback by the 35 fish released during spill conditions (2.9%); eleven of the 109 (10.1%) fall Chinook released after spill had been reduced fell back, all through the navigation lock. About 59% of the fall Chinook released at this site were detected only by

south shore of Bradford Island and/or Oregon shore receivers, 32.7% crossed to the Washington shore and 8.4% were detected near the spillway. Proportions assigned to the three migration routes during spill and no-spill were fairly similar (Table 12). Median time for 85 fall Chinook released at the NFG site to migrate upstream to the Bridge of the Gods receiver was 3.2 h (median rate = 1.4 km/h) (Table 9).

We released 142 fall Chinook at the end of the floating guidewall in 2001; 32 fish were released during spill conditions and 110 fish were released after spill had ceased. There were two fallbacks by the fall Chinook released during spill (6.3%) and eleven (10.0%) fallbacks by fall Chinook released after spill had been reduced. Two fallbacks occurred via the ice and trash sluiceway, ten were through the navigation lock and one fall Chinook fell back through a turbine intake. Most (62.3%) of the fall Chinook released at this site migrated along the south shore, 29.8% crossed to the Washington shore 7.9% were detected near the spillway. Median time for 81 fall Chinook released at the EFG site to migrate upstream to the Bridge of the Gods receiver was 2.7 h (median rate = 1.7 km/h) (Table 9).

Comparison of Routes used by Downstream- and Forebay-Released Fish

Spring–summer Chinook released at all three sites in the forebay migrated along the south shore in significantly higher proportions than Chinook that passed the dam via the Bradford Island fishway (χ^2 test, $P<0.0001$) (Table 13).

Only steelhead released at the end of the guidewall site were designated south shore migrants in significantly higher proportions than fish that passed the Bradford Island fishway (χ^2 test, $P<0.001$) (Table 13).

There were no significant differences in the migration routes of fall Chinook that passed the Bradford Island fishway and those released at the three forebay sites the forebay. There were no significant differences in the proportions of south and north shore migrants from the three forebay release sites (Table 13).

Spring–summer Chinook released in the forebay migrated along the south shore in significantly higher proportions (χ^2 test, $P<0.0001$) than Chinook that passed the Bradford Island fishway regardless of whether or not spill was occurring (Table 14). Proportions of spring– summer Chinook released in the forebay and determined to be south shore migrants were significantly higher (χ^2 test, $P<0.001$) during spill than when no spill was occurring although sample size during spill conditions was small. There was no significant difference in the proportions of south and north shore migrants for spring–summer Chinook that passed the dam via the BIF (Table 14).

Steelhead released in the forebay when spill was not occurring migrated along the south shore in significantly higher proportions (χ^2 test, $P<0.001$) than steelhead that passed the Bradford Island fishway during this time (Table 14). Steelhead that exited the Bradford Island fishway during spill conditions were more likely to migrate along the south shore than those steelhead that exited this fishway when spill was not occurring (χ^2 test, $P<0.001$) (Table 14).

Table 13. Numbers of spring–summer and fall Chinook salmon and steelhead classified as south and north shore migrants after exiting the Bradford Island fishway or after release in the forebay and χ^2 comparison of proportions in 2001.

Migration Route	Bradford Is. fishway	Oregon shore release	North guidewall release	End of guidewall release
Spring–Summer Chinook				
South shore migrant	92	79	63	59
North shore migrant	215	30	31	35
Steelhead				
South shore migrant	126	55	56	70
North shore migrant	139	41	42	33
Fall Chinook				
South shore migrant	89	72	70	71
North shore migrant	81	55	49	43

χ^2 comparison of proportions of fish that migrated along south and north shores.

Release Site	Bradford Is. fishway	Oregon shore release	North guidewall release
Spring–Summer Chinook			
Oregon shore release	P<0.0001	-	-
North guidewall release	P<0.0001	ns	-
End of guidewall release	P<0.0001	ns	ns
Steelhead			
Oregon shore release	ns	-	-
North guidewall release	ns	ns	-
End of guidewall release	P<0.001	ns	ns
Fall Chinook			
Oregon shore release	ns	-	-
North guidewall release	ns	ns	-
End of guidewall release	ns	ns	ns

Table 14. Numbers of spring–summer and fall Chinook and steelhead that passed the Bradford Island fishway (BIF) or were released in the forebay that were assigned south and north shore migration status during spill and no-spill conditions in 2001 and χ^2 comparison of proportions.

	Sp/su Chinook			Steelhead			Fall Chinook		
	BIF	Forebay	X^2 P	BIF	Forebay	X^2 P	BIF	Forebay	X^2 P
Spill									
south	28	53	<0.0001	89	107	ns	40	62	0.025
north	63	8		68	61		38	29	
No spill									
south	64	148	<0.0001	37	74	<0.001	49	151	ns
north	152	88		71	55		43	118	
Spill vs. no spill									
χ^2 P	ns	<0.001		<0.001	ns		ns	0.044	

During spill conditions, fall Chinook migrated along the south shore in significantly higher proportions (χ^2 test, P=0.025) than those that exited the Bradford Island fishway. There was no difference between these groups in the absence of spill (Table 14). A significantly higher proportion (χ^2 test, P=0.044) of fall Chinook released in the forebay during spill were south shore migrants than those fall Chinook released during the absence of spill (Table 14).

Fallback by Downstream- and Forebay-Released Fish

In 2001, a very low proportion of spring–summer Chinook that passed the Bradford Island fishway fell back (0.3%) (Table 10). Spring–summer Chinook released in the forebay had an overall fallback rate of 4.8% and an overall navigation lock fallback rate of 4.2%. Two groups of Chinook released at the end of the floating guidewall experienced multiple navigation lock fallbacks; one release had four of eight Chinook fall back and one release had two of two Chinook fall back through the navigation lock.

Steelhead that passed the Bradford Island fishway fell back at an overall proportion of 2.9% with 1.9% falling back via the navigation lock (Table 11). Steelhead released in the forebay fell back at an overall proportion of 7.2% and an overall navigation lock fallback proportion of 4.6%. Two steelhead from a group of five released on the Oregon shore fell back via the navigation lock.

Fall Chinook that passed the Bradford Island fishway fell back at an overall proportion of 1.5%; all of these fallbacks were via the navigation lock (Table 12). Fall Chinook released in the forebay fell back at an overall proportion of 8.8% with an overall navigation lock fallback of 7.9%. There were eight releases of fall Chinook in the forebay in which two fall Chinook from a release group (mean of 9.5 fish/group) fell back via the navigation lock (one release at the Oregon shore site, four releases at the north guidewall site and three releases at the end of the guidewall) and one release at the north guidewall site in which three of eight fall Chinook fell back through the navigation lock.

Discussion

Fallback at Bonneville Dam is a function of innate behavior (fish tend to orient with shoreline and current), flow management strategies and dam configuration. Flow, spill and powerhouse priority all influence current patterns in the forebay. Migrants appear to react differently to different management strategies and with the location of forebay entry. In our study years, few fish that passed the Washington shore fishway fell back. Fish that exit this fishway encounter a clearly defined shoreline that orients them upriver and out of the forebay. River flow discharged through Powerhouse 2 or passing over the spillway also offers a guiding current to which migrants can orient. In contrast, some fish that pass the Bradford Island fishway follow the shoreline of Bradford Island into the spillway forebay, the area from which most fallbacks originate. River flow discharged through Powerhouse 1 provides a channel of deep moving water off the upstream tip of Bradford Island which may encourage migrants to continue to follow the island shoreline and into the forebay of the spillway.

River conditions during the 2000 forebay releases were near average. River flow and spill patterns were close to long term means and river flow was discharged from both powerhouses for much of the migration season. We began releasing spring–summer Chinook on the Oregon shore in early May after the peak of the run, and began releasing steelhead at the Oregon shore at the beginning of June but did not add the north and south guidewall releases until the end of August. Steelhead and fall Chinook released at those sites were only exposed to spill for about one week. These releases were not optimal: runs and species could have been more evenly allocated among release sites and the south floating guidewall release site, immediately adjacent to the navigation lock entrance, was poorly located.

In all cases in 2000, salmon and steelhead released in the forebay migrated along the south shore in higher proportions than those that exited the Bradford Island fishway. There was only one significant difference in fish migration routes among the release sites. Oregon shore- released fall Chinook migrated along the south shore in significantly higher proportions than those released at the south guidewall, but sample sizes were relatively small. Differences in sample sizes of steelhead and fall Chinook released in the presence or absence of spill limited comparisons of migration routes during these conditions, but proportions of fish assigned to these routes were generally comparable.

Fallback proportions were significantly higher for spring–summer Chinook and steelhead that exited the Bradford Island fishway than for those that were released in the forebay. Fall Chinook released in the forebay fell back at a significantly higher proportion than those that passed the Bradford Island fishway with most of those fallbacks occurring through the navigation lock. Fall Chinook have historically shown a propensity for fallback via the navigation lock (Bjornn et al. 2000, Boggs et al. 2004). This may be due to lower river flows and less evident forebay currents during fall Chinook migration.

Spring-summer Chinook salmon and steelhead released in the forebay had lower migration rates than salmon and steelhead that passed either fishway or passed the dam via the navigation lock. Because fish released in the forebay were traveling approximately the same distance as those exiting the Bradford Island fishway or the navigation lock, this suggests an effect from the method of release. Fish released downstream from Bonneville Dam are often disoriented immediately after release from the transport tank and wander temporarily before moving upstream. This could be the cause of lower migration rates for forebay-released fish and also explain some of the navigation lock fallback associated with these releases.

The river conditions in 2001 were anomalous. Near-record low flows were coupled with restricted periods and low volumes of spill. Powerhouse 1 was offline for most of the migration season creating a slackwater environment in the forebay between Bradford Island and the Oregon shore. With the low flow and reduced spill, this meant that during the 2001 migration season about 75% of the Columbia River's flow was discharged through Powerhouse 2. We allocated runs and species to the three release sites more evenly in 2001 with fish released in the forebay throughout the migration season roughly in proportion to the run.

Similar to the 2000 releases, higher proportions of salmon and steelhead released in the forebay migrated along the south shore when moving upstream (compared to fish that exited the Bradford Island fishway), although these differences were only significant with spring–summer Chinook and with steelhead released at one location (EFG). As with 2000, there were no significant differences between the forebay release sites. Generally, higher proportions of salmon and steelhead released in the forebay migrated along the south shore during spill conditions than during periods of no spill. Given the slackwater environment in the forebay of Powerhouse 1 in 2001, moving water near the upstream tip of Bradford Island during spill conditions may have guided migrants across the river channel between Bradford Island and the Oregon shore. Between 2000 and 2001, we saw a decrease in the number of migrants detected near the spillway. We believe some of this difference was attributable to the increased specificity of the underwater antennas attached to the pier noses of the spillbays; the aerial antennas used in 2000 to monitor this area were much less discerning than the underwater antennas whose area of reception is more limited. The difference in the volume of spill between these two years would also be expected to affect the number of fish detected in the spillway forebay.

Due to the low flows and reduced spill, fallback by fish passing the Bradford Island fishway was very low in 2001; only one spring–summer Chinook out of the 338 that exited this fishway fell back without first being detected at an upriver receiver site. Steelhead and fall Chinook that exited the Bradford Island fishway also fell back at comparatively low rates in 2001. In all cases, Chinook salmon and steelhead released in the forebay fell back at higher rates than those that passed the dam by either fishway or the navigation lock. Most of the fallback by forebay-released fish occurred through the navigation lock. With almost no discharge through Powerhouse 1, fish released at these sites had no current to orient with and many moved into the navigation lock and fell back. This is supported by the prevalence of multiple navigation lock fallbacks from single release groups: in one instance four spring Chinook from a release group of eight fish fell back via this route.

Forebay migration rates in 2001 were again highest for fish that passed the Washington shore fishway. Fish that passed the dam via the navigation lock and the Bradford Island fishway had comparable migration rates and migration rates of forebay-released fish were substantially lower. These differences were consistent between 2000 and 2001, indicating this may be more of a handling/release effect than one influenced by river environment.

We believe there are several conclusions that can be drawn from these two years of data. There did not appear to be a difference in the migration routes of salmon and steelhead released at the three forebay release sites. Fish released at all three sites were less likely to be detected in the spillway area or to cross the river to the Washington shore than fish that passed Bonneville Dam via the Bradford Island fishway. The beneficial effect of release at these sites was less clear in regard to fallback behavior. Given the average river conditions and substantial Powerhouse 1 discharge in 2000, proportions of fish that fell back after passing the Bradford Island fishway were comparable to those calculated in past years of telemetry study. Spring–summer Chinook and steelhead released in the forebay fell back in significantly smaller proportions than those released downstream. In 2001, low flow and

reduced periods and volume of spill were likely responsible for the extremely low levels of fallback by fish that passed the Bradford Island fishway.

The proximity of the forebay release sites to the navigation lock probably resulted in the high proportions of fallback from these releases via this route. In 2001, most (80%) of the fallback associated with the forebay releases occurred through the navigation lock. In 2000, about 58% of the fallbacks by forebay–released fish occurred via this route. The differences in these two proportions can likely be attributed to the difference in discharge from Powerhouse 1 between the two years. With no guiding current to align with and guide them out of the forebay, more fish wandered into the navigation lock and were locked through the dam. Discharge through Powerhouse 1 could potentially mitigate this effect.

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