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ADULT SALMON AND STEELHEAD PASSAGE THROUGH FISHWAYS AND TRANSITION POOLS AT JOHN DAY DAM, 1997-2001

Report for project MPE-P-95-1

by

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Preface

Studies of adult salmon and steelhead *Oncorhynchus* spp. migrations past dams, through reservoirs, and into tributaries began in 1990 with planning, purchase, and installation of radio telemetry equipment for studies at the Snake River dams. Adult spring–summer Chinook salmon *O. tshawytscha* and steelhead *O. mykiss* were outfitted with transmitters at Ice Harbor Dam in 1991 and 1992, and at John Day Dam in 1993; reports of those studies are available (Bjornn et al. 1992; 1994; 1995; 1998a; 1998b). The focus of adult salmonid passage studies included the lower Columbia River dams in 1995, when telemetry equipment was set up at the dams and tributaries. Spring–summer Chinook salmon, steelhead and/or sockeye salmon were outfitted with transmitters at Bonneville Dam in 1996, 1997, 1998, 2000 and 2001. In this report we present information on the use of fishway entrances and movements of adult salmon and steelhead through fishways and transition pools and past John Day Dam during the migrations in 1997, 1998, 2000 and 2001.

Acknowledgments

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Abstract

Evaluation of fishway entrance use and passage through fishways by spring–summer Chinook salmon *Oncorhynchus tshawytscha*, steelhead *O. mykiss*, and sockeye salmon *O. nerka* at John Day Dam were objectives of the adult salmon and steelhead passage project in 1997, 1998, 2000, and 2001. Critical parameters studied were times for a fish to first approach and first enter a fishway, total time to pass over the dam, which entrances were approached, where fish entered and exited fishways, and fish passage through transition pools and over the dam. We report here on study results from four years of spring–summer Chinook salmon data, three years of steelhead data, and one year of sockeye salmon data.

After entering the tailrace, fish of all three species first approached a fishway entrance within 1.6 to 2.6 h (*medians*); median times to first enter a fishway were 1.9 h for sockeye salmon, 2.8 to 3.8 h for steelhead and 4.7 to 8.6 h for Chinook salmon. Median dam passage times, from first tailrace record to exit from the top of a ladder, were 13.3 h for sockeye salmon, 16.9 to 20.3 h for steelhead and 26.1 to 35.8 h for Chinook salmon. Median passage times for all segments decreased for Chinook salmon as migrations progressed. Flow and spill levels had limited influence on most passage time calculations compared to behaviors in the fishways and transition pools.

Chinook salmon approached monitored fishway entrances more often (*median* = 7 to 15 times, *mean* = 15 to 26 times) than steelhead (*median* = 5 to 13 times, *mean* = 9 to 19 times) or sockeye salmon (*median* = 4 time, *mean* = 5 times). Fish from all species approached all fishway entrances. Chinook salmon and steelhead tended to first approach entrances adjacent to the shorelines, and Chinook salmon increasingly approached the North Ladder Entrance (NLE) as spill increased. When all approaches were considered, Chinook salmon favored the North Powerhouse Entrance (NPE), steelhead and sockeye salmon approached most often at the South Ladder Entrance (SLE).

Fish from all runs entered fishways a median of 2 to 5 times (*mean* = 3 to 9 times). Chinook salmon and steelhead mostly first entered the SLE, and increasingly entered the NLE as spill increased. In contrast, sockeye salmon first entered the NLE preferentially, but were more likely to enter the SLE as spill increased.

In all years, 56 to 83% of Chinook salmon, 67 to 85% of steelhead, and 70% of sockeye salmon exited a fishway into the tailrace. The proportion of Chinook salmon that exited increased as migrations progressed each year while exit rates for steelhead tended to be highest in summer months. Fish that exited fishways had significantly longer dam passage times than those that did not exit. An exit typically resulted in dam passage delays of 8 h to more than a day for all species during all parts of the migrations. Delays related to exiting a fishway were greatest for Chinook salmon in 1997. The highest numbers of exits by Chinook salmon and steelhead were via the SLE, and were at the NLE and SLE for sockeye salmon. Many of the fish that exited fishways migrated upstream as far as transition pools before turning around and exiting to the tailrace. Very few fish exited fishways after migrating up ladders.

More fish from all species passed the dam via the OR-shore fishway than via the WA-shore fishway; 52 to 74% of Chinook salmon, 61 to 82% of steelhead, and 55% of sockeye salmon passed via the OR-shore.

Most fish of all species entered transition pools quickly after entering fishways. Median times to first enter the WA-shore transition pool were < 3 min for all species in all years. Median

times to first enter the OR-shore pool ranged from 0.6 to 2.0 h for Chinook salmon, from 0.2 to 0.4 h for steelhead, and was 2.5 h for sockeye salmon.

Fish behavior in transition pools were apportioned into four categories: fish that moved straight through with no downstream movement, fish that delayed (moved downstream) in a pool but did not exit, fish that exited the OR-shore pool into the collection channel but not the tailrace, and fish that exited a pool into the tailrace. Seven to 15% of Chinook salmon, 6 to 17% of steelhead and 23% of sockeye salmon moved straight through, while 19 to 42% of Chinook and sockeye salmon and 12 to 23% of steelhead delayed in a pool. Two to 7% of all species exited to the OR-shore collection channel. Between 41 and 68% of Chinook salmon, 57 to 79% of steelhead and 48% of sockeye salmon exited to the tailrace in each year.

Passage times from first transition pool record to exit a pool into a ladder were significantly different for the four groups for most species–years. Median pool passage times (all species) were < 0.25 h for fish that moved straight through, were 0.1 to 1.6 h for fish that delayed in a pool but did not exit to the collection channel, and were 0.6 to 6.4 h for fish that exited to the collection channel but not the tailrace. Fish that exited transition pools into the tailrace had the longest median pool passage times: 20.6 to 37.0 h for Chinook salmon, 12.5 to 13.2 h for steelhead, and 12.2 h for sockeye salmon. Between 24 and 64% of fish (all species) that exited into the tailrace took > 1 d to pass through a pool versus ≤ 2% of fish that did not exit.

The proportions of Chinook salmon that exited transition pools into the tailrace increased as migrations progressed. Water temperature was the best predictor of transition pool exit behavior for Chinook salmon, with the highest exit rates occurring at the highest temperatures. Sockeye salmon were also more likely to exit at higher temperatures. Fish from all species were significantly more likely to exit from the WA-shore transition pool to the tailrace than from the OR-shore pool, but only in some years.

Fish of all species that exited either transition pool to the tailrace had significantly longer median dam passage times (tailrace to exit from top of ladder) than fish that moved straight through or delayed in a pool in most months of most years. Overall, full-dam passage times for Chinook salmon transition pools into the tailrace were 19 to 37 h longer than those for fish that did not exit to the tailrace. Steelhead that exited had median times that were 12 to 15 h longer than non-exiting fish, and delays for sockeye salmon were about 12 h.

Fish of all species ascended ladders relatively quickly throughout the migrations. Median times were 2.5 to 3.1 h for all runs.

In a multivariate analysis of total dam passage time, an exit from a transition pool into the tailrace was the most influential predictor for fish from almost all runs. Time of day was important in some cases, because most fish that entered the tailrace late in the day passed the dam the following day. Water temperature and/or passage date was also predictive, particularly for Chinook salmon passage times: later migrants encountered warmer temperatures and tended to pass the dam more quickly. While flow and spill had some influence on dam passage times, fish behavior and migration timing appeared to be more important factors.

In each year, 3 to 6% of Chinook salmon of the salmon and steelhead recorded at the dam did not pass. On average, 22% of Chinook salmon, 34% of steelhead, and 6% of sockeye salmon that did not pass were recaptured in fisheries near or downstream from John Day Dam. Twenty percent of Chinook salmon and 24% of steelhead that did not pass were last recorded

in downstream tributaries. Between 31 and 65% of those that did not pass were unaccounted for and were presumably mortalities or unreported harvest.

Introduction

An important aspect of the adult salmon and steelhead *Oncorhynchus* spp. passage project was to describe how fish moved past dams in the lower Columbia and Snake rivers. Monitoring of fishway entrance use and movements within fishways by adult salmon and steelhead at lower Snake River dams began in the early 1990s and continued through 1994. Antennas connected to digital spectrum processors, combined with SRX radio receivers (SRX/DSP receivers) allowed simultaneous monitoring of all transmitter frequencies, and these receivers were placed near entrances to fishways, within fishways, and at the tops of ladders at Snake River dams. With the telemetry system, we could monitor movements of individual fish outfitted with transmitters as they approached entrances to fishways, determine openings used by fish to enter and exit fishways, document their movements within fishways, and assess the time fish required to pass the dams. Detailed information on fishway use and passage for Chinook salmon in years prior to 1996 was reported in Bjornn et al. (1994, 1995) and in Part III of Bjornn et al. (1998a).

Research objectives were expanded in 1996 to include lower Columbia River dams. Fishway use behaviors and basic passage time metrics for spring–summer Chinook salmon at Bonneville, McNary, Ice Harbor and Lower Granite dams in 1996 were reported in Keefer et al. (2003a). Adult passage at John Day Dam was compared to passage at The Dalles Dam for the 1997 and 1998 migration years, with particular emphasis on how fishway water temperatures affected behavior (Keefer et al. 2003b). Steelhead response to fall spill at John Day Dam was also evaluated in 1997 (Bjornn et al. 1999). In addition, basic dam passage times (from tailrace to top-of-ladder sites) were reported for all lower Columbia and lower Snake River dams in Keefer et al. (2004a), where passage times at John Day Dam were identified as consistently being among the longest within the monitored Hydrosystem.

From 1997 to 2001, adult passage study objectives for John Day Dam included assessments of a variety of fish behaviors and passage times. In this report, we present details of fishway entrance use, document fish movements in fishways, transition pools, and ladders, and detail passage times for fish to enter fishways, pass through various fishway segments, and eventually pass John Day Dam. Entrances approached and used to enter fishways and entrances and fishways used to pass the dam were also studied, as was delay associated with transition pool behavior. Adult fish behaviors and passage metrics are reported for eight migration-years, including for spring–summer Chinook salmon (1997, 1998, 2000, 2001), steelhead (1997, 2000, 2001) and sockeye salmon (1997).

Methods

Salmon and steelhead used for the studies were collected and outfitted with radio transmitters at the adult fish facility at Bonneville Dam on the Columbia River (river kilometer 235.1). Fish with transmitters were monitored in the tailrace of John Day Dam using SRX receivers (Lotek Engineering, Newmarket Ontario) connected to nine-element Yagi antennas. SRX/DSP receivers connected to underwater coaxial cable antennas were installed near major fishway entrances, and inside fishways and transition pools, as well as at top-of-ladder exits. Tailrace receivers were used to determine when fish first entered the tailrace area of the dam. The SRX/DSP receivers were used to determine when a fish approached the dam at a fishway entrance, entered a fishway, moved within the fishway, and exited the fishway. A detailed description of tagging and monitoring methods used throughout the basin can be found in Bjornn et al. (2000a).

Dam Passage Times

An important aspect of adult salmon and steelhead behavior at John Day Dam was a breakdown of the time required to pass the dam. Analytical emphasis was placed on determining passage times from tailrace entry to first approach at a fishway entrance, from first approach to first recorded entry into a fishway, and total time to pass over the dam. Start times were either the times fish were first recorded at tailrace receivers (~1.8 km downstream), or the times of first approach or entry into a fishway entrance. End times were when fish were recorded exiting from each passage segment. Only fish with telemetry records at both sites bracketing the passage areas were included in analyses.

The three major fishway entrances were monitored in all years. These included the North Ladder Entrance (NLE), North Powerhouse Entrance (NPE), and South Ladder Entrance (SLE) (Figure 1). As a result, we likely overestimated the time some fish took to first approach or enter a fishway entrance, because some likely first approached or entered at unmonitored orifice gates. In all years, some adult salmon and steelhead with transmitters were recorded

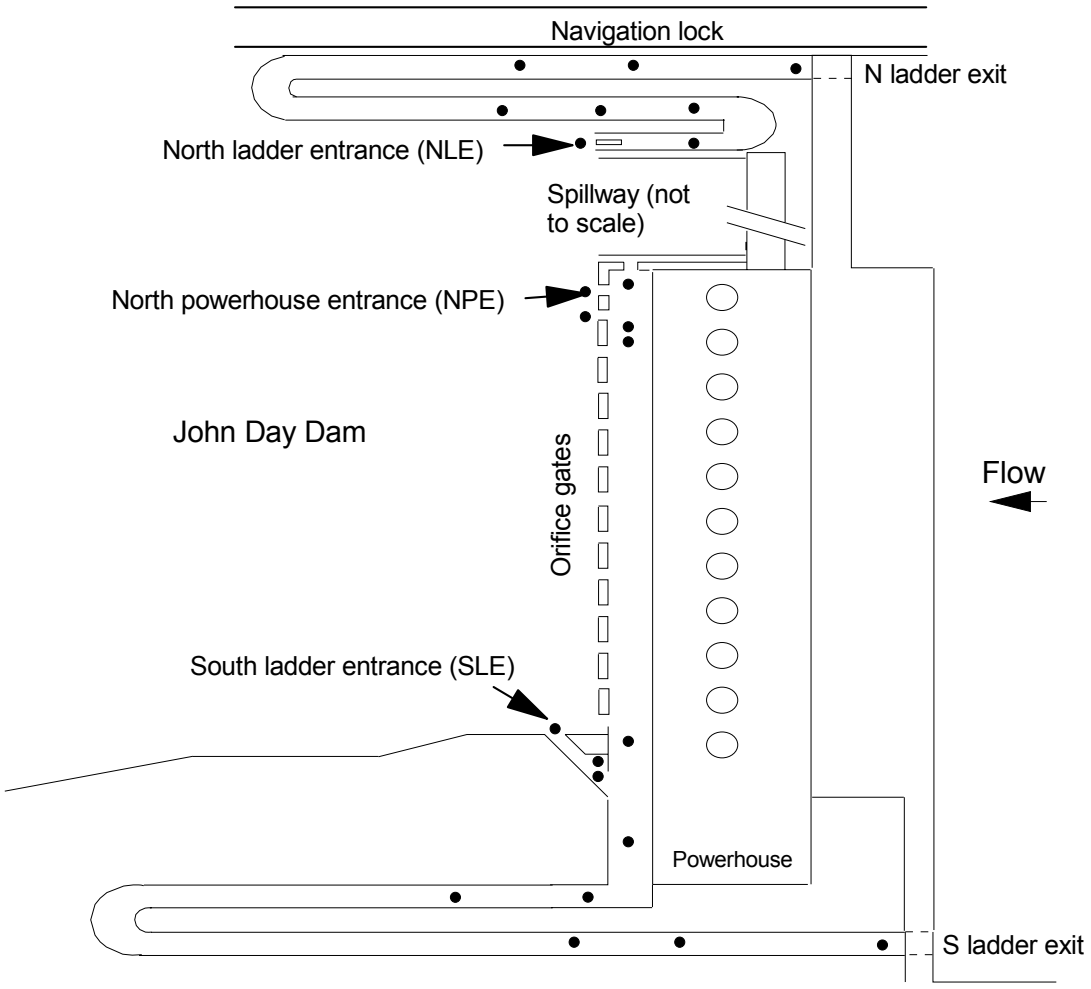

Figure 1. Locations of fishway entrances and ladders at John Day Dam, including approximate sites of underwater antennas (●) used to monitor fish passage. Minor antenna location changes occurred between years.

inside fishways before being recorded approaching an antenna outside the fishway. In these cases, the location of a fish's first approach at the dam was treated as unknown (most likely if a fish approached at an open orifice gate). However, if a fish's first record inside a fishway clearly indicated which entrance was used, the first approach was attributed to that entrance and only the time was unknown (e.g., if the first record was inside the north ladder fishway, the first approach was designated at the north ladder entrance, but the approach time was designated unknown). Similarly, the time or exact location of the first entry into fishways was unknown for some fish each year. Many unknown first entrances were likely via unmonitored orifice gates. To avoid bias, fish with unknown approach or entrance times were excluded from passage time analyses; they were included in fishway use summaries if the entrance location was known.

The numbers of radio-tagged fish with known times and locations for first tailrace record, first fishway approach, first fishway entry, first transition pool entry, transition pool exit into a ladder and exit from the tops of ladders are summarized in Table 1. Between 92 and 97% of all fish recorded at John Day Dam eventually passed the dam. Between 52 and 62% of Chinook salmon in all years, 43–55% of steelhead, and 58% of sockeye salmon had known times and locations at all passage points (Table 1). Between 13-27% of Chinook salmon had unknown first tailrace and first fishway entry times, and 3-8% had unknown first approach times (Figure 2). Unknown actions tended to be spread across the migrations for Chinook salmon, except missed first fishway approaches and entrances tended to be early in 2000. In general, slightly larger proportions of steelhead and sockeye salmon had unrecorded actions (Figure 3). In part this was because some steelhead and all sockeye salmon had smaller, lower-transmission 3-volt transmitters, which had lower detection rates at some sites. In 2001, 70 (7%) spring–summer Chinook salmon had Channel 8 transmitters, which were not monitored at tailrace receivers; most Channel 8 fish arrived at the dam in late May and June.

Table 1. Number of adult radio-tagged fish recorded at John Day Dam that passed the dam, that were recorded on their first passage of the tailrace, first approach at a fishway entrance, first fishway entry, first transition pool entry, last exit from a transition pool into a ladder, and exit from the top of a ladder. Also includes number and percentage of those that passed the dam with telemetry records at all passage points.

	Chinook salmon				Steelhead			Sockeye
	1997	1998	2000	2001	1997	2000	2001	1997
Recorded at dam	654	673	722	994	599	780	910	485
Known to pass dam	629	639	681	969	554	752	869	468
Percent known to pass dam	96%	95%	94%	97%	92%	96%	95%	96%
Recorded first tailrace passage	564	560	563	724	535	552	557	385
Recorded first fishway approach[1]	625	646	662	951	506	712	873	430
Recorded first fishway entrance[1]	484	522	529	812	390	599	718	381
Recorded first transition pool entry	597	642	689	968	527	699	880	420
Recorded transition pool exit	571	602	625	900	479	586	768	416
Recorded ladder exit	611	594	638	944	530	709	844	430
Recorded all passage points	389	398	354	551	304	358	373	271
Percent with all passage points[2]	62%	62%	52%	57%	55%	48%	43%	58%

[1] Some fish likely approached or entered at unmonitored sites prior to being recorded
[2] Percent of all fish known to pass dam

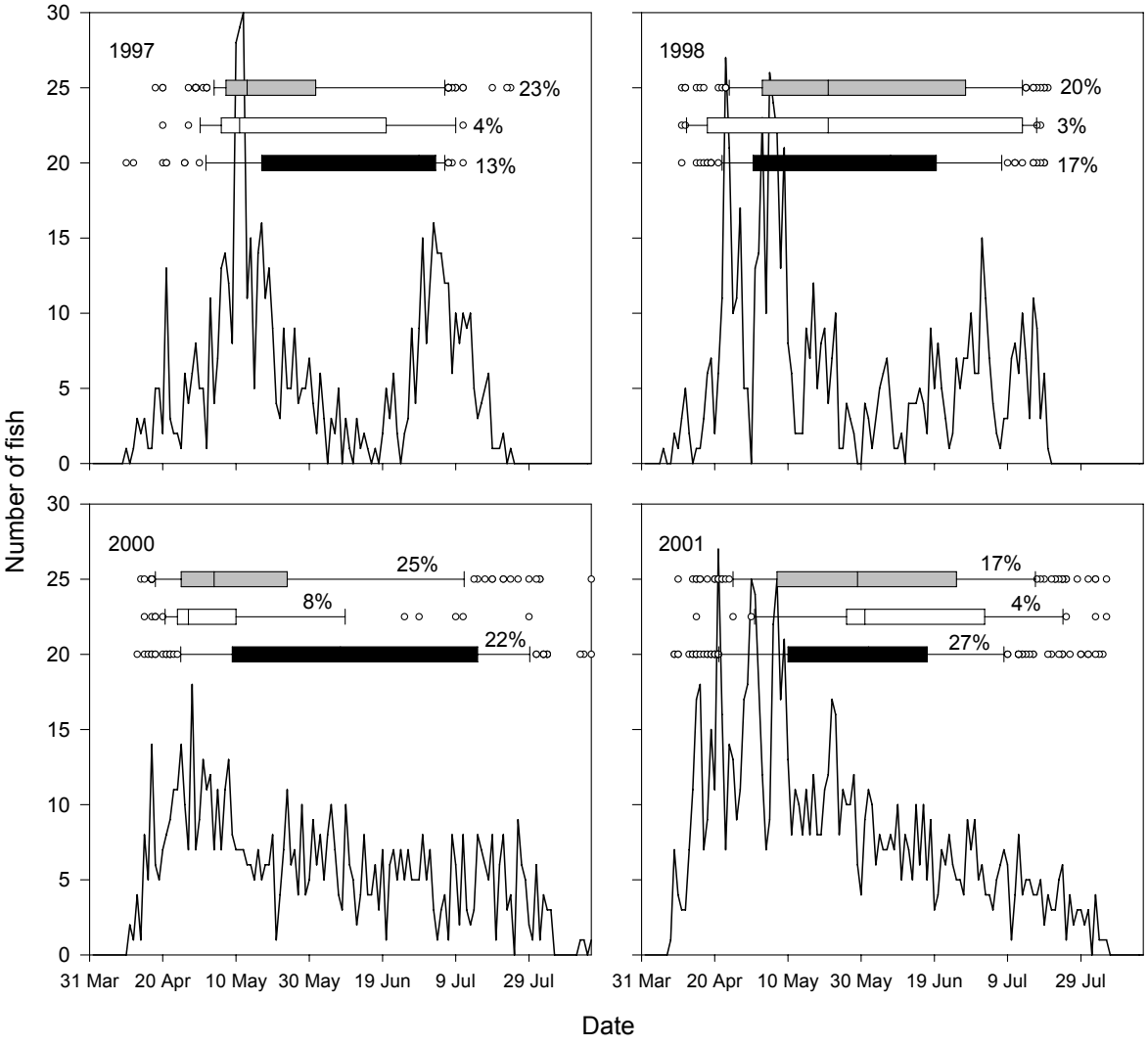

Figure 2. Distributions of first arrival by all radio-tagged spring–summer Chinook salmon at John Day Dam (lines), with distributions and percentages of fish with unknown times in the tailrace (black bars), at first fishway approach (white bars) and at first fishway entry (gray bars).

Unless otherwise reported, passage time calculations (time to first approach, time to first entry, time to pass a dam) were summarized over the entire migration period for all flow and spill conditions and for all fish with known time and location records bracketing both ends of the migration segment. In most cases we present medians because of the tendency for passage time distributions to be right-skewed.

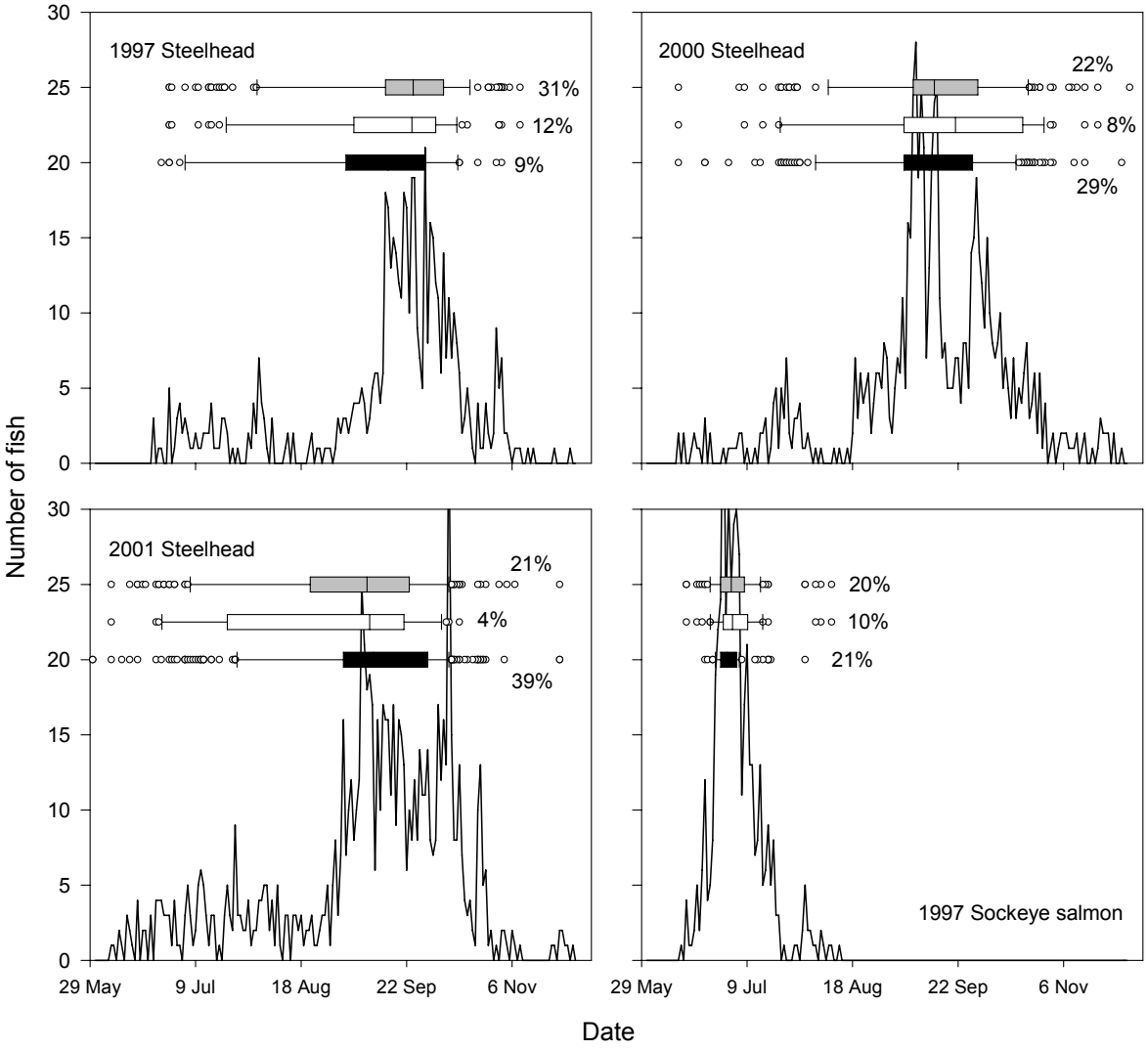

Figure 3. Distributions of first arrival by radio-tagged steelhead and sockeye salmon at John Day Dam (lines), with distributions and percentages of fish with unknown times in the tailrace (black bars), at first fishway approach (white bars) and at first fishway entry (gray bars).

Fishway Use

With the antenna/receiver setups at John Day Dam we were able to determine the movements of adult salmon and steelhead with transmitters in the tailrace, approaches at major entrances to fishways, entrances used to enter and exit the fishway, and the fishway used to pass the dam (Figure 1). Because fish could approach and enter fishways more than once, total approaches, entries, and exits made by fish were also summarized. John Day Dam has two fishways, one for the north ladder adjacent to the Washington shore and one that leads to the south ladder adjacent to the Oregon shore. Fish can enter the south ladder via three routes: from the entrance at the north end of the powerhouse, from orifice gates along the face of the powerhouse, or from the south ladder entrance at the base of the south ladder.

The migration history of each fish at the dam was contained in thousands of telemetry records collected as fish passed antenna sites. A program, based on a decision tree, was used to aid in manual coding of telemetry records at the dam. The program helped the person coding fish movements move through site records quickly and presented codes that could be accepted or rejected. Passage at the dams was the most complex and most intensively monitored part of the migration history of most fish. All data were coded once, checked, and then double-checked in the context of the entire migration of each fish.

Movement Through Transition Pools

We also collected telemetry data as fish passed through transition pools (the area at the bottom of the fish ladder where weirs are inundated by the tailwater) during dam passage. Underwater antennas were installed in the downstream portion of each transition pool to record when tagged fish entered or exited the pools. One or more antennas were also installed at the bottom of each ladder and in sequence up the ladder to record when fish passed through the transition pools and entered ladders. The sequence of antennas were set to accommodate fluctuating water elevations in the fishway and tailrace. Minor coverage differences existed between years, but should not have greatly biased interpretation.

For the WA-shore fishway, the transition pool extended from just inside the fishway entrance upstream to the first unsubmerged weir in the ladder (antenna locations described in Table 2). In the OR-shore fishway, the transition pool extended from the upper end of the powerhouse collection channels upstream to the first unsubmerged weirs. We identified when fish first entered transition pools, how much time fish spent between their first and last records in a pool, whether or not fish passed directly into the ladder from a pool, when fish exited a pool and began to ascend a ladder, and when fish exited the top of a ladder.

Table 2. Locations of underwater antennas used to monitor fish movements in transition pool areas.

WA-shore transition pool			OR-shore transition pool		
Antenna #	Elevation	Weir #	Antenna #	Elevation	Weir #
3	155	before 1	3	155	before 1
4	155	before 1	4	156	1-2
5	164	9-10	5	164-168	8-9, 12-13
6	168	13-14	6	173-174	17-18
			7	155	before 1[1]

[1] at upper end of collection channel

Based upon earlier studies at other dams by Bjornn et al. (1998a; 1998b) and Keefer et al. (2003a), fish behavior in transition pools was categorized into four groups:

1.) Fish passed through a pool without delay (no downstream movements recorded.)

2.) Fish delayed in a pool (downstream movement detected within the pool, but fish was not recorded at antennas within the collection channel or at a fishway entrance.)

3.) Fish exited the OR-shore pool into a collection channel (fish were detected at antennas inside collection channels, but were not recorded exiting the fishway into the tailrace. Note: some fish may have exited and re-entered the fishway via unmonitored orifice gates.)

4.) Fish that exited a pool into the tailrace of the dam.

Environmental Conditions

Flow and spill at John Day Dam during the study ranged from well above average (1997) to one of the lowest runoff years on record (2001) (USACE 1998; USACE 2002 DART electronic database). Peak flows in 1997 were > 550 kcfs and peak spill was > 250 kcfs; in comparison, peak flows were ~ 425 kcfs briefly in 1998, < 400 kcfs in 2000 and < 200 kcfs in 2001 (Figure 4). In all years except 2001, spill was continuous from mid-April through 1 September. Spill was limited in 2001 to one three-week periods from late May to mid-June. Peak temperatures at the dam were between 21 and 24° C in all years, with the highest levels in 1998 (Figure 5). Water temperature data were collected by USACE at the dam only through mid-September in all years. Turbidity levels were variable in all years, but visibility tended to be lowest in 1997 and 1998 and higher in 2000 and 2001 (Figure 5).

Results

Passage Times

Chinook salmon:

Median times for all spring–summer Chinook salmon to pass from the tailrace receiver (1.8 km downstream from John Day Dam) to their first recorded approach at a fishway entrance ranged from 1.5 to 2.6 h in the four study years (Table 3). At least 75% first approached a fishway entrance in < 12 h each year, and most fish first approached in < 6 h. Less than 1% took > 3 d to approach a fishway in 1998, 2000 and 2001. In 1997, the year with the highest flow and spill, 3% took > 3 d and 2% took > 5 d to first approach.

From first tailrace record, median times for Chinook salmon to first enter a fishway ranged from 4.7 h in 2000 to 8.6 h in 1997, the year with the highest flow and spill (Table 3). One to 4% took > 5 d to first enter a fishway in the latter three years, and 10% took > 5 d in 1997. The percentages that took more than 3 d to first enter were 17% (1997), 6% (1998), 4% (2000) and 3% (2001).

Median times from first fishway approach to first fishway entry ranged from 1.3 to 2.5 h (Table 3). Time to first enter after first approach was quite variable: 25% of the fish entered a fishway within 0.7 h (42 min) of first approaching in all years, while 5–17% took more than 5 h.

Median times from first tailrace record to exit from the top of a ladder were 35.8 h in 1997, 31.2 h in 1998, 28.4 h in 2000, and 26.1 h in 2001 (Table 3). In each year, 25% of the fish passed the dam in ≤ 15 h. Fourteen to 34% passed in > 3 d and 7–23% passed in > 5 d. Proportions that passed the dam in > 3 and > 5 d were highest in 1997 (high flow) and lowest in 2001 (low flow).

In all passage time measures, distributions were skewed to the right. Consequently, mean passage times were longer than median times and variance estimates were high. Longer passage times occurred when fish spent 1 d (or night) or more in the fishways or spent time

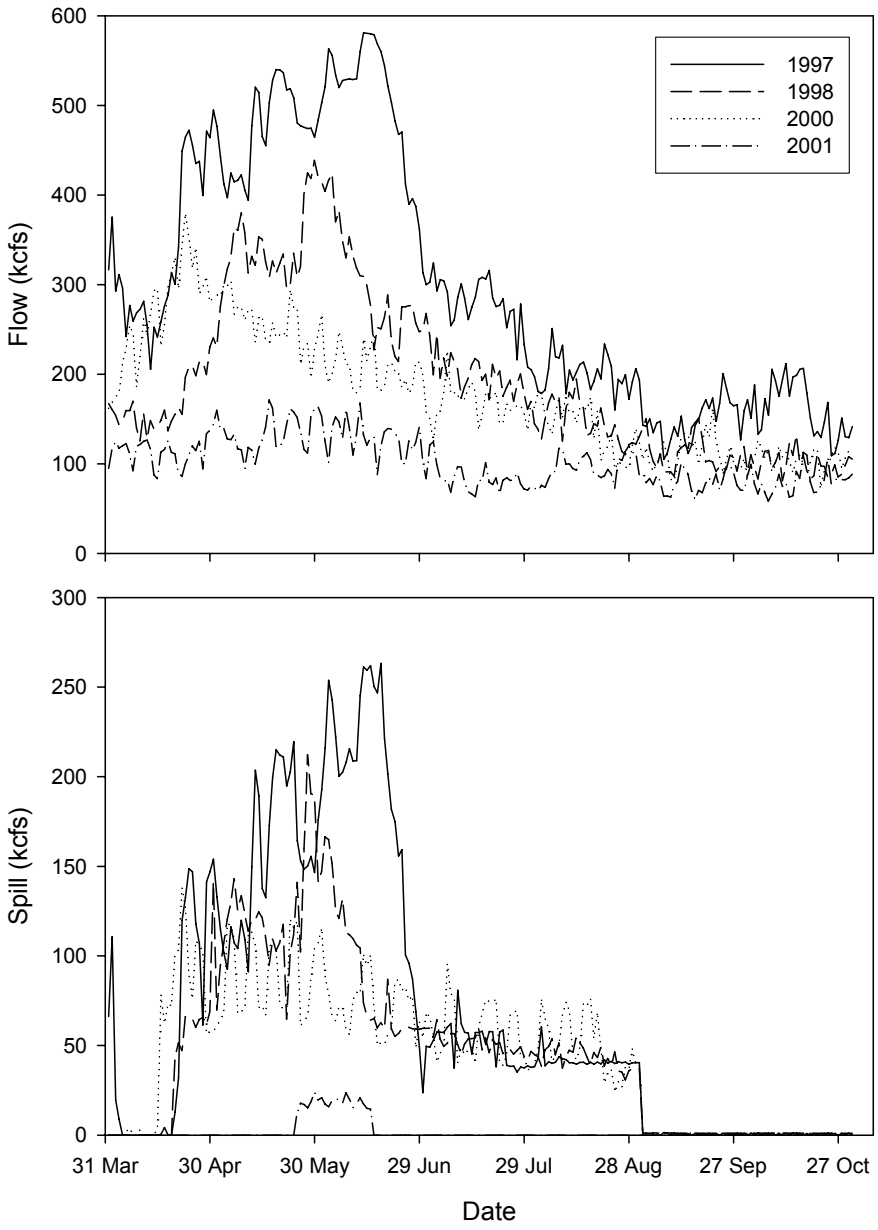

Figure 4. Mean daily flow and spill (kcfs) at John Day Dam in 1997, 1998, 2000, and 2001.

migrating up and down powerhouse collection channels, exiting and reentering fishways multiple times, or migrating between fishways. Passage times between the tailrace and exit from the tops of ladders included time used by fish that exited a fishway into the tailrace and then reentered a fishway.

In all years, median passage times for spring–summer Chinook salmon tended to decrease from April through July, particularly in 1997 and 1998 (Table 4). Median times to pass the dam decreased from 8–12 h (26 to 33%) from April to May in the last three years, and 112 h (77%)

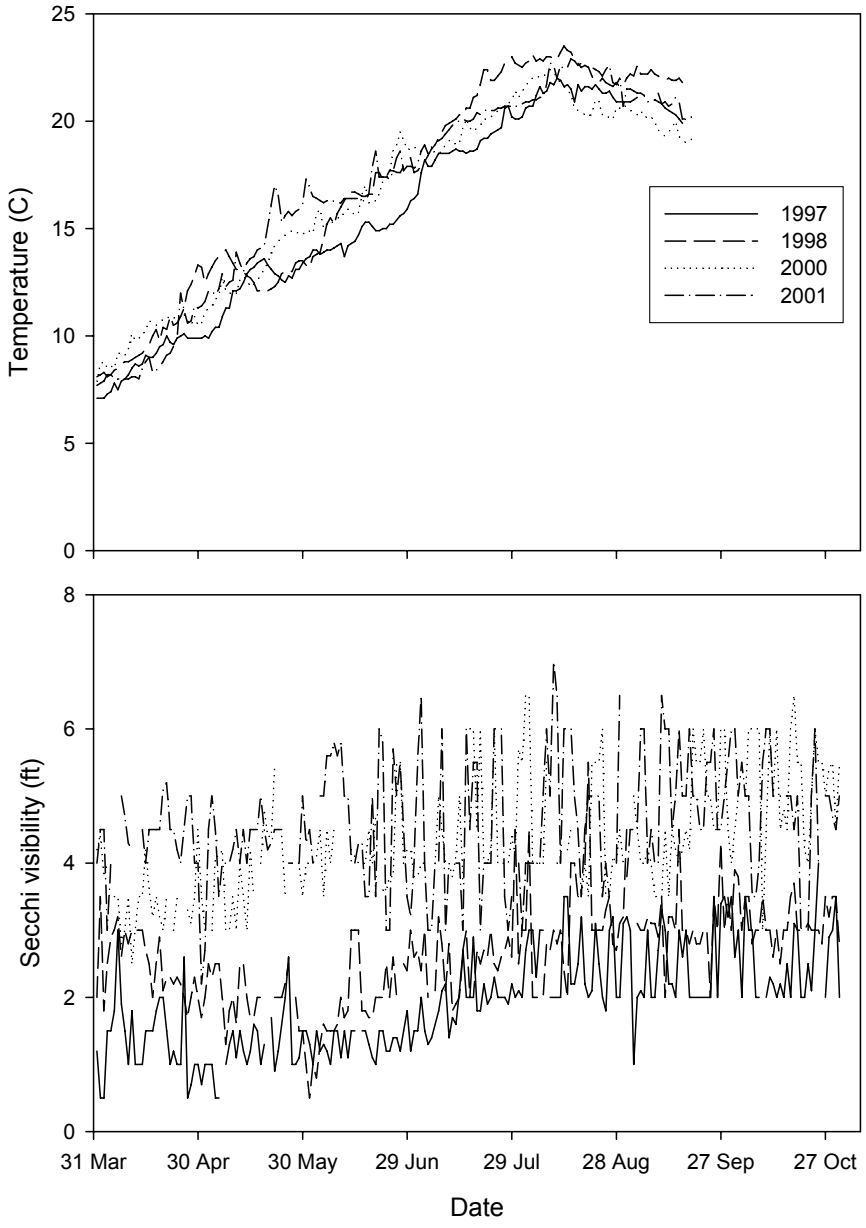

Figure 5. Mean daily water temperature (ºC) and Secchi disk visibility (ft) at John Day Dam in 1997, 1998, 2000, and 2001.

in 1997. Between May and June, median times to pass the dam decreased 3–4 h (10–12%) in 1997 and 1998, but increased 6 h (29%) in 2001 and 14 h (73%) in 2000. Between June and July, time to pass the dam decreased about 6 h (14%) in 1997, 7 h (23%) in 1998, and < 1 h (<1%) in 2000; times increased about 6 h (21%) from June to July in 2001 (Table 4).

In between-month comparisons, passage times from first tailrace to first fishway approach were significantly different ($P < 0.05$, K-W χ^2 tests) in 15 of 24 (63%) possible comparisons (small number of August passages excluded). In general, differences were greatest between

Table 3. Number of adult radio-tagged fish and median and quartile times to pass from first tailrace record to first fishway approach, first fishway entrance and to pass John Day Dam, and from first fishway approach to first fishway entry with percentages that took > 3 and > 5 d to pass through the migration segment.

	Chinook salmon				Steelhead			Sockeye
First tailrace to first approach	1997	1998	2000	2001	1997	2000	2001	1997
N	539	541	520	694	457	523	538	341
1st Quartile (h)	1.7	1.4	1.1	1.1	1.5	1.3	1.1	1.1
Median (h)	**2.6**	**2.0**	**1.5**	**1.6**	**2.3**	**1.8**	**1.6**	**1.6**
3rd Quartile (h)	5.6	3.6	3.2	3.3	3.9	3.3	2.6	2.5
Percent > 5 d	2%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Percent > 3 d	3%	<1%	1%	<1%	<1%	<1%	<1%	<1%
First tailrace to first entry								
N	414	440	414	598	351	442	438	309
1st Quartile (h)	3.9	2.9	2.5	2.4	2.0	1.9	1.7	1.2
Median (h)	**8.6**	**6.1**	**4.7**	**4.8**	**3.4**	**3.8**	**2.8**	**1.9**
3rd Quartile (h)	29.7	16.6	9.6	10.4	7.7	9.9	6.0	3.3
Percent > 5 d	10%	4%	3%	1%	1%	<1%	<1%	0%
Percent > 3 d	17%	6%	4%	3%	2%	2%	<1%	<1%
First tailrace to pass dam								
N	527	505	493	690	477	516	509	343
1st Quartile (h)	15.0	14.7	12.5	14.0	9.4	10.8	11.4	8.3
Median (h)	**35.8**	**31.2**	**28.4**	**26.1**	**16.9**	**19.6**	**20.3**	**13.3**
3rd Quartile (h)	108.8	60.2	58.1	50.0	33.3	35.7	37.9	24.3
Percent > 5 d	23%	10%	10%	7%	8%	8%	11%	3%
Percent > 3 d	34%	21%	18%	14%	12%	12%	16%	7%
First approach to first entry								
N	484	522	529	812	390	572	718	381
1st Quartile (h)	0.5	0.7	0.5	0.6	0.0	0.3	0.2	0.0
Median (h)	**2.4**	**2.5**	**1.9**	**1.7**	**0.3**	**0.9**	**0.8**	**0.0**
3rd Quartile (h)	17.1	8.4	5.9	5.5	1.6	3.4	2.3	0.7
Percent > 5 d	8%	3%	2%	<1%	<1%	<1%	<1%	0%
Percent > 3 d	13%	4%	2%	2%	1%	<1%	<1%	<1%

April and later months. Differences in passage times from first tailrace to first fishway entry and from first fishway approach to first fishway entry were each significant in 20 of 24 (83%) comparisons. Passage times from first tailrace to pass the dam differed ($P < 0.05$) in 4 of 6 comparisons in both 1997 and 1998, and in 3 of 6 in 2000 and 2001. Most non-significant dam passage times ($P > 0.05$) occurred when medians differed by less than 6 h (Table 4).

In individual years, spill and flow were not significantly correlated with passage time from the tailrace past the dam in individual months. All linear regression models with time to pass and mean daily spill or flow when fish passed the tailrace had r^2 values < 0.07 when we included all fish in each year/month separately.

Table 4. Number of adult radio-tagged spring–summer Chinook salmon and median times (h) to pass from first tailrace record to first fishway approach, to first fishway entrance, and to pass John Day Dam based on month fish were first detected in the tailrace.

	Chinook salmon							
	1997		1998		2000		2001	
First tailrace to first approach	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
April	62	**3.6**	116	**2.0**	111	**2.3**	222	**1.9**
May	276	**2.8**	245	**2.2**	169	**1.5**	274	**1.6**
June	73	**2.5**	80	**1.9**	137	**1.3**	111	**1.3**
July	128	**2.0**	100	**1.4**	96	**1.2**	85	**1.2**
August					7	**1.2**	2	**1.2**
First tailrace to first entry								
April	43	**21.1**	98	**9.0**	68	**9.6**	201	**7.1**
May	189	**14.8**	194	**8.7**	130	**5.2**	235	**4.7**
June	65	**7.3**	66	**5.2**	126	**3.7**	91	**3.4**
July	117	**4.9**	82	**3.0**	86	**2.8**	70	**2.8**
August					4	**7.1**	1	**1.4**
First tailrace to pass dam								
April	58	**144.9**	104	**44.2**	116	**27.6**	215	**31.0**
May	275	**33.1**	226	**32.9**	167	**19.1**	276	**20.9**
June	70	**29.9**	74	**28.8**	126	**33.1**	112	**27.0**
July	124	**25.8**	101	**22.2**	78	**33.0**	83	**32.7**
August					6	**28.1**	4	**42.4**
First approach to first entry								
April	43	**17.1**	98	**3.9**	68	**2.7**	201	**2.9**
May	189	**4.5**	194	**4.2**	130	**2.3**	235	**1.9**
June	65	**2.2**	66	**1.9**	126	**1.9**	91	**1.1**
July	117	**1.3**	82	**0.9**	86	**1.1**	70	**0.6**
August					4	**3.9**	1	**0.1**

Compared to flow and spill rates, behavior by spring–summer Chinook salmon in fishways explained much of the variability in passage times at the dam. Additional passage time summaries, relating to fishway exits and behavior in transition pools, are included in sections on fishway use and movements through transition pools.

Steelhead:

Median times for all steelhead to pass from the tailrace receiver to their first recorded approach at a fishway entrance ranged from 1.6 to 2.3 h (Table 3). At least 75% first approached within 4 h. Less than 1% took more than 3 d to first approach. Median times to first enter a fishway ranged from 2.8 to 3.8 h (Table 3). At least 75% first entered within 10 h and < 1% took more than 3 d to first enter a fishway. Median times from first tailrace record to exit from the top of a ladder were 16.9 h in 1997, 19.6 h in 2000 and 20.3 h in 2001 (Table 3). In each year, about a quarter of the steelhead passed the dam in < 12 h and another quarter passed in > 33 h. From 8 to 11% passed in > 5 d and 12–16% passed in > 3 d (Table 3).

Median times from first fishway approach to first fishway entry were < 1 h in all years, and 75% took less than 3.5 h to first enter after approaching the dam (Table 3).

As with Chinook salmon, passage time distributions for steelhead were skewed to the right, mean passage times were longer than median times and variance estimates were high. Longer passage times occurred when fish spent 1 d (or night) or more in the fishways or spent time migrating up and down powerhouse collection channels, exiting and reentering fishways multiple times, or migrating between fishways.

Between-month differences in median passage times from first tailrace to first fishway approach were mostly non-significant ($P > 0.05$, K-W χ^2 tests), although times in September 1997 tended to be significantly shorter than in other months, and times in November of 2000 and 2001 and June of 2001 tended to be longer (Table 5). Patterns were similar for median times from first tailrace to first fishway entry: most between-month differences were not significant, except that times in November 2000 and 2001, June 2001, and October 1997 tended to be significantly ($P < 0.05$) longer. Median time to pass the dam, from first tailrace record, was shorter in September than in October or November in 1997 ($P < 0.02$, K-W χ^2 tests) (Table 5). In 2000, median dam passage time was longer in November than in most other months ($P < 0.05$). In 2001, dam passage times in October were generally significantly shorter than in other months, while times in November tended to be longer than other months ($P < 0.05$) (Table 5). For the most part, between-month differences in first fishway approach to first fishway entry were not significant.

We found no strong correlation between steelhead passage times and spill/no spill conditions or mean flow rates. As with Chinook salmon, behavior by steelhead in fishways explained much more of the variability in steelhead passage times at the dam. Additional passage time summaries, relating to fishway exits and behavior in transition pools, are included in sections on fishway use and movements through transition pools.

Sockeye salmon:

Migration times for sockeye salmon were less variable than for spring–summer Chinook salmon or steelhead. Median times for sockeye salmon to first approach and first enter a fishway at John Day Dam were 1.6 h, and > 75% first approached and entered within 3.3 h after first passing the tailrace receiver (Table 3). Less than 1% took > 3 d to first approach or first enter a fishway. Median time between first fishway approach and first fishway entry was < 42 min (0.7 h) for almost all fish. Median passage time from the tailrace over the dam was 13.3 h; 25% passed in < 8.3 h and 25% passed in > 24.3 h. Seven percent took more than 3 d to pass the dam (Table 3).

About 30% of sockeye salmon first approached and entered fishways and passed the dam in June, compared to ~67% in July and ~3% in August (Table 5). Differences in median times to pass from the tailrace to first fishway approach, first fishway entry, and to pass the dam were significantly ($P < 0.005$, K-W χ^2 tests) in June than in July. Times in June were also shorter than times for the few fish that arrived at the dam in August (Table 5). Individual sockeye salmon passage times were very weakly correlated with flow and spill at the dam, with longer passage times during high flows ($r^2 \leq 0.10$ for all fish, and for June and July fish separately).

Table 5. Number of adult radio-tagged steelhead and sockeye salmon and median times (h) to pass from first tailrace record to first fishway approach, to first fishway entrance, and to pass John Day Dam based on month fish were first detected in the tailrace.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
First tailrace to first approach	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
June	6	**2.4**	11	**1.8**	32	**2.0**	103	**2.1**
July	40	**2.4**	38	**1.9**	52	**1.7**	229	**1.4**
August	21	**2.4**	56	**1.9**	50	**1.7**	9	**1.2**
September	197	**1.9**	228	**1.7**	217	**1.4**		
October	164	**2.6**	165	**1.8**	171	**1.5**		
November	21	**3.4**	25	**3.0**	15	**2.9**		
December	2	**9.5**			1	**4.7**		
First tailrace to first entry								
June	6	**4.2**	11	**3.1**	24	**3.2**	92	**2.8**
July	32	**3.0**	35	**2.7**	39	**2.4**	209	**1.7**
August	18	**2.7**	49	**3.7**	37	**2.4**	8	**1.5**
September	154	**2.8**	185	**3.8**	173	**3.0**		
October	121	**5.4**	140	**3.9**	152	**2.9**		
November	16	**3.9**	22	**8.1**	12	**7.1**		
December	1	**3.6**			1	**5.1**		
First tailrace to pass dam								
June	7	**15.9**	11	**13.2**	33	**25.7**	100	**20.5**
July	41	**19.5**	39	**19.7**	48	**25.9**	236	**12.3**
August	23	**15.5**	53	**21.0**	44	**24.1**	7	**8.6**
September	207	**14.8**	226	**20.3**	217	**20.7**		
October	175	**20.7**	165	**17.9**	155	**16.1**		
November	19	**26.8**	22	**24.9**	11	**40.8**		
December	1	**17.7**			1	**13.9**		
First approach to first entry								
June	6	**1.4**	11	**0.1**	24	**0.7**	92	**0.0**
July	32	**0.1**	35	**0.4**	39	**0.4**	209	**0.0**
August	18	**0.1**	49	**0.7**	37	**0.6**	8	**0.0**
September	154	**0.3**	185	**1.0**	173	**1.0**		
October	121	**0.5**	140	**0.9**	152	**0.7**		
November	16	**0.5**	22	**1.5**	12	**0.7**		
December	1	**0.1**			1	**0.4**		

Additional summaries of sockeye salmon passage times, relating to fishway exits and behavior in transition pools, are included in sections on fishway use and movements through transition pools.

Fishway Use

Chinook salmon:

In all years, spring–summer Chinook salmon were monitored as they approached and entered three major fishway entrances at John Day Dam: the north ladder entrance (NLE), the north powerhouse entrance (NPE) and the south ladder entrance (SLE). The NLE was the only entrance into the WA-shore fishway, while the NPE and SLE were part of the OR-shore fishway (Figure 1). Orifice gate entrances were not monitored in any year, and fish could enter them undetected. The NLE and SLE each had one of two entrances open, and each was approximately 3.7 m wide by 2.5 m deep. The NPE had two open entrances about 1.8 m wide which were also about 2.5 m deep. At the NLE, approximate discharges were 700 cfs (summer) to 900 cfs (spring). Discharge was ~940 cfs at the SLE. Unmonitored orifice gates were 0.6 by 1.2 m and each discharged approximately 100 cfs (USACE, personal communication).

Between 645 and 989 Chinook salmon were known to have approached fishways each year, 629 to 985 were known to have entered fishways, and 352 to 814 exited fishways (Table 6). In each year, > 97% of fish that approached fishways subsequently entered and 56 to 83% of the fish that entered eventually exited into the tailrace. Salmon approached fishways a median of 7 to 15 times (*means* = 15 to 26 times), and entered a median of 2 to 4 times (*means* = 1.8 to 4.2). Fish that exited fishways exited a median of 1 time in 1997 and 2 times in 1998, 2000 and 2001 (*means* = 4 to 9). The median numbers of exits for all fish that entered a fishway were 1 to 3 times (*means* = 3 to 8 exits/fish that entered). Median (3 to 5) and mean (5 to 10) numbers of exits per fish that exited a fishway (Table 6) were higher than for all fish that entered a fishway. Because orifice gate entrances were unmonitored, some fish approached, entered and exited through orifice gates undetected, resulting in a loss of precision for behavior summaries.

Table 6. Number of radio-tagged spring–summer Chinook salmon that approached, entered and exited fishway entrances at John Day Dam, and the median and mean number of approaches, entrances and exits per fish. Also includes the percentages that entered after approaching fishways and exited after entering fishways.

	Chinook salmon											
	1997			1998			2000			2001		
	N	Med	Avg	N	Med	Avg	N	Med	Avg	N	Med	Avg
Approached	645	7	15.0	660	11	16.4	714	15	25.7	989	15	22
Entered	632	2	4.0	653	3	5.1	704	3	7.6	985	4	9.3
Exited	352	3	5.5	506	3	5.3	512	5	9.1	814	4	10
Percentage of those that approached that subsequently entered												
	97.5%			98.9%			98.6%			99.6%		
Percentage of those that entered that subsequently exited												
	56.0%			77.5%			72.7%			82.6%		

Approaches to fishways - Chinook salmon first approached fishways at John Day Dam at all monitored entrances (Table 7). A majority (52–62%) first approached the SLE in all but

2000, when more fish (43%) first approached the NPE. The NLE was first approached least (5–14% in all years).

Table 7. Location of first and total approaches to fishway entrances by radio-tagged spring–summer Chinook salmon at John Day Dam; approaches with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified approach site.

	Chinook salmon							
	1997		1998		2000		2001	
First approach	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
North Ladder Entrance	92	**14.2**	62	**9.4**	85	**11.9**	51	**5.2**
North PH Entrance	139	**21.5**	242	**36.7**	307	**43.0**	309	**31.2**
South Ladder Entrance	401	**62.1**	342	**51.8**	276	**38.7**	593	**60.0**
Unknown	14	**2.2**	14	**2.1**	46	**6.4**	36	**3.6**
Total	646		660		714		989	
Total approaches								
North Ladder Entrance	1,240	**12.8**	1,290	**12.0**	2,012	**10.9**	2,458	**11.2**
North PH Entrance	5,122	**52.7**	5,136	**47.6**	11469	**62.4**	10242	**46.6**
South Ladder Entrance	2,891	**29.8**	3,926	**36.4**	4,411	**24.0**	7,812	**35.5**
Unknown	457	**4.7**	441	**4.1**	487	**2.6**	1,466	**6.7**
Total	9,710		10793		18379		21978	

Site preferences for first fishway approaches varied with spill volume, but few strong patterns emerged across years. More than 50% of Chinook salmon first approached at the SLE under all spillway discharge levels in 1997, with the lowest use of this site occurring when spill levels were intermediate (< 100 kcfs) (Table 8). In 1998, more than 45% first approached the SLE under almost all spill levels, and relatively more fish (25–50%) first approached the NPE than in 1997. In 2000 and 2001, salmon slightly favored the SSE at low and zero spill and the WPE at low to moderate spill. Fewer than 15% first approached the NLE at all spill levels in all years except 1997 when 17–19% first approached there at zero and low spill (Table 8).

Distributions of combined first and subsequent approaches at fishway entrances (total approaches) differed from those for first approaches (Table 7). The highest percentages of total fishway approaches were at the NPE in all years, ranging from 47 to 62%. The second most approached site was the SLE (24–36%), and the NLE was least approached (11–13%).

In 1997 and 1998, the highest proportions of total approaches were at the SLE during no spill and at the NPE under almost all other spill volumes (Table 8). In 2000 and 2001, the highest proportions were at the NPE during both zero spill and spill conditions. Under all spill scenarios except one, the NLE had the lowest proportion of total approaches. The exception was during zero spill in 1997 when the NLE had approximately twice as many approaches as the NPE (Table 8).

Table 8. Percentage of first and total approaches to fishway entrances by radio-tagged spring–summer Chinook salmon at John Day Dam based on mean daily spill on the date of the approach. Approaches with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified approach site; approaches with unknown time and site were included in the unknown category.

Chinook salmon - 1997										
	% of first approaches					% of total approaches				
Spill	N	NLE	NPE	SLE	Unk[1]	N	NLE	NPE	SLE	Unk
0	18	17	11	**72**	0	137	27	15	**57**	1
1-49	73	19	23	**55**	3	1,634	17	**45**	34	5
50-99	192	15	30	**53**	2	4,333	17	**56**	24	4
100-149	182	10	17	**70**	3	1,571	5	**56**	33	6
150-199	91	14	15	**70**	0	1,116	6	**56**	32	6
200-249	84	19	18	**61**	2	828	7	**50**	38	5
250-299	6	0	33	**67**	0	91	6	34	**54**	7
Chinook salmon – 1998										
0	22	14	27	**46**	14	150	16	35	**44**	5
1-49	40	0	25	**73**	3	835	13	**47**	34	6
50-99	344	9	36	**53**	2	6,466	13	**44**	39	5
100-149	240	12	39	**48**	1	3,066	11	**55**	32	2
150-199	8	0	50	**50**	0	167	4	**59**	31	7
200-249	4	0	**75**	0	25	40	3	**58**	35	5
Chinook salmon – 2000										
0	7	14	**43**	**43**	0	117	6	**59**	33	2
1-49	91	8	28	**63**	2	3,824	13	**51**	33	3
50-99	432	12	**46**	35	6	11,441	12	**63**	22	3
100-149	184	14	**43**	34	9	2,997	5	**74**	18	3
Chinook salmon – 2001										
0	813	5	28	**65**	2	17,477	12	**43**	38	7
1-49	176	6	**46**	39	10	4,467	8	**60**	27	6
Chinook salmon – all years combined										
0	860	6	28	**64**	3	17,764	12	**43**	38	7
1-49	380	8	35	**51**	6	7,053	11	**55**	29	5
50-99	968	12	40	**45**	4	14,623	14	**49**	33	4
100-149	606	12	34	**51**	4	16,078	11	**61**	25	3
150-199	99	13	18	**69**	0	4,280	5	**69**	22	4
200-249	88	18	21	**58**	3	868	7	**51**	38	5
250-299	6	0	33	**67**	0	91	6	34	**54**	7

When all approaches from all years were combined, spring–summer Chinook salmon tended to approach most often at the NPE at all spill levels, while the proportion using the NLE decreased as spill increased (Table 8).

Entries to fishways - Chinook salmon first entered fishways at John Day Dam at all monitored entrances (Table 9). The largest percentages (30–56%) first entered the SLE in all

years, followed by the NLE (20–29%). The percentage first entering the NPE ranged from 9% in 2001 to 21% in 1997. Estimated first entries via orifice gates were 4–15%, though some unknown first entries may also have been via this route. Distributions of total fishway entries were comparable to those for first entries, though fewer of the total entries were at the SLE in all years (Table 9).

Table 9. Location of first and total fishway entrances by radio-tagged spring–summer Chinook salmon at John Day Dam; entries with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified entry site.

	Chinook salmon							
	1997		1998		2000		2001	
First fishway entrance	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
North Ladder Entrance	140	**22.2**	144	**22.1**	203	**28.8**	197	**20.0**
North PH Entrance	130	**20.6**	98	**15.0**	140	**19.9**	89	**9.0**
South Ladder Entrance	241	**38.1**	281	**43.0**	212	**30.1**	550	**55.8**
Orifice Gate (probable)[1]	n/a	**n/a**	97	**14.9**	31	**4.4**	80	**8.1**
Unknown	121	**19.1**	33	**5.1**	118	**16.8**	69	**7.0**
Total	632		653		704		985	
Total[2] fishway entrances								
North Ladder Entrance	670	**26.2**	677	**20.4**	1,293	**24.2**	1,314	**14.4**
North PH Entrance	655	**25.6**	453	**13.6**	1,129	**21.2**	921	**10.1**
South Ladder Entrance	753	**29.4**	1,416	**42.6**	1,995	**37.4**	4,100	**44.8**
Orifice Gate (probable)	n/a	**n/a**	482	**14.5**	541	**10.1**	1,874	**20.5**
Unknown	479	**18.7**	295	**8.9**	379	**7.1**	934	**10.2**
Total	2,557		3,323		5,337		9,143	

[1] Orifice gate entrances were unmonitored, but data suggests entrance via this route; not available 1997
[2] Totals differ from Table 5 because includes unknown entries

Variable-duration periods of zero spill occurred in all four years. Very few Chinook salmon first entered the NPE during zero spill, instead favoring the SLE (38–58%) and NLE (22–42%) (Table 10). During spill, salmon were most likely to first enter the SLE, followed by either the NLE or NPE; however, relatively large percentages (e.g. > 20%) first entered at unknown sites (presumably orifice gates), and particularly at higher spill levels (Table 10). In 2001, 58% of 842 fish first entered the SLE on days with zero spill, compared to 42% of 177 fish that first entered on days with spill ($P < 0.0001$). Significantly higher percentages first entered the NPE and at unknown locations ($P < 0.005$) on days with spill than on days without in 2001. The distributions of total approaches were comparable to those for first entrances in all years (Table 10).

Exits from fishways – The highest percentages of first and total fishway exits by spring–summer Chinook salmon were via the SLE (32–48%) in all years (Table 11) The second highest percentages were via the NPE (25–36%), followed by the NLE (12–27%). Less than 10% of first and total fishway exits were via unknown or probable orifice gates.

Table 10. Percentage of first and total entrances to fishways by radio-tagged spring–summer Chinook salmon at John Day Dam based on mean daily spill on the date of the entrance. Entrances with unknown times were included at specific sites if subsequent telemetry records inside fishways clearly identified entrance site; entrances with unknown time and site were included in the unknown category.

Chinook salmon - 1997										
		% of first entrances					% of total entrances			
Spill	N	NLE	NPE	SLE	Unk[1]	N	NLE	NPE	SLE	Unk
0	12	42	0	**50**	8	7	32	0	**64**	5
1-49	69	25	30	**36**	9	98	20	26	**38**	16
50-99	189	29	**39**	19	13	452	**34**	33	19	15
100-149	169	12	8	**53**	27	46	15	10	**47**	29
150-199	106	20	15	**41**	25	33	15	15	**37**	33
200-249	76	28	5	**45**	22	32	20	13	**42**	24
250-299	11	9	18	**73**	0	2	5	28	**49**	18
Chinook salmon - 1998										
0	21	**38**	5	**38**	19	41	32	2	**46**	20
1-49	37	14	19	**54**	14	313	20	15	**38**	27
50-99	353	17	14	**48**	21	2,188	17	13	**47**	24
100-149	229	30	17	**35**	18	725	**32**	17	**32**	18
150-199	8	25	25	0	**50**	25	12	16	4	**68**
200-249	3	0	0	33	**67**	7	0	0	29	**71**
Chinook salmon - 2000										
0	7	29	0	**57**	14	11	18	0	**55**	27
1-49	90	16	16	**54**	14	1,573	19	14	**47**	19
50-99	439	**34**	21	25	20	3,239	28	23	**33**	16
100-149	168	22	19	**30**	29	514	19	27	**34**	20
Chinook salmon – 2001										
0	842	22	9	**58**	11	7,524	15	9	**47**	30
1-49	177	11	17	**42**	30	1,619	11	18	**37**	34
Chinook salmon - all years combined										
0	882	23	8	**58**	12	7,587	15	8	**47**	30
1-49	373	15	19	**45**	21	2,431	14	19	**38**	29
50-99	981	27	22	**32**	19	5,078	22	18	**40**	20
100-149	566	22	15	**39**	24	4,281	27	21	**34**	17
150-199	114	20	16	**38**	26	756	17	24	**34**	26
200-249	79	27	5	**44**	24	164	20	13	**42**	26
250-299	11	9	18	**73**	0	39	5	28	**49**	18

Most upstream point reached before first fishway exit – We estimated where spring–summer Chinook salmon turned around in fishways and ladders before their first fishway exit to the tailrace (Table 12). Relatively sparse telemetry coverage in some portions of fishways, particularly in the collection channel and in ladders upstream from transition pools, limited

Table 11. Location of first and total fishway exits by radio-tagged spring–summer Chinook salmon at John Day Dam; exits with unknown times were included at specific entrances if telemetry records inside fishways clearly identified exit site.

	Chinook salmon							
	1997		1998		2000		2001	
First fishway exit	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
North Ladder Entrance	79	**22.4**	107	**21.1**	115	**22.5**	111	**13.6**
North PH Entrance	88	**25.0**	142	**28.1**	177	**34.6**	290	**35.6**
South Ladder Entrance	153	**43.5**	191	**37.8**	164	**32.0**	344	**42.3**
Orifice Gate (probable)[1]	n/a	**n/a**	24	**4.7**	7	**1.4**	24	**2.9**
Unknown	32	**9.1**	42	**8.3**	49	**9.5**	45	**5.5**
Total	352		506		512		814	
Total[2] fishway exits								
North Ladder Entrance	525	**27.0**	500	**18.6**	981	**21.0**	949	**11.6**
North PH Entrance	539	**27.8**	838	**31.1**	1,591	**34.1**	2,479	**30.3**
South Ladder Entrance	778	**40.1**	1,091	**40.5**	1,735	**37.1**	3,957	**48.3**
Orifice Gate (probable)[1]	n/a	**n/a**	92	**3.4**	70	**1.5**	343	**4.2**
Unknown	99	**5.1**	172	**6.4**	295	**6.3**	460	**5.6**
Total	1,941		2,693		4,672		8,188	

Table 12. Most upstream point reached in fishways before Chinook salmon first exited into the tailrace.

	Chinook salmon							
	1997		1998		2000		2001	
Antenna location	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
Inside N. coll. channel	64	**18.2**	67	**13.3**	95	**18.6**	70	**8.6**
Inside S. coll. channel	121	**34.4**	217	**43.0**	206	**40.2**	445	**54.7**
Below OR trans. pool	10	**2.8**	9	**1.8**	19	**3.7**	42	**5.2**
First OR trans. pool weir	5	**1.4**	76	**15.0**	16	**3.1**	107	**13.1**
OR transition pool	57	**16.2**	--	**--**	30	**5.9**	12	**1.5**
Above OR trans pool[1]	12	**3.4**	26	**5.1**	24	**4.7**	27	**3.3**
Near ladder diffuser	4	**1.1**	5	**1.0**	--	**--**	--	**--**
Top of OR ladder	1	**0.3**	--	**--**	2	**0.4**	--	**--**
WA transition pool	78	**22.2**	95	**18.8**	110	**21.5**	101	**12.4**
Above WA pool[1]	--	**--**	9	**1.8**	10	**2.0**	10	**1.2**
Count window	--	**--**	1	**0.2**	--	**--**	--	**--**
Top of WA ladder	--	**--**	--	**--**	--	**--**	--	**--**
Total OR fishway	274	**77.8**	400	**79.2**	392	**76.6**	703	**86.4**
Total WA fishway	78	**22.2**	105	**20.8**	120	**23.4**	111	**13.6**

[1] Some fish recorded 'above' transition pool were likely still in submerged-weir portion of pool

resolution in this analysis. In the first three years, 34 to 43% were recorded at antennas inside the SSE entrance before exiting to the tailrace, as were 55% in 2001. Another 9 to 19% were recorded inside the NPE entrance in all years. Between 14 and 24% first turned around in, just before, or just upstream from the submerged-weir portions of the two transition pools each year. The upper end of transition pools was determined by daily tailwater elevation. Given the detection range of antennas, it was likely that some fish recorded at antennas upstream from the submerged-weir were still in the transition pool. Relatively few fish were recorded for extended periods at the upper antennas before being recorded at downstream sites, suggesting that few fish moved far up the ladder. In addition, low power on many of these telemetry records also indicated that many fish were furhter downstream. Very small proportions moved upstream from transition pools to ladder diffusers, count windows, or to the tops of ladders before turning around and exiting to the tailrace (Table 12).

Fishway entrance effectiveness - In each year some fishway entrances had more exits than entries by spring–summer Chinook salmon (Table 13). In 1998, 2000, and 2001, the NPE was the only entrance with negative first and total net entries, while only the SLE was negative for total entries in 1997. The most effective first entry site was the SLE in 1997, 1998, and 2001, and was the NLE in 1998. The most effective site for total entries was unknown in 1997, probable orifice gate in the last three years (Table 13). The large numbers of unknown entry and exit locations suggest widespread use of the orifice gates, although we emphasize that these sites were unmonitored and numbers are estimates. The distributions suggest that many Chinook salmon entered orifice gates at the dam, then moved down the collection channel and exited at the NPE.

Table 13. Net first and total fishway entrances and exits by radio-tagged spring–summer Chinook salmon at John Day Dam; entrances and exits with unknown times were included at specific entrances if telemetry records inside fishways clearly identified the site.

	Chinook salmon							
	1997		1998		2000		2001	
Net entrances	First	Total	First	Total	First	Total	First	Total
South Ladder Entrance	88	**-25**	90	325	48	260	206	143
North PH Entrance	42	116	**-44**	**-385**	**-37**	**-462**	**-201**	**-1,558**
North Ladder Entrance	61	145	37	177	88	312	86	365
Orifice Gate (probable)[1]	n/a	n/a	73	390	24	471	56	1,531
Unknown[2]	89	380	**-9**	123	69	84	24	474

[1] Orifice gate entrances were unmonitored, but data suggests entrance via this route; not available 1997
[2] All unknown entrances and exits were at entrances to the OR-shore fishway

A negative net entry rate at a fishway entrance did not mean that the entrance did not produce dam passages. Net entry rates were negative at the NPE in the last three years, but between 7–12% of spring–summer Chinook salmon last used the NPE just prior to passing the dam (Table 14). Between 18 and 47% of salmon used the SLE just prior to passing the dam, 24–29% used the NLE, and 14–24% used unknown entrances (most likely orifice gates). In all years, majorities (52–74%) of Chinook salmon used the OR-shore fishway, and 23–48% passed via the WA-shore fishway. Three percent or less passed the dam via unknown routes (navigation lock most likely) (Table 14).

Table 14. Last fishway entrance used by radio-tagged spring–summer Chinook salmon at John Day Dam and ladder used to pass the dam; entrances with unknown times were included at specific entrances if telemetry records inside fishways clearly identified the site.

	Chinook salmon							
	1997		1998		2000		2001	
Last entrances	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
South Ladder Entrance[1]	208	**34.0**	291	**46.6**	116	**17.5**	374	**39.3**
North PH Entrance	94	**15.4**	46	**7.4**	85	**12.9**	69	**7.3**
North Ladder Entrance	147	**24.0**	180	**28.8**	300	**45.4**	370	**38.9**
Orifice Gate (probable)[1]	n/a	**n/a**	95	**15.2**	49	**7.4**	122	**12.8**
Unknown[2]	163	**26.6**	12	**1.9**	111	**16.8**	16	**1.7**
Dam passage route								
OR-shore ladder	465	**73.9**	445	**51.5**	361	**57.7**	582	**60.0**
WA-shore ladder	147	**23.4**	179	**47.7**	300	**41.4**	369	**38.1**
Passed unknown[3]	17	**2.7**	15	**0.8**	20	**0.9**	18	**1.9**

[1] Configuration of South Ladder Entrance antennas in 1997 resulted in a higher proportion of unknown entries; configuration in 1998-2001 allowed for identification of probable orifice gate entries; receiver outage at SLE in 2000 inflated percentage of unknown entries in that year
[2] All unknown last entrances were at entrances to the OR-shore fishway
[3] Likely passage via navigation lock, or with malfunctioning transmitter

Fishway exits may have occurred for a variety of reasons, including time of day that fish entered fishways, upstream migration rates, tailrace elevation, number and location of submerged weirs, water velocity in fishways, turbidity, water temperature, etc. We calculated the number of exits per entry for each fishway entrance based on mean daily flow. Fishway exit rates exceeded 100% at some flow levels from the NPE and SLE in some years (Table 15). Rates could exceed 100% at those sites because fish could enter the NPE, SLE, or orifice gates, travel upstream to the OR-shore transition pool and then move back downstream and exit these sites (see Figure 1).

Movement between fishways - In all years, Chinook salmon moved between entrances and between fishways at high rates before passing the dam (Table 16). From 33 to 64% of the fish that first approached the dam at the NLE (WA-shore) made their first fishway entrance into the OR-shore fishway (presuming almost all unknown entries were at the OR-shore fishway) (Table 16). After first approaching OR-shore fishway entrances, 18–33% (NPE) and 13–19% (SLE) migrated through the tailrace to first enter at the NLE (WA-shore fishway). Fish that first approached at the NLE and ELE tended to first enter at those sites in all years; a notable exception was that more than half of the salmon that first approached NLE in 2001 made their first fishway entrance at SLE (Table 16). First entry locations for fish that first approached at the NPE were the least predictable.

Despite considerable movement between fishways, Chinook salmon tended to pass the dam via the fish ladder adjoining the fishway they first approached: 42 to 54% of fish that first approached the NLE eventually passed the dam via the WA-shore ladder, and 49 to 79% that first approached OR-shore entrances eventually passed the dam via that fishway (Table 16).

Table 15. Fishway exit rates [(total exits/total entrances)•100] for radio-tagged spring–summer Chinook salmon at each monitored fishway entrance at John Day Dam, by total flow (kcfs) 1997-2001.

	Flow (kcfs)	1997	1998	2000	2001	All years
North ladder entrance	50-99				80	80
	100-149		70	86	66	69
	150-199		85	84	78	83
	200-249		83	78		80
	250-299	89	70	50		73
	300-349	85	63	44		73
	350-399	53	53	15		49
	400-449	6				15
	450-499	48				48
	500-549	49				49
North powerhouse entrance	50-99				278	279
	100-149			137	266	243
	150-199		237	142	265	173
	200-249		211	141		162
	250-299	92	199	132		117
	300-349	79	104	90		85
	350-399	46	83			64
	400-449	88				86
	450-499	85				85
	500-549	96				96
	550-600	25				25
South ladder entrance	50-99			79	119	118
	100-149		70	113	85	88
	150-199		81	89	71	83
	200-249		79	81		80
	250-299	114	76	66		90
	300-349	150	64			107
	350-399	126	62			81
	400-449	59				72
	450-499	81				81
	500-549	62				62
	550-600	105				105
Unknown entrance	50-99			17	28	28
	100-149			40	27	29
	150-199		30	47	35	39
	200-249		31	43		35
	250-299	31	27	23		27
	300-349	27	59	24		35
	350-399	16	41	20		30
	400-449	18	40			25
	450-499	8				8
	500-549	13				13

Table 16. Location of first fishway entrances and ladders passed by radio-tagged spring–summer Chinook salmon at John Day Dam based on first approach site; approaches and entries with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified approach site.

		Chinook salmon						
		Percent that first entered[1]				Percent that Pass	Percent that Pass	Did not
First approach NLE	N	NLE	NPE	SLE	Unk	OR	WA	Pass
1997	92	**67**	4	12	14	46	**50**	3
1998	62	**56**	5	26	13	**55**	42	2
2000	84	**64**	4	11	20	43	**54**	4
2001	50	36	2	**54**	8	**50**	48	2
First approach NPE								
1997	139	18	**37**	24	17	**71**	23	4
1998	242	24	21	**36**	15	**69**	25	5
2000	307	**33**	23	24	18	**49**	45	5
2001	309	22	15	**45**	17	**61**	37	1
First approach SLE								
1997	401	13	18	**49**	17	**79**	17	3
1998	342	15	12	**52**	21	**70**	25	4
2000	276	18	23	**48**	11	**49**	41	6
2001	594	19	7	**64**	9	**58**	38	2
First approach Unk								
1997	14				**100**	**71**	21	7
1998	13				**100**	38	**46**	15
2000	46				**100**	**87**	9	2
2001	36				**100**	**69**	25	3

[1] numbers don't add up to 100% because some fish did not enter fishways

Some Chinook salmon that approached John Day Dam did not pass the dam, but where fish first approached the dam did not appear to be related to non-passage. It was more likely that fish migrated past tributaries in the Bonneville or The Dalles pools and turned around when they reached John Day Dam, died, or were recaptured in fisheries near the dam after first approaching (see Appendix Table 1).

Fishway exits and dam passage time – Spring–summer Chinook salmon that exited a fishway into the tailrace one or more times at John Day Dam had longer dam passage times than fish that did not exit in all months of all years (Table 17). Exiting fish had significantly longer passage times ($P < 0.005$, K-W χ^2 tests) than non-exiting fish in 14 of 18 months. The difference was significant at a lower level ($P < 0.05$) in June 1998. Delays associated with exiting a fishway into the tailrace in April were 3 h in 1997, 53 h in 1998, 42 h in 2000, and 18 h in 2001. Median delays for fish that exited in May were 54 h in 1997 and 14–24 h the other years. Delays for exiting fish were 13–32 h in June and 16–25 h in July in all years (Table 17).

The percentage of fish that exited a fishway into the tailrace tended to increase through the migration in each year (Table 17), with exit percentages generally less than 65% in April and May and between 70 and 95% in June and July. The majority of between-month differences in

exit percentages were significant ($P < 0.005$, Z tests) in all years. Non-significant pairs were mostly between April and May or between June and July.

Table 17. Number of adult radio-tagged spring–summer Chinook salmon, and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and whether or not fish exited from a fishway into the tailrace.

	Chinook salmon							
	1997		1998		2000		2001	
Did not exit fishway	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
April	33	**143.2**	40	**15.9**	60	**16.1**	77	**18.2**
May	170	**23.3**	111	**22.4**	64	**11.2**	43	**9.6**
June	27	**12.1**	20	**13.5**	15	**10.0**	4	**16.0**
July	21	**9.6**	27	**9.9**	5	**9.2**	7	**12.3**
August								
Exited fishway one or more times								
April	25	**146.3**	64	****69.2**	56	****57.6**	138	****36.5**
May	105	****76.9**	115	****43.0**	103	****29.6**	233	****23.8**
June	43	****44.3**	54	***32.4**	111	****37.2**	108	**28.5**
July	103	****31.9**	74	****26.1**	73	****34.6**	76	****34.0**
August					6	****28.1**	4	**42.4**

* P < 0.05, ** P < 0.005 Kruskal-Wallis χ^2 test

Steelhead:

In all years, steelhead were monitored as they approached and entered three major fishway entrances at John Day Dam: the north ladder entrance (NLE), the north powerhouse entrance (NPE) and the south ladder entrance (SLE) (see Figure 1). Orifice gate entrances were not monitored in any year.

Between 576 and 904 steelhead were known to have approached fishways each year, more than 99% entered fishways each year, and 386 to 765 exited fishways (Table 18). In each year, 67 to 85% of the fish that entered eventually exited into the tailrace. Steelhead approached fishways a median of 5 to 13 times (*means*= 9.1 to 18.6 times), entered a median of twice in 1997, four times in 2000 and 5 times on 2001 (*means* = 4.9 to 9.1 times). Fish that exited fishways exited a median of 3 to 5 times (*means* = 5.9 to 9.6 times). The median numbers of exits for all fish that entered a fishway were 1 in 1997, 3 in 2000 and 4 in 2001 (*means* = 4.0 to 8.1 exits/fish that entered). Because orifice gate entrances were open and unmonitored, entrance use summaries were somewhat imprecise.

Approaches to fishways – Steelhead first approached fishways at all monitored entrances (Table 19). Eight to 18% first approached at the NLE, 10–18% first approached the NPE, and the majority (60-73%) first approached the SLE in all years (Table 19). Total approaches were more evenly distributed, although the largest percentages approached at the SLE in all but 2000, when slightly more approaches were at the NPE. In all years the fewest total fishway approaches were at the NLE.

Table 18. Numbers of radio-tagged steelhead and sockeye salmon that approached, entered, and exited fishway entrances at John Day Dam, and the median and mean numbers of approaches, entrances and exits per fish. Also includes the percentages that entered after approaching fishways and exited after entering fishways.

	Steelhead									Sockeye		
	1997			2000			2001			1997		
	N	Med	Avg	N	Med	Avg	N	Med	Avg	N	Med	Avg
Approached	576	5.0	9.1	749	9.0	15.0	904	13.0	18.6	472	4.0	5.2
Entered	573	2.0	4.9	743	4.0	6.5	903	5.0	9.1	468	3.0	3.1
Exited	386	3.0	5.9	565	4.0	7.3	765	5.0	9.6	328	2.0	3.1
Percentage of those that approached that subsequently entered												
	99.5%			99.2%			99.9%			99.2%		
Percentage of those that entered that subsequently exited												
	67.4%			76.0%			84.7%			70.1%		

Table 19. Location of first and total approaches to fishway entrances by radio-tagged steelhead and sockeye salmon at John Day Dam; approaches with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified approach site.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
First approach	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
North Ladder Entrance	106	**18.4**	88	**11.7**	72	**8.0**	177	**37.5**
North PH Entrance	58	**10.1**	131	**17.5**	138	**15.3**	51	**10.8**
South Ladder Entrance	346	**60.1**	505	**67.4**	663	**73.3**	208	**44.1**
Unknown	66	**11.5**	25	**3.3**	31	**3.4**	36	**7.6**
Total	576		749		904		472	
Total[1] approaches								
North Ladder Entrance	1,003	**19.7**	1,555	**13.8**	1,960	**11.6**	431	**17.5**
North PH Entrance	1,319	**25.1**	4,752	**42.2**	6,863	**40.8**	768	**31.2**
South Ladder Entrance	2,091	**39.8**	4,155	**36.9**	6,877	**40.9**	1,003	**40.8**
Unknown	842	**16.0**	804	**7.1**	1,128	**6.7**	258	**10.5**
Total	5,255		11,266		16,828		2,460	

[1]Totals differ from Table 16 because includes unknown approaches

With few exceptions, the largest proportions of steelhead first approached at the SLE under all spill conditions in all years. The exceptions were that larger proportions approached the NLE during moderate spill (e.g. 50-99 kcfs) in 1997 and at the NPE at low spill (e.g. < 50 kcfs) in 2001 (Table 20). The distributions of total approaches relative to spill followed patterns similar to that for first approaches, but with more even distributions among sites. Most steelhead (72 to 80%) first approached the dam during no-spill or low-spill conditions in each year, and we note that many fish in the low-spill category (<50 kcfs) in 1997 and 2000 passed in fall when spill levels were intermittently less than 2 kcfs.

Table 20. Percent of first and total approaches to fishway entrances by radio-tagged steelhead and sockeye salmon at John Day Dam based on mean daily spill on the date of the approach. Approaches with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified approach site; approaches with unknown time and site were included in the unknown category.

		% of first approaches					% of total approaches			
Spill	N	NLE	NPE	SLE	Unk[1]	N	NLE	NPE	SLE	Unk[1]
Steelhead - 1997										
0	279	14	11	**65**	10	2,635	15	24	**45**	16
1-49	252	19	9	**58**	14	2,109	20	24	**38**	18
50-99	35	**51**	6	37	6	207	**35**	25	28	12
100-149	1	**100**	-	-	-	3	**100**	-	-	-
150-199	3	**-**	-	**100**	-	9	**-**	-	100	n/-
Steelhead - 2000										
0	28	7	29	**61**	4	563	14	41	**43**	2
1-49	663	10	18	**69**	3	9,973	14	**42**	37	7
50-99	46	20	13	**61**	7	699	13	**48**	31	8
100-149	2	**50**	-	**50**	-	14	**29**	21	**29**	21
Steelhead - 2001										
0	883	8	15	**74**	3	16,345	11	**41**	**41**	**7**
1-49	14	-	**50**	43	7	258	12	**50**	33	5
Sockeye salmon - 1997										
1-49	176	34	12	**44**	11	944	17	30	**42**	12
50-99	254	**43**	9	**43**	5	1,348	18	32	**40**	10
100-149	6	**67**	-	-	33	23	**44**	17	26	13
150-199	25	20	24	**52**	4	101	12	**46**	35	8
200-249	6	-	17	**67**	17	19	-	**42**	**42**	16
250-299	5	-	-	**100**	-	25	4	16	**72**	8

[1] All unknown approaches were at the OR-shore fishway entries

Entries to fishways – Steelhead first entered fishways at John Day Dam at all monitored entrances (Table 21). Between 40 and 60% first entered at the SLE in all years. Fourteen to 28% first entered the NLE, and about 8% first entered the NPE in each year. About 30% first entered at unknown sites in 1997, most likely through unmonitored orifice gates. Smaller proportions entered via unknown routes or probable orifice gates in 2000 and 2001.

Site preference for first fishway entrances varied with spill volume. In all years, mean daily spill was < 100 kcfs for almost all radio-tagged steelhead at John Day Dam. Under most spill conditions, the SLE was the most-used entrance (Table 22). There was a tendency for higher first entrance proportions at the SLE during zero and low spill, while use of NLE increased as spill increased. The NPE was the least used for first entrances under all spill conditions. The distribution of first and subsequent fishway entrances (total entrances) by steelhead was similar to that for first entrances, both in aggregate (Table 21) and in relation to spill levels (Table 22).

Table 21. Location of first and total fishway entrances by radio-tagged steelhead and sockeye salmon at John Day Dam; entries with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified entry site.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
First fishway entrance	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
North Ladder Entrance	103	**18.0**	207	**27.9**	124	**13.7**	205	**43.8**
North PH Entrance	46	**8.0**	55	**7.4**	74	**8.2**	59	**12.6**
South Ladder Entrance	246	**42.9**	371	**49.9**	526	**58.3**	126	**26.9**
Orifice Gate (probable)[1]	n/a	**n/a**	60	**8.1**	119	**13.2**	n/a	**n/a**
Unknown	178	**31.1**	50	**6.7**	60	**6.6**	78	**16.7**
Total	573		743		903		468	
Total[2] fishway entrances								
North Ladder Entrance	532	**18.9**	1,053	**21.9**	1,240	**15.1**	375	**26.0**
North PH Entrance	234	**8.3**	506	**10.5**	687	**8.4**	235	**16.3**
South Ladder Entrance	1,183	**42.1**	1,940	**40.3**	3,696	**45.1**	566	**39.2**
Orifice Gate (probable)	n/a	**n/a**	761	**15.8**	1,595	**19.5**	n/a	**n/a**
Unknown	860	**30.6**	551	**11.5**	975	**11.9**	267	**18.5**
Total	2809		4,811		8,193		1,443	

[1] Orifice gate entrances were unmonitored, but data suggests entrance via this route; not available 1997
[2] Totals differ from Table 16 because includes unknown entries

Exits from fishways – The highest percentages of first and subsequent fishway exits by steelhead were almost all via the SLE in all years (31-47%), although relatively high percentages also exited via the NPE (25-34%) (Table 23). Percentages that exited from the NLE were lowest, ranging from 13-25%. Exits from unknown locations ranged from 6-14% (Table 23).

Most upstream point reached before first fishway exit – We estimated where steelhead turned around in fishways and ladders before their first fishway exit to the tailrace (Table 24). Relatively sparse telemetry coverage in some portions of fishways, particularly in the collection channel and in ladders upstream from transition pools, limited precision in this analysis. Each year, 29 to 39% were recorded at antennas inside the south collection channel and 24 to 32% were recorded at the first OR-shore transition pool weir or in that pool. From 11 to 22% were recorded in the WA-shore transition pool before turning around (Table 24). Relatively few fish were recorded for extended periods at antennas in the upper transition pools or upstream from transition pools before being recorded at downstream sites, suggesting few fish moved far up the ladder.

Fishway entrance effectiveness - In each year the NPE had more exits than entries for both first and total entries by steelhead, and the SLE was the most effective entrance (Table 25). The second most effective entrance was the NLE. The relatively high proportions of unknown entrances and exits raises some uncertainty about absolute values of net entry rates, particularly in 1997, but patterns were similar in all years.

Table 22. Percent of first and total entrances to fishways by radio-tagged steelhead and sockeye salmon at John Day Dam based on mean daily spill on the date of the entrance. Entrances with unknown times were included at specific sites if subsequent telemetry records inside fishways clearly identified entrance site; entrances with unknown time and site were included in the unknown category.

Steelhead - 1997										
		Percent of first entries					Percent of total entries			
Spill	N	NLE	NPE	SLE	Unk[1]	N	NLE	NPE	SLE	Unk[1]
0	283	11	7	**50**	32	1,413	14	8	**48**	30
1-49	244	22	9	**39**	31	1,206	22	9	**38**	32
50-99	38	**42**	11	24	24	122	**48**	12	20	21
100-149	1	**100**	-	-	-	1	**100**	-	-	-
150-199	1	-	-	**100**	-	4	-	-	**50**	**50**
Steelhead - 2000										
0	27	26	11	**56**	7	132	24	8	**50**	18
1-49	658	26	7	**51**	15	4,335	22	10	**41**	28
50-99	45	33	9	**47**	11	317	22	17	**37**	24
100-149	2	**100**	-	-	-	10	**40**	10	20	30
Steelhead - 2001										
0	882	13	8	**59**	20	8,000	15	8	**45**	32
1-49	14	29	21	**36**	14	118	14	19	**43**	24
Sockeye salmon - 1997										
1-49	174	**40**	12	32	17	564	24	14	**43**	20
50-99	254	**50**	13	22	15	798	28	19	**36**	17
100-149	6	**67**	-	-	33	17	**47**	-	29	24
150-199	23	26	17	**35**	22	41	20	15	**44**	22
200-249	7	-	27	**57**	14	12	-	33	**42**	25
250-299	4	-	-	**75**	25	11	9	-	**73**	18

[1] All unknown approaches were at the OR-shore fishway entries

Negative net entry rates at the NLE do not mean that the entrance did not produce dam passages. Seven to nine percent of steelhead last used the NLE just prior to passing the dam in all years (Table 26). From 37 to 49% last used the SLE and 16 to 36% last used the NLE before passing the dam. In 1997, 45% of last entry sites were unknown, compared to 5% or less in 2000 and 2001 (Table 26).

In each year, >60% of tagged steelhead first passed John Day Dam via the OR-shore ladder and 15 to 34% passed via the WA-shore ladder (Table 26). Between 2.8 and 5.2% passed via unknown routes (most likely via the navigation lock) each year.

Movement between fishways – In all years, steelhead moved between entrances and between fishways before passing the dam. Between 37 and 65% of fish that first approached the dam at the NLE (WA-shore) made their first fishway entrance at the OR-shore fishway (Table 27). After first approaching OR-shore fishway entrances, 10 to 27% (NPE) and 9 to 22% (SLE) migrated through the tailrace to first enter at the NLE entrance to the WA-shore fishway. Approximately 60% of the steelhead that first approached the SLE also first entered

Table 23. Location of first and total fishway exits by radio-tagged steelhead and sockeye salmon at John Day Dam; exits with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified exit site.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
First fishway exit	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
North Ladder Entrance	74	**19.2**	139	**24.6**	97	**12.7**	118	**36.0**
North PH Entrance	118	**30.6**	182	**32.2**	263	**34.4**	58	**17.7**
South Ladder Entrance	154	**39.9**	176	**31.2**	296	**38.7**	107	**32.6**
Orifice Gate (probable)[1]	n/a	**n/a**	26	**4.6**	54	**7.1**	n/a	**n/a**
Unknown	40	**10.4**	42	**7.4**	55	**7.2**	45	**13.7**
Total	386		565		765		328	
Total[2] fishway exits								
North Ladder Entrance	417	**18.3**	798	**19.5**	1,106	**15.1**	202	**20.0**
North PH Entrance	558	**24.5**	1,339	**32.7**	2,183	**29.7**	216	**21.4**
South Ladder Entrance	1,060	**46.6**	1,509	**36.8**	3,093	**42.1**	456	**45.2**
Orifice Gate (probable)	n/a	**n/a**	207	**5.1**	531	**7.2**	n/a	**n/a**
Unknown	241	**10.6**	244	**6.0**	434	**5.9**	134	**13.3**
Total	2,276		4,097		7,347		1,008	

[1] Orifice gate entrances were unmonitored, but data suggests entrance via this route; not available 1997
[2] Totals differ from Table 16 because includes unknown entries

Table 24. Most upstream point reached in fishways before steelhead and sockeye salmon first exited into the tailrace.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Antenna location	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
Inside N. coll. channel	49	**12.8**	40	**7.1**	47	**6.1**	38	**11.6**
Inside S. coll. channel	110	**28.8**	164	**29.0**	299	**39.1**	139	**42.4**
Below OR trans. pool	14	**3.7**	53	**9.4**	44	**5.8**	6	**1.8**
First OR trans. pool weir	103	**27.0**	107	**18.9**	175	**22.9**	7	**2.1**
OR transition pool	8	**2.1**	30	**5.3**	66	**8.6**	7	**2.1**
Above OR trans pool[1]	3	**0.8**	32	**5.7**	34	**4.4**	13	**4.0**
Near ladder diffuser	20	**5.2**	n/a	**n/a**	n/a	**n/a**	--	**--**
Top of OR ladder	2	**0.5**	--	**--**	3	**0.4**	--	**--**
WA transition pool	70	**18.3**	122	**21.6**	84	**11.0**	115	**35.1**
Above WA pool[1]	--	**--**	17	**3.0**	12	**1.6**	3	**0.9**
Count window	3	**0.8**	n/a	**n/a**	n/a	**n/a**	--	**--**
Top of WA ladder	--	**--**	--	**--**	1	**0.1**	--	**--**
Total OR fishway	309	**80.1**	426	**75.4**	668	**87.3**	210	**64.0**
Total WA fishway	73	**19.9**	139	**24.6**	97	**12.7**	118	**36.0**

[1] Some fish recorded 'above' transition pool were likely still in submerged-weir portion of pool

Table 25. Net first and total fishway entrances and exits by radio-tagged steelhead and sockeye salmon at John Day Dam; entrances and exits with unknown times were included at specific entrances if telemetry records inside fishways clearly identified the site.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Net entrances	First	Total	First	Total	First	Total	First	Total
North Ladder Entrance	29	115	68	255	27	134	87	173
North PH Entrance	**-72**	**-324**	**-127**	**-833**	**-189**	**-1,496**	1	19
South Ladder Entrance	92	123	195	431	230	603	19	110
Orifice Gate (probable)[1]	n/a	n/a	34	554	65	1,064	n/a	n/a
Unknown	138	619	8	307	5	541	33	133

[1] Orifice gate entrances were unmonitored, but data suggests entrance via this route; not available 1997

Table 26. Last fishway entrance used by radio-tagged steelhead and sockeye salmon at John Day Dam and ladder used to pass the dam; entrances with unknown times were included at specific entrances if telemetry records inside fishways clearly identified the site.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Last entrances	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
South Ladder Entrance[1]	199	**37.1**	283	**39.9**	411	**48.6**	140	**32.6**
North PH Entrance	38	**7.1**	49	**6.9**	76	**9.0**	49	**11.4**
North Ladder Entrance	115	**21.4**	255	**35.9**	133	**15.7**	173	**40.2**
Orifice Gate (probable)[1]	n/a	**n/a**	99	**13.9**	183	**21.7**	n/a	**n/a**
Unknown[2]	185	**34.5**	24	**3.4**	42	**5.0**	68	**15.8**
Dam passage route								
OR-shore ladder	421	**76.0**	453	**60.5**	712	**81.9**	257	**54.9**
WA-shore ladder	115	**20.8**	257	**34.3**	133	**15.3**	173	**37.0**
Passed unknown[3]	18	**3.2**	39	**5.2**	24	**2.8**	38	**8.1**

[1] Configuration of South Ladder Entrance in 1998-2001 allowed for identification of probable orifice gate entries and exits
[2] All unknown last entrances were at entrances to the OR-shore fishway
[3] Likely passage via navigation lock, or with malfunctioning transmitter

the SLE. In comparison, <25% or more of fish that first approached at the NPE also first entered there (Table 27).

Regardless of the entrance first approached or first entered, steelhead tended to pass the dam via the OR-shore ladder (Table 27). Between 15 and 58% of fish that first approached at the NLE eventually passed the dam via the WA-shore fishway: 39 to 78% crossed the tailrace and passed the dam via the OR-shore fishway. Between 58 and 79% of fish that first approached the SLE or NPE passed the dam via the OR-shore ladder.

Some steelhead that approached John Day Dam did not pass the dam (Table 27). Where fish first approached, however, did not appear to be related to unsuccessful passage (see Appendix Table 1).

Table 27. Location of first fishway entrances and ladders passed by radio-tagged steelhead and sockeye salmon at John Day Dam based on first approach site; approaches and entries with unknown times were included at specific entrances if subsequent telemetry records inside fishways clearly identified approach site.

		Percent that first entered[1]				Percent that Passed	Percent that Passed	Percent that Did not
First approach NLE	N	NLE	NPE	SLE	Unk	OR	WA	Pass
Steelhead 1997	106	**63**	7	13	16	**55**	36	8
Steelhead 2000	88	**69**	6	19	5	39	**58**	2
Steelhead 2001	72	**35**	10	**35**	19	**78**	15	4
Sockeye 1997	177	**93**	2	3	1	44	**53**	1
First approach NPE								
Steelhead 1997	58	10	24	28	**38**	**81**	12	7
Steelhead 2000	131	27	19	**40**	11	**58**	32	6
Steelhead 2001	138	17	17	**46**	19	**79**	17	4
Sockeye 1997	51	18	**49**	20	12	**61**	31	2
First approach SLE								
Steelhead 1997	346	9	7	**62**	21	**75**	19	5
Steelhead 2000	505	22	5	**60**	13	**64**	31	3
Steelhead 2001	694	11	6	**63**	20	**79**	14	4
Sockeye 1997	208	15	14	**53**	16	**61**	27	4
First approach Unk								
Steelhead 1997	66				**100**	**85**	6	6
Steelhead 2000	25				**100**	**72**	20	8
Steelhead 2001	31				**100**	**65**	19	6
Sockeye 1997	36				**100**	**58**	19	0

[1] numbers don't add up to 100% because some fish did not enter fishways

Fishway exits and dam passage time – Steelhead that exited a fishway into the tailrace one or more times had longer median dam passage times than fish that did not exit in all months of all years (Table 28). Exiting fish had significantly longer passage times ($P < 0.005$, K-W χ^2 tests) than non-exiting fish in September and October of all years, and in August of 2000. Differences were also significant ($P < 0.05$) in July of all years and June of 2001. Based on median times, delays associated with exiting a fishway into the tailrace were 13 to 16 h in August,12 to 16 h in September, and 10 to 14 h in October in all years (Table 28).

Steelhead exit percentages were higher than 60% in all but one month in the three years (Table 28). Percentages were highest (>90%) from June through August of 2001. Exit percentages were >80% in July 2000 and August 2001, and >70% in August 1997, June and September 2000, and October and November 2001. Differences in exit rates between months may have been related to water temperatures in the fishways or tailrace, or to overall upstream migration rates: steelhead tend to migrate more slowly through the lower Columbia River in summer than in fall and exit behavior at the dam may have been a function of that rate.

Table 28. Number of adult radio-tagged steelhead and sockeye salmon and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and whether or not fish exited from a fishway into the tailrace.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Did not exit fishway	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
June	5	**15.8**	3	**6.0**	2	**7.8**	29	**12.0**
July	15	**11.3**	6	**5.6**	2	**4.8**	77	**7.5**
August	7	**7.9**	16	**12.4**	2	**8.3**	1	**6.2**
September	66	**7.4**	48	**9.0**	38	**8.2**		
October	67	**15.6**	51	**9.6**	37	**9.1**		
November	7	**10.8**	7	**24.9**	3	**18.1**		
Exited fishway one or more times								
June	2	**29.5**	8	**39.1**	31	***26.0**	71	****24.7**
July	26	***24.2**	33	***22.3**	46	***28.7**	159	****14.6**
August	16	***21.8**	37	****25.1**	42	**24.8**	6	**11.4**
September	140	****19.0**	178	****23.8**	179	****24.0**		
October	109	****28.1**	114	****23.2**	118	****19.1**		
November	12	***55.0**	15	**24.9**	8	**959.9**		

* P < 0.05, ** P < 0.005 Kruskal-Wallis χ^2 test

Sockeye salmon:

Sockeye salmon were monitored in 1997 as they approached and entered three major fishway entrances at John Day Dam: the north ladder entrance (NLE), the south ladder entrance (SLE), and the north powerhouse entrance (NPE).

Almost all (99.2%) of the 472 sockeye salmon that approached fishways subsequently entered and 328 (70%) exited fishways (Table 18). Sockeye salmon approached fishways a median of 4 times (*mean* = 5.2 times) and entered a median of 3 time (*mean* = 3.1 times). Fish that exited fishways exited a median of 2 times (*mean* = 3.1 times). The median number of exits for all fish that entered was also 2 (*mean* = 2.2 times). Some tagged sockeye salmon likely approached, entered and exited at unknown locations or undetected, so estimates above are minimums.

Approaches to fishways – Sockeye salmon first approached fishways at John Day Dam at all monitored entrances, but slightly favored the SLE (44%) and NLE (38%) (Table 19). Eleven percent first approached at the NPE, and 8% first approached at unknown locations. The distribution of total approaches to fishways was somewhat different: 41% were at the SLE, 31% were at the NPE, 18% were at the NLE, and 11% were unknown (Table 19).

Mean daily spill during the sockeye salmon migration ranged from < 50 to about 300 kcfs (Table 20). Between 34 and 44% first approached at both the NLE and SLE at spill levels <100 kcfs, with 12% or less first approaching at the NPE or at unknown sites. Sample sizes were small above 100 kcfs spill, but there was a tendency for fewer first approaches at NLE and more approaches at SLE at the higher spill. The distribution of total approaches was generally similar to first approaches, although proportions were lower at the NLE and higher at the NPE at all spill levels (Table 20).

Entries to fishways – Sockeye salmon first entered fishways at all monitored entrances, but favored the NLE (44%) and the SLE (27%) (Table 21). Thirteen percent first entered the NPE and 17% first entered at unknown sites. The distribution of total entries to fishways showed that sockeye salmon favored the SLE (39%), followed by the NLE (26%) and NPE (16%) (Table 21).

At low (<150 kcfs) spill levels the highest percentages (40 to 67%) of sockeye salmon first entered the NLE (Table 22); the highest percentages (35 to 75%) first entered the SLE at spill between 150 and 300 kcfs. Use of the NPE as the first entry site increased as spill increased, but never exceeded 30%. The distribution of total entries showed greater use of the SLE and slightly more use of the NPE, while use of NLE was relatively lower (Table 22).

Exits from fishways – Similar percentages (33 to 36%) of first exits by sockeye salmon were at the NLE and SLE, while 18% were at the NPE and 14% were unknown (most likely orifice gates) (Table 23). More of the total exits were via the SLE (45%), with approximately equal percentages (20 to 21%) via the NPE and NLE (Table 23).

Most upstream point reached before first fishway exit – We estimated where sockeye salmon turned around in fishways and ladders before their first fishway exit to the tailrace (Table 24). As with the other runs, precision was somewhat limited in this analysis. The largest percentage (42%) was recorded at antennas inside the south collection channel, and 25% were inside the WA-shore transition pool. The percentages that turned at the first OR-shore transition pool weir or in that pool (2% each) were substantially lower than observed for the other runs. Less than 5% turned around after being detected at sites upstream from either transition pool, and no sockeye salmon moved to the top of ladders before first turning around and exiting to the tailrace (Table 24).

Fishway entrance effectiveness – All fishway entrances had more net first entrances than exits for sockeye salmon (Table 25). The NLE had the highest number of net first and total entrances, followed by the SLE. About 40% of sockeye salmon used the NLE just prior to passing the dam. The SLE was the last entrance used for 33% of the fish, 11% last used the NPE, and 16% last used an unknown south fishway entrance (Table 26).

Fifty-five percent of sockeye salmon first passed John Day Dam via the OR-shore ladder and 37% first passed via the WA-shore ladder. Eight percent passed by an unknown route, most likely via the navigation lock.

Movement between fishways – Sockeye salmon moved between fishways less frequently than Chinook salmon or steelhead. About 7% of the fish that first approached at the NLE (WA-shore) crossed the tailrace and made their first fishway entrance at the OR-shore fishway (Table 27). Eleven to 18% of the fish that first approached at the SLE or NPE subsequently made their first entrance at the WA-shore fishway.

Sockeye salmon tended to pass John Day Dam via the fishway they first approached (Table 27). About 53% that first approached the NLE eventually passed the dam via the WA-shore ladder, 61% that first approached the NPE and 61% that first approached the SLE and passed via the OR-shore ladder. Ten sockeye salmon that approached John Day Dam did not pass.

Fishway exits and dam passage time – Sockeye salmon that exited a fishway into the tailrace one or more times at John Day Dam had longer median dam passage times than fish that did not exit in all months (Table 28). Fish that exited into the tailrace had significantly

longer passage times ($P < 0.005$, K-W χ^2 tests) than non-exiting fish in June and July; only 7 fish passed in August. Based on median times, delays associated with exiting a fishway into the tailrace were 13 h in June and 7 h in July (Table 28). Seventy-one percent exited in June and 67% exited in July, a non-significant difference ($P = 0.51$, Z test).

Movements Through Fishways and Transition Pools

Chinook salmon:

Transition pool selection and behavior in pools -- We analyzed behavior of 354 to 551 Chinook salmon with complete passage histories as they moved into fishways, through transition pools and up ladders at John Day Dam in four years; another 78 to 86 fish had complete tailrace, transition pool and top-of-ladder histories but were not recorded on their first fishway entry (Table 29). Passage behaviors for fish that missed antennas appeared to be similar to fish with complete records. However, for between-year consistency, summaries below are only for fish with complete passage histories.

Table 29. Transition pool behavior by adult radio-tagged spring–summer Chinook salmon at John Day Dam for fish with telemetry records at all passage points (tailrace, first fishway entry, first transition pool entry, transition pool exit into a ladder and exit from the top of a ladder) and for fish with records at all sites except first fishway entry.

	Chinook salmon							
	1997		1998		2000		2001	
Records at all passage points	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
N	389		398		354		551	
Moved straight through pool	57	**14.7**	55	**13.8**	28	**7.9**	37	**6.7**
Moved downstream, but didn't exit	163	**41.9**	87	**21.9**	98	**27.7**	102	**18.5**
Exited pool to collection channel	8	**2.1**	8	**2.0**	10	**2.8**	40	**7.3**
Exited pool to tailrace	161	**41.4**	248	**62.3**	218	**61.6**	372	**67.5**
All records but fishway entry								
N	85		86		78		82	
Moved straight through pool	20	**23.5**	13	**15.1**	5	**6.4**	11	**13.4**
Moved downstream, but didn't exit	32	**37.6**	19	**22.1**	31	**39.7**	8	**9.8**
Exited pool to collection channel	4	**4.7**	2	**2.3**	4	**5.1**	7	**8.5**
Exited pool to tailrace	29	**34.1**	52	**60.5**	38	**48.7**	56	**68.3**

Most fish (68 to 79%) passed the dam via the same transition pool they first entered, while the remainders (21 to 32%) exited the first transition pool they entered, crossed the tailrace and passed the dam via the other fishway (Figure 6). Between 31 and 62% first entered the transition pool at the bottom of the OR-shore ladder and passed the dam via the OR-shore ladder in all years. Seventeen to 27% first entered the pool at the bottom of the WA-shore ladder and passed via the WA-shore ladder in the 1997, 1998, and 2001; 45% first entered and passed via the WA-shore in 2000. Five to 15% first entered the transition pool in the OR-shore fishway, exited the pool into the tailrace and passed the dam via the WA-shore ladder. Fifteen to 19% first entered the WA-shore transition pool, but passed the dam via the OR-shore ladder (Figure 6).

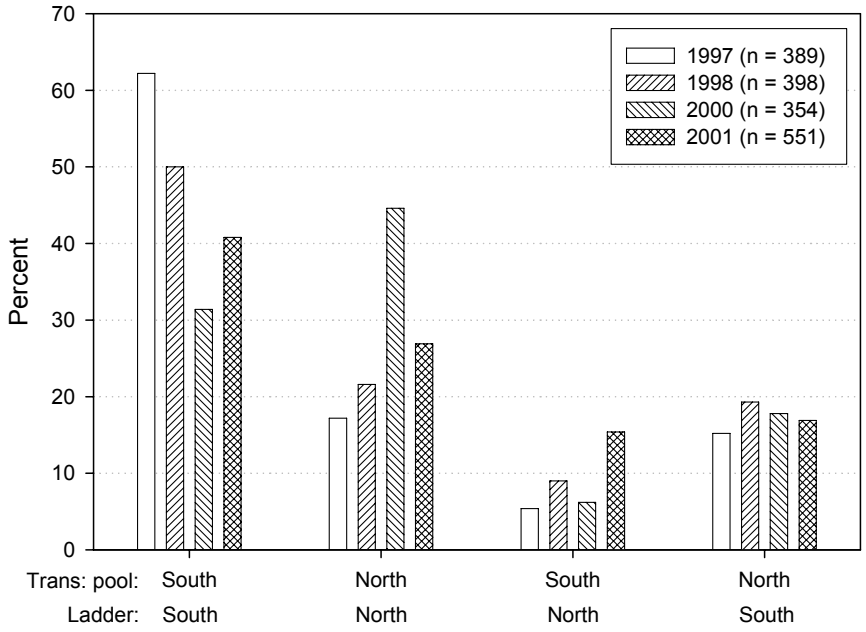

Figure 6. Number of Chinook salmon with telemetry records at all passage points that passed John Day Dam, the transition pool first entered, and the ladder used to pass the dam.

Seven to 15% of fish with complete passage histories moved straight through a transition pool and entered a ladder with no downstream movement (Table 29). Nineteen to 42% moved downstream in a transition pool before entering the ladder but were not recorded at antennas inside the collection channel downstream from the transition pool and were not recorded exiting into the tailrace. Two to 7% exited the OR-shore transition pool and were recorded at antennas in the collection channel but did not exit into the tailrace. The remaining fish exited a transition pool into the tailrace before passing the dam: 41% in 1997, 62% in 1998, 62% in 2000 and 68% in 2001 (Table 29).

More fish first entered the OR- than WA-shore transition pool in 1997 (68%), 1998 (59%) and 2001 (56%). More fish first entered the WA-shore pool in 2000 (62%). Percentages that exited to the tailrace ranged from 32 to 69% from the OR-shore pool and from 61 to 71% from the WA-shore pool (Table 30). Higher percentages (12 to 21%) moved straight through the OR-shore transition pool than through the WA-shore pool (3 to 6%) in the first three years, although antenna configurations in the WA-shore pool may have led to underestimates of straight-through behavior. Transition pool delay (fish turned around in submerged-weir area, but did not exit to the collection channel or tailrace) was the most common behavior in the OR-shore pool only in 1997. Exiting into the tailrace was the most common behavior at both fishways in all other cases (Table 30). The proportions of Chinook salmon that exited the OR-shore transition pool into the tailrace tended to be higher later in the migrations each year (Table 31).

Table 30. Transition pool behavior by adult radio-tagged spring–summer Chinook salmon at John Day Dam for fish with telemetry records at all passage points based on first transition pool entered.

	Chinook salmon							
	1997		1998		2000		2001	
First entered OR-shore pool	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
N	263		235		133		310	
Moved straight through pool	49	**18.6**	50	**21.3**	16	**12.0**	18	**5.8**
Moved downstream, but didn't exit	122	**46.4**	45	**19.1**	24	**18.0**	39	**12.6**
Exited pool to collection channel	8	**3.0**	8	**3.4**	10	**7.5**	40	**12.9**
Exited pool to tailrace	84	**31.9**	132	**56.2**	83	**62.4**	213	**68.7**
First entered WA-shore pool								
N	126		163		221		241	
Moved straight through pool	8	**6.3**	5	**3.1**	12	**5.4**	19	**7.9**
Moved downstream, but didn't exit	41	**32.5**	42	**25.8**	74	**33.5**	63	**26.1**
Exited pool to tailrace	77	**61.1**	116	**71.2**	135	**61.1**	159	**66.0**

Table 31. Percent (*n*) of spring–summer Chinook salmon that exited transition pools into the tailrace at John Day Dam by month each fish first entered a transition pool. Only includes fish with complete dam passage histories.

	OR-shore transition pool				WA-shore transition pool			
Month	1997	1998	2000	2001	1997	1998	2000	2001
April	38 (21)	40 (48)	33 (9)	66 (94)	70 (10)	94 (32)	51 (51)	49 (75)
May	24 (147)	51 (92)	45 (55)	59 (117)	35 (34)	56 (82)	47 (58)	71 (118)
June	31 (52)	71 (41)	71 (42)	81 (52)	58 (19)	74 (23)	66 (73)	71 (34)
July	56 (43)	69 (54)	93 (27)	85 (46)	75 (63)	88 (26)	87 (38)	100 (14)

Passage time from first fishway entry to first transition pool entry – Chinook salmon passage times from first fishway entry to first entry into a transition pool varied little between years or months. Median times to first enter the WA-shore transition pool, which was almost immediately inside the fishway was < 1 min (0.02 h) in all years. Median times to first enter the OR-shore transition pool for all fishway entrances combined ranged from 0.56 h in 1997 to 1.95 h in 2000 (Table 32). Between 1.3% (OR-shore, 2001) and 10.5% (OR-shore, 2000) of the fish took more than 24 h from first fishway entry to first transition pool entry at either fishway (Table 32).

Chinook salmon behavior in the WA-shore transition pool (pass straight through, delay, exit) was not a good predictor of differences in time to first enter that pool. In contrast, behavior in the OR-shore pool was associated with significant ($P < 0.05$; K-W χ^2 tests) differences in pool entry times. In 1997, median times for fish that exited to the tailrace or collection channel were 0.5 to 1.5 h longer than for fish that moved through the pool without exiting. The pattern was reversed in 2000 and 2001: fish that did not exit the OR-shore pool took 1 to 4 h longer to first enter a pool than did fish that eventually exited the pool. No differences were significant in 1998.

Table 32. Number of adult radio-tagged spring–summer Chinook salmon and median and quartile times to pass from first fishway entry to first transition pool entry at John Day Dam, based on first transition pool entered and for all fish.

	OR-shore fishway				WA-shore fishway			
First fishway entry to first pool	1997	1998	2000	2001	1997	1998	2000	2001
N	263	235	133	310	126	163	221	241
1st Quartile (h)	0.16	0.32	0.69	0.17	0.01	0.00	0.00	0.01
Median (h)	**0.56**	**0.96**	**1.95**	**0.80**	**0.01**	**0.01**	**0.01**	**0.02**
3rd Quartile (h)	1.96	3.70	6.86	3.53	1.59	2.88	3.41	3.18
Percent that took > 24 h	5.7%	4.3%	11%	1.3%	4.8%	5.5%	4.5%	2.9%
	Both fishways combined							
First fishway entry to first pool	1997	1998	2000	2001				
N	389	398	354	551				
1st Quartile (h)	0.05	0.02	0.01	0.05				
Median (h)	**0.41**	**0.52**	**0.86**	**0.64**				
3rd Quartile (h)	1.86	3.52	4.37	3.48				
Percent that took > 24 h	5.4%	4.8%	6.8%	2.0%				

Passage time from first transition pool entry to exit a pool into a ladder – Chinook salmon passage times from first transition pool entry to exit a pool into a ladder were the most variable of all dam passage segments. For all fish with telemetry records at each passage point, median pool passage times ranged from 1.4 to 6.0 h for both ladders combined; medians were longer for the WA-shore pool (5.2 to 9.5 h) than for the OR-shore pool (0.5 to 5.6 h) (Table 33). Fish that moved straight through a transition pool on their first attempt, with no recorded downstream movements, had median passage times ≤ 0.15 h (9 min) (Table 34). Few fish that moved straight through either transition pool had pool passage times > 30 min. Fish that delayed in a transition pool by moving downstream (but were not recorded at antennas in the collection channel or tailrace) had median passage times from 0.1 to 0.4 h through the OR-shore pool and 0.3 to 1.6 h through the WA-shore pool. Fish that delayed in the OR-shore pool and exited into the collection channel—but not into the tailrace—had median times of 0.6 to 3.2 h from first pool entry to exit the pool into the OR-shore ladder. Those that exited the OR-shore pool into the tailrace had median times from 22.0 to 26.0 h from first pool entry to exit into the ladder; median times for those that exited the WA-shore pool into the tailrace were 20.6 to 37.0 h (Table 34). Between 40 and 64% of fish that exited a pool into the tailrace took > 24 h to pass through a pool into a ladder (Table 34); in comparison, < 2% of all fish that did not exit took > 24 h to pass through a pool.

Fish that moved straight through the OR-shore transition pool had the shortest median pool passage times, followed by fish that delayed but did not exit the pool and then by those that exited the pool into the collection channel. Fish that exited into the tailrace had the longest passage times. Differences between groups were all significant ($P < 0.005$, K-W χ^2 tests) in each year. Patterns were similar for the WA-shore transition pool: Chinook salmon that exited

Table 33. Number of adult radio-tagged spring–summer Chinook salmon and median and quartile times to pass from first transition pool entry to exit a transition pool into a ladder at John Day Dam.

	First entered OR-shore fishway				First entered WA-shore fishway			
First pool to last pool	1997	1998	2000	2001	1997	1998	2000	2001
N	263	235	133	310	126	163	221	241
1st Quartile (h)	0.18	0.28	0.14	0.62	1.40	2.05	0.49	0.46
Median (h)	**0.46**	**4.05**	**3.91**	**5.59**	**9.06**	**9.47**	**6.46**	**5.23**
3rd Quartile (h)	13.14	24.82	25.01	28.11	48.10	29.15	30.38	24.64
Percent that took > 24 h	19%	27%	27%	32%	40%	33%	35%	26%
	Both fishways combined							
First pool to last pool	1997	1998	2000	2001				
N	389	398	354	551				
1st Quartile (h)	0.23	0.91	0.42	0.50				
Median (h)	**1.43**	**6.02**	**5.74**	**5.53**				
3rd Quartile (h)	24.47	27.06	29.49	27.03				
Percent that took > 24 h	26%	29%	32%	29%				

Table 34. Number of adult radio-tagged spring–summer Chinook salmon and median and quartile times to pass from first transition pool entry to exit a transition pool into a ladder at John Day Dam based on fish behavior in each pool.

	First entered OR-shore fishway				First entered WA-shore fishway			
	1997	1998	2000	2001	1997	1998	2000	2001
Moved straight through pool	49	50	16	18	8	5	12	19
1st Quartile (h)	0.08	0.07	0.04	0.06	0.01	0.14	0.12	0.07
Median (h)	**0.11**	**0.10**	**0.05**	**0.08**	**0.10**	**0.15**	**0.13**	**0.10**
3rd Quartile (h)	0.16	0.17	0.08	0.10	3.72	0.15	0.20	0.16
Moved downstream, didn't exit	122	45	24	39	41	42	74	63
1st Quartile (h)	0.19	0.22	0.09	0.10	0.46	1.15	0.30	0.20
Median (h)	**0.30**	**0.43**	**0.12**	**0.15**	**0.96**	**1.58**	**0.43**	**0.30**
3rd Quartile (h)	0.67	0.67	0.23	0.22	2.37	2.16	0.98	0.50
Exited pool to collection chan	8	8	10	40	N/A			
1st Quartile (h)	1.12	2.52	0.26	0.37				
Median (h)	**1.39**	**3.19**	**0.65**	**0.58**				
3rd Quartile (h)	1.54	4.12	1.98	1.78				
Exited pool to tailrace	84	132	83	213	77	116	135	159
1st Quartile (h)	10.01	6.80	5.40	4.90	11.18	7.03	16.66	5.65
Median (h)	**25.95**	**22.59**	**22.08**	**21.99**	**37.04**	**21.68**	**27.05**	**20.56**
3rd Quartile (h)	66.53	45.40	43.02	45.26	99.01	44.56	50.74	32.93
Percent that took > 24 h	54%	48%	43%	46%	64%	46%	57%	40%

the pool into the tailrace had significantly longer median times to enter the ladder than fish that delayed, and fish that delayed had longer times than those that went straight through (P < 0.005, K-W χ^2 tests). (Note: samples sizes were small for the straight-though groups in 1997 and 1998.)

Passage time to ascend a ladder – After exiting transition pools into ladders, Chinook salmon ascended ladders relatively quickly at John Day Dam in all years. Median times to ascend both the OR- and WA-shore ladders were 2.7 to 3.1 h (Table 35). More than 75% of the fish ascended in < 4 h and < 1% took more than 24 h to ascend. Salmon behavior in the OR-shore transition pool (pass straight through, delay, exit) did not significantly affect ladder ascension times except in 2001, when fish that moved exit the pool took ~ 20 min longer than fish that delayed in the pool (P = 0.041, K-W χ^2 test). Similarly, behavior in the WA-shore pool was not significantly associated with ladder ascension times in any year except fish that exited took about 45 min longer to ascend in 1998 (P < 0.001).

Table 35. Number of adult radio-tagged spring–summer Chinook salmon and median and quartile times to pass from the last record in a transition pool to exit from the top of a ladder at John Day Dam based on the transition pool first entered.

	First entered OR-shore fishway[1]				First entered WA-shore fishway[1]			
Last pool record to pass dam	1997	1998	2000	2001	1997	1998	2000	2001
N	263	235	133	310	126	163	221	241
1st Quartile (h)	2.45	2.29	2.18	2.54	2.66	1.88	2.54	2.47
Median (h)	**2.91**	**2.77**	**2.83**	**3.07**	**3.13**	**2.58**	**3.04**	**3.04**
3rd Quartile (h)	3.58	3.42	3.68	3.85	4.09	3.18	3.68	3.73
Percent that took > 24 h	0.4%	0.4%	0.0%	0.3%	0.0%	0.0%	0.9%	0.4%

	Both fishways combined[1]			
Last pool record to pass dam	1997	1998	2000	2001
N	389	398	354	551
1st Quartile (h)	2.49	2.13	2.42	2.52
Median (h)	**2.98**	**2.71**	**2.97**	**3.06**
3rd Quartile (h)	3.81	3.31	3.68	3.76
Percent that took > 24 h	0.3%	0.3%	0.6%	0.4%

[1] includes fish that passed via either ladder

Passage time from first tailrace record to pass the dam – Chinook salmon behavior in transition pools was a good predictor of overall time to pass John Day Dam (Table 36). When all fish and both transition pools were included, median passage times from first tailrace record to exit from the top of a ladder were significantly longer for fish that exited into the tailrace than for fish that moved straight through a transition pool in all years (P < 0.001, K-W χ^2 tests). Fish that exited to the tailrace also took significantly longer than fish that delayed in a transition pool in all years (P < 0.001). Differences in median times between exiting fish and those that did not exit ranged from 19 h in 2001 to 37 h in 1997.

Fish that exited to the tailrace had longer dam passage times than fish that moved straight through a pool or those that delayed in a pool or fishway in almost all months of all years (Table 36). To facilitate statistical comparisons, fish that exited a pool into the collection channel were

combined with those that delayed in a pool for Table 36. In most months of all years, fish that exited to the tailrace had significantly longer ($P < 0.05$) median dam passage times than those that moved straight through or delayed.

Table 36. Numbers of adult radio-tagged Chinook salmon and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and transition pool behavior. Small number of fish that exited to collection channel, but not into tailrace, combined with fish that delayed in transition pool.

	Chinook salmon							
	1997		1998		2000		2001	
Moved straight through pool	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
April	5	**20.5**	22	**12.0**	4	**9.4**	13	**16.9**
May	25	**14.8**	19	**16.7**	9	**12.6**	18	**15.1**
June	13	**17.9**	5	**55.0**	12	**10.5**	4	**17.7**
July	14	**13.5**	9	**10.4**	3	**12.6**	2	**13.5**
August	-	**-**	-	**-**	-	**-**	-	**-**
All months	57	**14.6**	55	**14.5**	28	**11.1**	37	**15.8**
Moved downstream, no tailrace[1]								
April	15	**104.2**	9	**10.8**	27	**17.9**	57	**17.0**
May	105	**27.1**	62	**22.9**	53	**11.8**	65	**12.8**
June	30	**18.7**	13	**16.9**	24	**10.7**	15	**16.4**
July	21	**11.6**	7	**8.4**	4	**8.6**	5	**10.4**
August	-	**-**	-	**-**	-	**-**	-	**-**
All months	171	**23.4**	95	**18.6**	108	**11.8**	142	**15.1**
Exited pool to tailrace								
April	15	**131.4**	49	**60.2**	29	**69.8**	103	**37.3**
May	49	**94.7**	94	**45.0**	53	**37.5**	149	**29.4**
June	26	**54.8**	45	**40.0**	77	**44.8**	67	**40.3**
July	71	**40.1**	60	**25.8**	56	**34.7**	52	**38.3**
August	-	**-**	-	**-**	3	**30.1**	1	**42.3**
All months	161	**55.2**	248	**41.9**	218	**42.8**	372	**34.0**

[1] includes fish that moved downstream in transition pool and those that exited pool into collection channel, but not tailrace

Similar patterns emerged when we considered each transition pool separately. Fish that exited either the OR- or WA-shore transition pool into the tailrace had longer passage times than fish that moved straight through a pool or delayed in the pool or collection channel each year (Table 37). For fish that first entered the OR-shore transition pool, median passage times for all behavior groups were longest in 1997.

Between 66 and 85% of Chinook salmon that exited the OR-shore transition pool into the tailrace took > 24 h to pass the dam each year (Table 38). Percentages that took > 24 h to pass the dam were lower for fish that moved straight through (29 to 38%) or delayed or exited the pool into the collection channel (18 to 52%). Patterns were similar for fish that first entered the WA-shore pool: 67 to 82% of the fish that exited to the tailrace took > 24 h to pass the dam,

while percentages were mostly < 50% for fish that moved straight through or delayed in the pool (Table 38).

Table 37. Number of adult radio-tagged spring–summer Chinook salmon and median and quartile times to pass from first tailrace record over the dam, based on transition pool behavior at John Day Dam.

	First entered OR-shore fishway				First entered WA-shore fishway			
	1997	1998	2000	2001	1997	1998	2000	2001
Moved straight through pool	49	50	16	18	8	5	12	19
1st Quartile (h)	10.19	8.68	8.58	11.56	9.48	8.61	6.60	7.61
Median (h)	**14.42**	**13.60**	**16.16**	**16.37**	**17.34**	**26.58**	**8.49**	**15.43**
3rd Quartile (h)	27.69	29.49	34.40	29.51	115.5	49.84	13.37	25.88
Moved downstream, didn't exit	122	45	24	39	41	42	74	63
1st Quartile (h)	10.67	7.85	11.22	9.03	10.43	10.66	8.70	9.47
Median (h)	**24.45**	**14.49**	**18.23**	**13.39**	**17.30**	**24.76**	**11.74**	**16.41**
3rd Quartile (h)	115.0	26.76	35.75	16.90	60.68	44.84	23.12	30.55
Exited pool to collection chan	8	8	10	40	N/A			
1st Quartile (h)	11.47	17.55	6.16	9.80				
Median (h)	**30.32**	**25.39**	**9.04**	**15.69**				
3rd Quartile (h)	52.48	39.47	14.39	24.22				
Exited pool to tailrace	84	132	83	213	77	116	135	159
1st Quartile (h)	31.60	23.92	19.41	18.83	27.16	24.02	28.70	18.38
Median (h)	**54.21**	**38.36**	**33.17**	**35.80**	**58.33**	**46.66**	**49.86**	**32.80**
3rd Quartile (h)	121.9	79.41	67.47	56.46	136.7	70.62	79.22	59.23

Table 38. Percent (*n*) of spring–summer Chinook salmon that took > 24 h to pass John Day Dam based on behavior in the Oregon- and WA-shore transition pools.

	OR-shore transition pool				WA-shore transition pool			
Month	1997	1998	2000	2001	1997	1998	2000	2001
Straight	29 (49)	32 (50)	38 (16)	28 (18)	38 (8)	60 (5)	8 (12)	26 (19)
Delay[1]	52 (130)	38 (53)	35 (34)	18 (79)	44 (41)	50 (42)	24 (74)	33 (63)
Exit	85 (84)	75 (132)	66 (83)	67 (213)	78 (77)	75 (116)	82 (135)	67 (159)

[1] includes fish that moved downstream in transition pool and those that exited pool into collection channel, but not tailrace

As with both transition pools combined (Table 36), fish that exited the OR-shore transition pool had the longest dam passage times in almost every month of each year (Table 39). Compared to fish that moved straight through a transition pool in April, fish that exited took 11 to 169 h longer. Median times were 18 to 46 h longer for fish that exited in May. Patterns were more variable in June and July, when sample sizes for fish that moved straight through the OR-shore pool were small (Table 39).

Table 39. Numbers of adult radio-tagged Chinook salmon and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and transition pool behavior in the OR-shore pool. Small number of fish that exited to collection channel, but not into tailrace, combined with fish that delayed in transition pool.

	Chinook salmon							
	1997		1998		2000		2001	
Moved straight through pool	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
April	4	**20.4**	21	**11.9**	2	**33.5**	6	**24.3**
May	23	**13.6**	15	**16.7**	6	**10.6**	8	**15.1**
June	12	**22.4**	5	**55.0**	7	**33.6**	2	**19.8**
July	10	**13.7**	9	**10.4**	1	**12.6**	2	**13.5**
August	-	**-**	-	**-**	-	**-**	-	**-**
All months	49	**14.4**	50	**13.6**	16	**16.2**	18	**16.4**
Moved downstream, no tailrace[1]								
April	13	**104.2**	8	**10.2**	4	**37.9**	26	**17.3**
May	85	**27.0**	30	**21.7**	24	**15.4**	40	**12.5**
June	23	**26.0**	7	**14.5**	5	**7.4**	8	**18.3**
July	9	**14.3**	8	**9.0**	1	**5.8**	5	**10.4**
August	-	**-**	-	**-**	-	**-**	-	**-**
All months	130	**24.6**	53	**15.1**	34	**15.4**	79	**13.8**
Exited pool to tailrace								
April	8	**189.2**	19	**94.6**	3	**17.0**	62	**34.9**
May	36	**59.2**	48	**37.5**	25	**35.3**	69	**33.4**
June	16	**62.1**	28	**36.4**	30	**33.7**	42	**34.4**
July	24	**35.8**	37	**26.5**	23	**29.8**	39	**38.6**
August	-	**-**	-	**-**	2	**36.2**	1	**42.3**
All months	84	**54.2**	132	**38.4**	83	**33.2**	213	**35.8**

[1] includes fish that moved downstream in transition pool and those that exited pool into collection channel, but not tailrace

Relatively few Chinook salmon moved straight through the WA-shore transition pool in any individual month and fewer than 10 delayed or exited to the tailrace in many months (Table 40). Again, however, the strong tendency was for longer dam passage times for those fish that exited into the tailrace.

***Steelhead*:**

Transition pool selection and behavior in pools -- We analyzed behavior of 304 to 373 steelhead with complete passage histories as they moved into fishways, through transition pools and up ladders at John Day Dam in three years; another 60 to 115 fish had complete tailrace, transition pool and top-of-ladder histories but were not recorded on their first fishway entry (Table 41). Passage behaviors for fish that missed antennas appeared to be similar to fish with complete records. However, for between-year consistency, summaries below are for fish with complete passage histories only.

Table 40. Number of adult radio-tagged Chinook salmon and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and transition pool behavior in the WA-shore pool.

	Chinook salmon							
	1997		1998		2000		2001	
Moved straight through pool	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
April	1	**212.8**	1	**26.6**	2	**7.8**	7	**14.8**
May	2	**234.0**	4	**29.2**	3	**15.5**	10	**15.1**
June	1	**17.3**	-	**-**	5	**7.6**	2	**17.7**
July	4	**9.3**	-	**-**	2	**11.9**	-	**-**
August	-	**-**	-	**-**	-	**-**	-	**-**
All months	8	**17.4**	5	**26.6**	12	**8.5**	19	**15.4**
Moved downstream, no tailrace[1]								
April	2	**107.4**	1	**37.5**	23	**15.3**	31	**16.1**
May	20	**35.7**	32	**24.8**	29	**11.7**	25	**18.7**
June	7	**15.1**	6	**36.2**	19	**11.0**	7	**16.3**
July	12	**10.8**	3	**8.4**	3	**11.4**	-	**-**
August	-	**-**	-	**-**	-	**-**	-	**-**
All months	41	**17.3**	42	**24.8**	74	**11.7**	63	**16.4**
Exited pool to tailrace								
April	7	**121.0**	30	**53.1**	26	**78.3**	41	**44.5**
May	13	**189.6**	46	**48.3**	28	**39.2**	80	**28.7**
June	10	**40.4**	17	**44.4**	47	**49.9**	25	**42.8**
July	47	**42.8**	23	**25.1**	33	**35.0**	13	**24.1**
August	-	**-**	-	**-**	1	**13.4**	-	**-**
All months	77	**58.3**	116	**46.7**	135	**49.9**	159	**32.8**

[1] includes fish that moved downstream in transition pool and those that exited pool into collection channel, but not tailrace

Most fish (69 to 78%) passed the dam via the same transition pool they first entered, while remainders (22 to 31%) exited the first transition pool they entered, crossed the tailrace and passed the dam via the other fishway (Figure 7). Between 47 and 66% first entered the transition pool at the bottom of the OR-shore ladder and passed the dam via the OR-shore ladder each year. Eleven to 22% first entered the pool at the bottom of the WA-shore ladder and passed via the WA-shore ladder. Seven to 14% first entered the transition pool in the OR-shore fishway, exited the pool into the tailrace and passed the dam via the WA-shore ladder. Fifteen to 17% first entered the WA-shore transition pool, but passed the dam via the OR-shore ladder (Figure 7).

Six to 17% of fish with complete passage histories moved straight through a transition pool and entered a ladder with no downstream movement (Table 41). Twelve to 23% moved downstream in a transition pool before entering the ladder but were not recorded at antennas inside the collection channel and were not recorded exiting into the tailrace. Less than 6% exited the OR-shore transition pool and were recorded at antennas in the collection channel but did not exit into the tailrace. The remaining fish exited a transition pool into the tailrace before passing the dam: 57% in 1997, 71% in 2000 and 79% in 2001 (Table 41).

Table 41. Transition pool behavior by adult radio-tagged steelhead and sockeye salmon at John Day Dam for fish with telemetry records at all passage points (tailrace, first fishway entry, first transition pool entry, transition pool exit into a ladder and exit from the top of a ladder) and for fish with records at all sites except first fishway entry.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Records at all passage points	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
N	304		358		373		271	
Moved straight through pool	53	**17.4**	20	**5.6**	23	**6.2**	62	**22.9**
Moved downstream, but didn't exit	69	**22.7**	64	**17.9**	43	**11.5**	74	**27.3**
Exited pool to collection channel	9	**3.0**	20	**5.6**	13	**3.5**	4	**1.5**
Exited pool to tailrace	173	**56.9**	254	**70.9**	294	**78.8**	131	**48.3**
All records except fishway entry								
N	115		60		78		24	
Moved straight through pool	20	**17.4**	7	**11.7**	7	**9.0**	10	**41.7**
Moved downstream, but didn't exit	30	**26.1**	8	**13.3**	13	**16.7**	8	**33.3**
Exited pool to collection channel	8	**7.0**	9	**15.0**	6	**7.7**		
Exited pool to tailrace	57	**49.6**	36	**60.0**	52	**66.7**	6	**25.0**

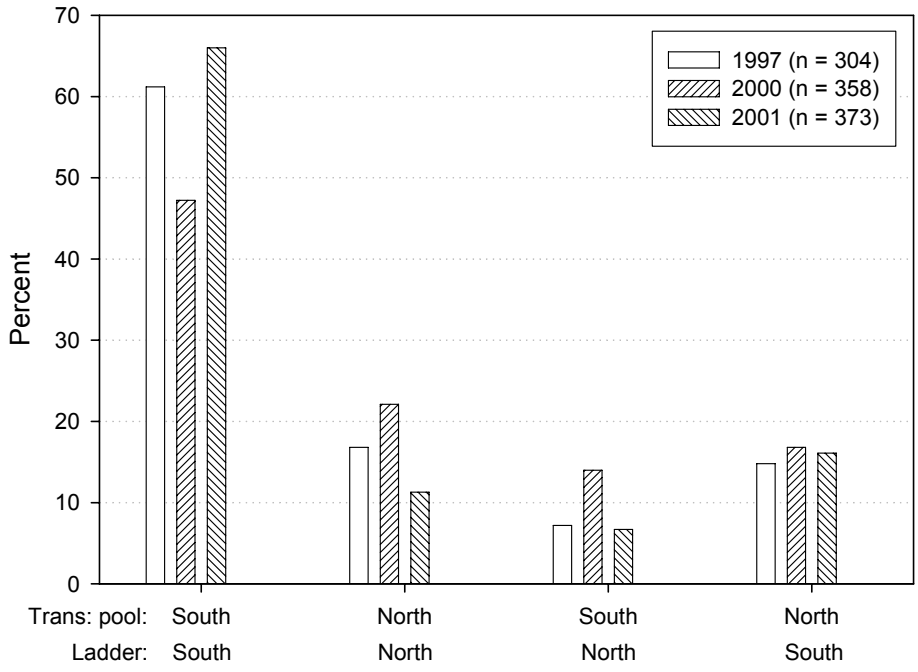

Figure 7. Number of steelhead with telemetry records at all passage points that passed John Day Dam, the transition pool first entered, and the ladder used to pass the dam.

More steelhead (61 to 73%) first entered the OR- than WA-shore transition pool in all years. Between 51 and 79% of fish that first entered the OR-shore pool and 69 to 79% that first entered the WA-shore pool exited into the tailrace (Table 42). Higher percentages (7 to 20%) moved straight through the OR-shore transition pool than through the WA-shore pool (3 to 12%) in all years, but antenna configurations in the WA-shore pool may have led to underestimates of straight-through behavior. Between 9 and 24% delayed in the OR-shore pool, but were not recorded in the collection channel or in the tailrace; 18 to 20% delayed in the WA-shore pool (Table 42).

Table 42. Transition pool behavior by adult radio-tagged steelhead and sockeye salmon at John Day Dam for fish with telemetry records at all passage points based on first transition pool entered.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
First entered OR-shore pool	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
N	208		219		271		88	
Moved straight through pool	42	**20.2**	16	**7.3**	20	**7.4**	38	**43.2**
Moved downstream, but didn't exit	50	**24.0**	36	**16.4**	25	**9.2**	19	**21.6**
Exited pool to collection channel	9	**4.3**	20	**9.1**	13	**4.8**	4	**4.5**
Exited pool to tailrace	107	**51.4**	147	**67.1**	213	**78.6**	27	**30.7**
First entered WA-shore pool								
N	96		139		102		183	
Moved straight through pool	11	**11.5**	4	**2.9**	3	**2.9**	24	**13.1**
Moved downstream, but didn't exit	19	**19.8**	28	**20.1**	18	**17.6**	55	**30.1**
Exited pool to tailrace	66	**68.8**	107	**77.0**	81	**79.4**	104	**56.8**

Proportions that exited the OR-shore transition pool into the tailrace tended to be higher in summer (June-August) than in fall of 2000 and 2001 and were highest in August 1997 (Table 43). Due to the small numbers of steelhead that entered the WA-shore transition pool each month, proportions that exited were more variable than for the OR-shore pool, though proportions also tended to be higher in summer.

Table 43. Percent (*n*) of steelhead and sockeye salmon (SK) that exited transition pools into the tailrace at John Day Dam by month each fish first entered a transition pool. Only includes fish with telemetry records at all passage points.

	First entered OR-shore fishway				First entered WA-shore fishway			
	Steelhead			SK	Steelhead			SK
Month	1997	2000	2001	1997	1997	2000	2001	1997
June	50 (2)	80 (5)	88 (16)	24 (29)	33 (3)	67 (6)	100 (5)	65 (52)
July	43 (14)	76 (17)	93 (27)	34 (56)	86 (14)	83 (12)	100 (6)	53(129)
August	90 (10)	61 (18)	100(21)	33 (3)	60 (5)	73 (22)	85 (13)	50 (2)
September	54 (95)	80 (83)	76(103)	-	68 (44)	74 (62)	77 (48)	-
October	47 (73)	56 (84)	73 (97)	-	68 (28)	85 (33)	73 (26)	-
November	55 (11)	50 (12)	67 (6)	-	100 (1)	75 (4)	75 (4)	-
December	0 (1)	0 (1)	-	-	-	-	-	-

Passage time from first fishway entry to first transition pool entry – Steelhead passage times from first fishway entry to first transition pool entry varied little between years or months. Median times to first enter the WA-shore transition pool, which fish entered almost immediately inside the fishway was < 1 min (0.02 h) in all years (Table 44). Median times to first enter the OR-shore transition pool for all fishway entrances combined were < 20 min (0.30 h).

Table 44. Number of adult radio-tagged steelhead and sockeye salmon (SK), and median and quartile times to pass from first fishway entry to first transition pool entry at John Day Dam. Includes fish with telemetry records at all passage points.

	OR-shore fishway				WA-shore fishway			
	Steelhead			SK	Steelhead			SK
First fishway entry to first pool	1997	2000	2001	1997	1997	2000	2001	1997
N	208	219	271	88	96	139	102	183
1st Quartile (h)	0.15	0.10	0.12	1.03	0.01	0.00	0.00	0.01
Median (h)	**0.35**	**0.23**	**0.30**	**2.53**	**0.01**	**0.01**	**0.02**	**0.01**
3rd Quartile (h)	1.48	1.03	1.26	7.25	0.04	0.04	2.23	0.02
Percent that took > 24 h	1.9%	1.8%	0.4%	3.4%	0.0%	1.4%	0.0%	0.5%
	Both fishways combined							
	Steelhead			SK				
First fishway entry to first pool	1997	2000	2001	1997				
N	304	358	373	271				
1st Quartile (h)	0.07	0.01	0.09	0.01				
Median (h)	**0.21**	**0.11**	**0.27**	**0.02**				
3rd Quartile (h)	1.21	0.64	1.43	1.74				
Percent that took > 24 h	1.3%	1.7%	0.3%	1.5%				

Steelhead behavior in transition pools (pass straight through, delay, exit) was not a good predictor of differences in time to first enter a pool. Median passage times for all behavior groups at the OR-shore pool, for example, were less than 1 h, and differences were probably not biologically significant.

Passage time from first transition pool entry to exit a pool into a ladder – Steelhead passage times from first transition pool entry to exit a pool into a ladder were the most variable of all dam passage segments. For fish with telemetry records at each passage point, median pool passage times ranged from 2.0 to 7.6 h for both ladders combined; medians were 1.4 to 6.1 h for the OR-shore pool and 4.2 to 12.8 h for the WA-shore pool (Table 45). Fish that moved straight through a transition pool on their first attempt, with no recorded downstream movements, had median passage times < 0.15 h (9 min) (Table 46). Few fish that moved straight through either transition pool had pool passage times > 30 min. Fish that delayed in a transition pool by moving downstream (but were not recorded at antennas in the collection channel or tailrace) had median passage times from 0.5 to 0.4 h through both transition pools in all years. Median times were 0.6 to 1.0 h for fish that delayed in the OR-shore pool and exited into the collection channel, but not into the tailrace. Steelhead that exited the OR-shore pool into the tailrace had median times from 12.5 to 13.2 h from first pool entry to exit into the ladder; medians for those that exited the WA-shore pool into the tailrace were 9.8 to 20.3 h (Table 46). Between 24 and 43% of fish that exited a pool into the tailrace took > 24 h to pass through a

pool into a ladder; in comparison, none of the fish that did not exit a fishway took > 24 h to pass through a pool in any year.

Table 45. Number of adult radio-tagged steelhead and sockeye salmon (SK), and median and quartile times to pass from first transition pool entry to exit a transition pool into a ladder at John Day Dam. Includes fish with telemetry records at all passage points.

	First entered OR-shore fishway				First entered WA-shore fishway			
	Steelhead			SK	Steelhead			SK
First pool to last pool	1997	2000	2001	1997	1997	2000	2001	1997
N	208	219	271	88	96	139	102	183
1st Quartile (h)	0.14	0.43	1.76	0.13	0.70	1.31	1.40	0.66
Median (h)	**1.41**	**4.39**	**6.06**	**0.42**	**4.19**	**4.95**	**12.77**	**3.40**
3rd Quartile (h)	12.88	21.80	22.35	4.92	16.61	19.19	41.68	16.11
Percent that took > 24 h	18%	22%	24%	14%	20%	19%	34%	15%
	Both fishways combined							
	Steelhead			SK				
First pool to last pool	1997	2000	2001	1997				
N	304	347	373	271				
1st Quartile (h)	0.24	0.69	1.76	0.31				
Median (h)	**1.99**	**4.64**	**7.56**	**2.01**				
3rd Quartile (h)	13.90	20.63	24.64	13.49				
Percent that took > 24 h	19%	21%	27%	14%				

In all years, fish that moved straight through the OR-shore transition pool had the shortest median pool passage times, followed by fish that delayed but did not exit the pool and then by those that exited the pool into the collection channel. Fish that exited into the tailrace had the longest passage times. Differences between groups were almost all significant ($P < 0.005$, K-W χ^2 tests) in each year. Patterns were similar for the WA-shore transition pool: steelhead that exited the pool into the tailrace had significantly longer median times to enter the ladder than fish that delayed ($P < 0.005$, K-W χ^2 tests); too few steelhead passed straight through the WA-shore pool for meaningful tests in some years.

Passage time to ascend a ladder – After exiting transition pools into ladders, steelhead ascended ladders relatively quickly at John Day Dam in all years. Median times to ascend both the OR- and WA-shore ladders were 2.5 to 2.9 h (Table 47). More than 75% of the fish ascended ladders in < 8 h and < 5% took more than 24 h to ascend. Steelhead behavior in the OR-shore transition pool (pass straight through, delay, exit) was not strongly associated with ladder ascension times. Ladder times differed by less than 0.5 h between most behavior categories. Similarly, behavior in the WA-shore pool did not appear to substantively affect ladder ascension times in any year.

Passage time from first tailrace record to pass the dam – Steelhead behavior in transition pools was a good predictor of overall time to pass John Day Dam. When all fish and both transition pools were included, median passage times from first tailrace record to exit from

Table 46. Number of adult radio-tagged steelhead and sockeye salmon (SK), and median and quartile times to pass from first transition pool entry to exit a transition pool into a ladder at John Day Dam based on fish behavior in each pool. Includes fish with telemetry records at all passage points.

	First entered OR-shore fishway				First entered WA-shore fishway			
	Steelhead			SK	Steelhead			SK
	1997	2000	2001	1997	1997	2000	2001	1997
Moved straight through pool	42	16	20	38	11	4	3	24
1st Quartile (h)	0.05	0.05	0.06	0.07	0.10	0.12	0.09	0.14
Median (h)	**0.09**	**0.07**	**0.07**	**0.10**	**0.13**	**0.12**	**0.10**	**0.20**
3rd Quartile (h)	0.11	0.08	0.10	0.18	0.21	0.44	0.11	0.28
Moved downstream, didn't exit	50	36	25	19	19	28	18	55
1st Quartile (h)	0.13	0.11	0.13	0.31	0.28	0.32	0.21	0.42
Median (h)	**0.30**	**0.15**	**0.18**	**0.49**	**0.40**	**0.43**	**0.32**	**0.83**
3rd Quartile (h)	0.72	0.21	0.23	1.55	0.80	0.59	0.42	1.56
Exited pool to collection chan	9	20	13	4	N/A			
1st Quartile (h)	0.91	0.43	0.43	2.18				
Median (h)	**1.03**	**0.60**	**0.60**	**6.44**				
3rd Quartile (h)	1.70	1.49	1.20	12.52				
Exited pool to tailrace	107	147	213	27	66	107	81	104
1st Quartile (h)	2.82	3.82	3.73	3.03	3.48	2.69	7.56	6.14
Median (h)	**12.79**	**12.53**	**13.17**	**12.16**	**11.42**	**9.81**	**20.27**	**13.49**
3rd Quartile (h)	41.64	27.78	26.83	64.37	27.50	22.47	48.88	24.25
Percent that took > 24 h	36%	33%	30%	41%	29%	24%	43%	26%

the top of a ladder were significantly longer for fish that exited into the tailrace than for fish that moved straight through or delayed in a transition pool in all years ($P < 0.001$, K-W χ^2 tests). Differences in median times between fish that exited to the tailrace and those that moved straight through a transition pool ranged from 11.8 to 17.7 h (Table 48). Median times for fish that exited to the tailrace were 11.2 to 15.0 h longer than fish for that delayed. Differences in median times between fish that moved straight through and those that delayed ranged from -3.2 h to 4.9 h.

Unlike for spring–summer Chinook salmon, no clear patterns emerged between dam passage time and month of passage by steelhead (Table 48). In general, steelhead that moved straight through or delayed in transition pools had similar median times to pass the dam and fish that exited into the tailrace had longer median times than fish in the other categories in each month. Fish that exited to the tailrace in June, July, and November tended to have the longest median dam passage times among all groups and months, perhaps due to temporary straying into downstream tributaries or other high temperature avoidance behaviors in summer and the onset of over-wintering behavior in November (Table 48). To facilitate statistical comparisons, fish that exited a pool into the collection channel were combined with those that delayed in a pool for Table 48.

Table 47. Numbers of adult radio-tagged steelhead and sockeye salmon (SK), and median and quartile times to pass from the last record in a transition pool to exit from the top of a ladder at John Day Dam based on the transition pool first entered. Includes fish with telemetry records at all passage points.

	First entered OR-shore fishway[1]				First entered WA-shore fishway[1]			
	Steelhead			SK	Steelhead			SK
Last pool record to pass dam	1997	2000	2001	1997	1997	2000	2001	1997
N	208	219	271	88	96	139	102	183
1st Quartile (h)	2.35	2.15	2.30	2.48	2.47	2.17	2.45	2.48
Median (h)	**2.91**	**2.54**	**2.70**	**2.84**	**2.93**	**2.68**	**2.85**	**3.02**
3rd Quartile (h)	7.69	3.46	3.81	3.33	4.71	3.47	4.46	3.89
Percent that took > 24 h	3.4%	1.8%	2.2%	0.0%	4.2%	1.4%	2.0%	0.5%

	Both fishways combined[1]			
	Steelhead			SK
Last pool record to pass dam	1997	2000	2001	1997
N	304	358	373	271
1st Quartile (h)	2.37	2.15	2.37	2.48
Median (h)	**2.92**	**2.60**	**2.79**	**2.91**
3rd Quartile (h)	6.13	3.46	3.92	3.67
Percent that took > 24 h	3.6%	1.7%	2.1%	0.4%

[1] includes fish that passed via either ladder

Similar patterns emerged when we considered transition pools separately (Table 49). Compared to other behavior groups, steelhead that exited from the OR-shore transition pool into the tailrace were delayed 13 to 14 h in 1997, 10 to 19 h in 2000, and 10 to 13 h in 2001. Fish that exited the WA-shore pool were delayed 9 to 20 h compared to those that hesitated or moved straight through the WA-shore pool.

Between 45 and 52% of steelhead that exited the OR-shore transition pool into the tailrace took > 24 h to pass the dam in each year (Table 49), versus < 22% of fish that moved straight through, delayed, or exited the pool into the collection channel. Between 44 and 65% of fish that exited the WA-shore pool took > 24 h to pass the dam, compared to 7 to 27% for fish that had other behaviors (Table 49).

As with both transition pools combined (Table 48), steelhead that exited the OR-shore transition pool had the longest dam passage times in almost every month of each year (Table 50). Compared to fish that moved straight through the OR-shore transition pool, fish that exited took 7 to 35 h (*medians*) longer to pass the dam in all months of all years (comparisons for months with > 5 fish in each category only). Median times were 10 to 35 h longer for fish that exited than for those that delayed in a pool in all months of all years, except fish that delayed took 9 h longer than exiting fish in November 2000 (Table 50).

Table 48. Numbers of adult radio-tagged steelhead and sockeye salmon, and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and transition pool behavior. Small number of fish that exited to collection channel, but not into tailrace, combined with fish that delayed in transition pool. Includes fish with telemetry records at all passage points.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
All fish	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
All months	304	**16.6**	358	**19.7**	373	**21.0**	271	**13.2**
Moved straight through pool								
June	2	**42.2**	1	**6.0**	1	**14.6**	18	**14.6**
July	4	**10.2**	2	**10.0**	1	**5.5**	43	**10.6**
August	1	**7.9**	-	**-**	1	**6.6**	1	**8.6**
September	20	**7.0**	7	**7.7**	4	**5.2**	-	**-**
October	21	**16.6**	9	**6.4**	14	**12.8**	-	**-**
November	3	**23.5**	1	**5.8**	2	**19.3**	-	**-**
All months	53	**10.4**	20	**6.4**	23	**12.4**	62	**10.6**
Moved downstream, no tailrace[1]								
June	1	**7.0**	2	**8.5**	1	**8.0**	22	**17.2**
July	6	**15.8**	4	**10.6**	1	**4.2**	54	**7.7**
August	12	**19.2**	13	**16.4**	1	**6.9**	2	**13.7**
September	38	**7.9**	26	**9.8**	32	**9.3**	-	**-**
October	27	**15.8**	33	**14.0**	19	**9.2**	-	**-**
November	2	**19.4**	6	**25.1**	1	**14.5**	-	**-**
December	1	**17.7**	-	**-**	1	**13.9**	-	**-**
All months	78	**12.4**	84	**11.3**	56	**9.2**	78	**8.7**
Exited pool to tailrace								
June	2	**29.6**	8	**39.0**	19	**30.4**	41	**29.5**
July	18	**23.3**	23	**30.4**	31	**34.2**	88	**17.6**
August	12	**19.2**	27	**26.7**	32	**26.1**	2	**78.3**
September	81	**19.2**	112	**23.6**	115	**24.7**	-	**-**
October	53	**36.1**	75	**23.6**	90	**20.9**	-	**-**
November	7	**81.5**	9	**17.5**	7	**>70 d**	-	**-**
All months	173	**23.6**	254	**24.1**	294	**24.2**	131	**21.1**

[1] includes fish that moved downstream in transition pool and those that exited pool into collection channel, but not tailrace

Relatively few steelhead moved straight through the WA-shore transition pool in any individual month and fewer than 15 delayed in the pool in all months (Table 51). For combinations with > 5 fish that exited and delayed in individual months of each year, exiting fish took 11 to 22 h longer than those that delayed in those months with > 5 fish in each category (the single exception was that exiting fish took 2.5 h longer in October 2000).

Table 49. Number of adult radio-tagged steelhead and sockeye salmon (SK), and median times to pass from first tailrace record over the dam, based on transition pool behavior at John Day Dam. Includes fish with telemetry records at all passage points.

	First entered OR-shore fishway				First entered WA-shore fishway			
	Steelhead			SK	Steelhead			SK
	1997	2000	2001	1997	1997	2000	2001	1997
Moved straight through pool	42	16	20	38	11	4	3	24
1st Quartile (h)	6.48	5.11	5.09	8.22	6.10	7.30	12.37	4.86
Median (h)	**11.26**	**6.12**	**11.32**	**12.77**	**7.60**	**10.57**	**18.14**	**8.17**
3rd Quartile (h)	18.60	6.97	15.84	17.38	23.10	16.26	46.17	10.54
Percent that took > 24 h	21%	0%	10%	11%	27%	25%	33%	4%
Moved downstream, didn't exit	50	36	25	19	19	28	18	55
1st Quartile (h)	7.29	6.52	7.34	6.73	7.66	5.27	6.99	6.28
Median (h)	**12.19**	**13.84**	**9.14**	**13.57**	**12.69**	**8.10**	**9.38**	**8.35**
3rd Quartile (h)	17.09	20.46	14.32	19.43	16.88	16.77	19.73	11.82
Percent that took > 24 h	18%	19%	0%	16%	11%	7%	22%	5%
Exited pool to collection chan	9	20	13	4	N/A			
1st Quartile (h)	4.68	8.47	7.55	17.94				
Median (h)	**12.14**	**14.81**	**14.53**	**21.34**				
3rd Quartile (h)	15.99	17.10	9.24	26.22				
Percent that took > 24 h	11%	20%	0%	50%				
Exited pool to tailrace	107	147	213	27	66	107	81	104
1st Quartile (h)	13.85	15.03	12.62	13.41	14.27	16.60	20.51	11.35
Median (h)	**25.10**	**24.73**	**22.05**	**24.15**	**21.64**	**23.52**	**29.10**	**20.58**
3rd Quartile (h)	69.62	48.14	40.56	73.23	46.12	42.71	65.71	33.61
Percent that took > 24 h	52%	52%	45%	52%	44%	49%	65%	39%

Sockeye salmon:

Transition pool selection and behavior in pools – We analyzed behavior of 271 sockeye salmon with complete passage histories as they moved into fishways, through transition pools and up ladders at John Day Dam in 1997; another 24 fish had complete tailrace, transition pool and top-of-ladder histories but were not recorded on their first fishway entry (Table 41). Fish that missed antennas behaved like those with complete records.

Most sockeye salmon (70%) passed the dam via the same transition pool they first entered; 30% exited the first pool they entered, crossed the tailrace and passed the dam via the other fishway. Thirty-one percent first entered the transition pool at the bottom of the OR-shore ladder and passed the dam via the OR-shore ladder, 39% first entered the pool at the bottom of the WA-shore ladder and passed via the WA-shore ladder. One percent first entered the OR-shore pool, but passed the dam via the WA-shore ladder, and 28% first entered the WA-shore pool, but passed via the OR-shore ladder.

Twenty-three percent of the fish with complete passage histories moved straight through a transition pool and entered a ladder with no downstream movement, and 27% delayed in a

transition pool without exiting to the collection channel or tailrace (Table 41). Two percent exited the OR-shore transition pool into the collection channel but did not exit into the tailrace. The remaining 48% exited a pool into the tailrace before passing the dam (Table 41).

Table 50. Numbers of adult radio-tagged steelhead and sockeye salmon, and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and transition pool behavior in the **OR-shore pool**. Small number of fish that exited to collection channel, but not into tailrace, combined with fish that delayed in transition pool. Includes fish with telemetry records at all passage points.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Moved straight through pool	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
June	1	**80.5**	-	**-**	1	**14.6**	11	**19.3**
July	1	**11.4**	2	**10.0**	1	**5.6**	26	**12.5**
August	1	**7.9**	-	**-**	-	**-**	1	**8.6**
September	13	**6.8**	4	**4.8**	4	**5.2**	-	**-**
October	20	**16.1**	9	**6.4**	13	**12.4**	-	**-**
November	3	**23.5**	-	**-**	1	**20.5**	-	**-**
All months	42	**11.3**	16	**6.1**	20	**11.3**	38	**12.8**
Moved downstream, no tailrace[1]								
June	-	**-**	1	**3.7**	1	**8.0**	11	**19.8**
July	5	**15.3**	2	**10.6**	1	**4.2**	11	**8.0**
August	-	**-**	7	**20.9**	-	**-**	1	**21.2**
September	31	**7.9**	13	**11.1**	21	**8.8**	-	**-**
October	19	**15.5**	28	**11.0**	13	**9.2**	-	**-**
November	2	**19.4**	5	**25.2**	1	**14.5**	-	**-**
December	1	**17.7**	-	**-**	1	**13.9**		
All months	59	**12.1**	56	**14.5**	38	**9.2**	23	**17.5**
Exited pool to tailrace								
June	1	**48.1**	4	**22.9**	14	**34.2**	7	**101.3**
July	6	**25.5**	13	**26.5**	25	**26.4**	19	**15.7**
August	9	**18.4**	11	**30.5**	21	**24.0**	1	**7.9**
September	51	**18.1**	66	**24.9**	78	**22.5**	-	**-**
October	34	**50.6**	47	**24.3**	71	**19.1**	-	**-**
November	6	**50.6**	6	**16.6**	4	**>90 d**	-	**-**
All months	107	**25.1**	147	**24.7**	213	**22.1**	27	**24.2**

[1] includes fish that moved downstream in transition pool and those that exited pool into collection channel, but not tailrace

Unlike steelhead, more sockeye salmon (68%) first entered the WA- than OR-shore transition pool. Thirty-one percent of fish that first entered the OR-shore pool and 57% that first entered the WA-shore pool exited into the tailrace (Table 42). A higher percentage (43%) moved straight through the OR-shore transition pool than through the WA-shore pool (13%) in 1997, although the antenna configuration in the WA-shore pool may have led to under-estimates of straight-through behavior. Twenty-two percent delayed in the OR-shore pool; 30% delayed in the WA-shore pool (Table 42).

Table 51. Numbers of adult radio-tagged steelhead and sockeye salmon, and median times (h) to pass from first tailrace record to pass John Day Dam based on month fish were first detected in the tailrace and transition pool behavior in the WA-shore pool. Includes fish with telemetry records at all passage points.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Moved straight through pool	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
June	1	**3.9**	1	**6.0**	-	**-**	7	**6.0**
July	1	**8.9**	-	**-**	-	**-**	17	**8.5**
August	-	**-**	-	**-**	1	**6.6**	-	**-**
September	7	**7.2**	3	**13.4**	-	**-**	-	**-**
October	1	**26.2**	-	**-**	1	**74.2**	-	**-**
November	-	**-**	-	**-**	1	**18.1**	-	**-**
All months	11	**7.6**	4	**10.6**	3	**18.1**	24	**8.2**
Moved downstream, no tailrace[1]								
June	1	**7.0**	1	**13.2**	-	**-**	11	**12.5**
July	1	**16.3**	2	**25.9**	-	**-**	43	**7.7**
August	2	**10.1**	6	**6.1**	1	**6.9**	1	**6.2**
September	7	**7.9**	13	**6.4**	11	**18.1**	-	**-**
October	8	**18.0**	5	**18.0**	6	**8.6**	-	**-**
November	-	**-**	1	**18.1**	-	**-**	-	**-**
All months	19	**12.7**	28	**8.1**	18	**9.4**	55	**8.4**
Exited pool to tailrace								
June	1	**11.1**	4	**163.5**	5	**29.1**	34	**24.0**
July	12	**21.7**	10	**31.9**	6	**53.4**	69	**17.9**
August	3	**20.0**	16	**25.9**	11	**26.8**	1	**148.6**
September	30	**20.1**	46	**22.3**	37	**28.7**	-	**-**
October	19	**24.1**	28	**20.5**	19	**30.4**	-	**-**
November	1	**116.8**	3	**38.8**	3	**23.2**	-	**-**
All months	66	**21.6**	107	**23.5**	81	**29.1**	104	**20.6**

[1] includes fish that moved downstream in transition pool and those that exited pool into collection channel, but not tailrace

The percentage of sockeye salmon that exited the OR-shore transition pool into the tailrace was higher in July (34%) than in June (24%). In contrast, the exit percentage from the WA-shore pool was higher in June (65%) than July (53%) (Table 43).

Passage time from first fishway entry to first transition pool entry – Sockeye salmon passage times from first fishway entry to first entry into a transition pool varied little between months. Median times to first enter the WA-shore transition pool, which fish entered almost immediately inside the fishway was < 1 min (0.01 h). Median time to first enter the OR-shore transition pool for all fishway entrances combined was 2.5 h (Table 44). A total of four sockeye salmon took > 24 h from first fishway entry to first transition pool entry (Table 44).

Sockeye salmon behavior in transition pools (pass straight through, delay, exit) was not a good predictor of differences in time to first enter a pool.

Passage time from first transition pool entry to exit a pool into a ladder – Sockeye salmon passage times from first transition pool entry to exit a pool into a ladder were the most variable of all dam passage segments. For fish with telemetry records at each passage point, median pool passage time was 2.0 h for both ladders combined, 0.4 h for the OR-shore pool, and 3.4 h for the WA-shore pool (Table 45). Fish that moved straight through a transition pool on their first attempt, with no recorded downstream movements, had median times ≤ 0.2 h (12 min) (Table 46). Fish that delayed in a transition pool by moving downstream had median passage times from 0.5 to 0.8 h through both transition pools. Fish that delayed in the OR-shore pool and exited into the collection channel (but not into the tailrace) had a median time of 6.4 h from first pool entry to exit into the OR-shore ladder. Sockeye salmon that exited the OR-shore pool into the tailrace had a median time of 12.2 h from first pool entry to exit into the ladder; the median for those that exited the WA-shore pool into the tailrace was 13.5 h (Table 46). Eleven of 27 (41%) sockeye salmon that exited the OR-shore pool into the tailrace and 27 of 104 (26%) that exited the WA-shore pool took more than 24 h to pass through a pool into a ladder, compared to < 1% (1 fish) for fish that did not exit to the tailrace (Table 45).

Sockeye salmon that moved straight through the OR-shore transition pool had the shortest median pool passage times, followed by fish that delayed but did not exit the pool and then by those that exited the pool into the collection channel. Fish that exited into the tailrace had the longest passage times (Table 46). Differences between groups with > 5 fish were all significant ($P < 0.05$, K-W χ^2 tests). Patterns were similar for the WA-shore transition pool (Table 45).

Passage time to ascend a ladder – After exiting transition pools into ladders, sockeye salmon ascended ladders quickly at John Day Dam. Median times were 2.8 h up the OR-shore ladder and 3.0 h up the WA-shore ladder (Table 47). More than 75% of the fish ascended a ladder in < 4 h and only one fish took more than 24 h to ascend.

Passage time from first tailrace record to pass the dam – Sockeye salmon behavior in transition pools was a good predictor of overall time to pass John Day Dam. When all fish and both transition pools were included, median passage times from first tailrace record to exit from the top of a ladder were significantly longer for fish that exited into the tailrace than for fish that moved straight through or delayed in a transition pool ($P < 0.001$, K-W χ^2 tests). Fish that exited to the tailrace took 11 h longer than those that moved straight through a transition pool, and 12 h longer than those that delayed in a pool (Table 48). Sockeye salmon in all behavior categories passed the dam more rapidly in July than in June, but delays related to exiting to the tailrace were similar to those for all fish combined. Overall, steelhead that exited took 12 to 15 h longer to pass and sockeye that exited took 12 h longer than fish that did not exit.

Similar patterns emerged for each transition pool separately. Fish that exited either the OR- or WA-shore transition pool into the tailrace had longer passage times than fish that moved straight through a pool or delayed in the pool or collection channel (Table 49). In all behavior categories, fish migrated through the WA-shore pool and ladder more rapidly than through the OR-shore. Using median times, sockeye salmon that exited the WA-shore pool were delayed about 12 h compared to those that did not exit; fish that exited the OR-shore pool took about 11 h longer to pass (Table 49).

Fifty-two percent (14/27) of fish that exited the OR-shore pool to the tailrace took > 24 h to pass the dam, versus 15% (9/61) of fish that moved straight through, delayed, or exited the pool into the collection channel. Thirty-nine percent (41/104) of fish that exited the WA-shore pool into the tailrace took > 24 h to pass the dam, versus 5% of 79 that did not exit.

Monthly comparisons were similar. As with both transition pools combined (Table 48), fish that exited the OR-shore transition pool had the longest dam passage times in both June and July (Table 50). Fish that exited took 82 h (*medians*) longer to pass the dam than fish that moved straight through the OR-shore transition pool in June (small sample) and 3 h longer in July. Sockeye salmon that exited from the WA-shore pool took 10 to 18 h longer than fish that moved straight through or delayed in both June and July.

Factors Influencing Transition Pool Exits by Salmon and Steelhead

The largest dam passage delays for all studied runs occurred when fish exited transition pools into the tailrace. We used univariate and multiple logistic regression models to evaluate how several variables may have affected pool exit behavior including transition pool entered (WA vs. OR), date, transition pool entry time, tailwater elevation, total flow, spill, and water temperature. Temperature data were not available for the later portions of steelhead migrations. Logistic models were selected because exit behavior is binary: fish either exited or did not exit a transition pool.

Tailwater elevation at John Day Dam fluctuates with discharge continuously during the spring–summer Chinook and sockeye salmon migrations. As elevations increase, additional overflow weirs are completely submerged inside fishways, and concerns have been raised that resulting changes in flows through weir orifices and over overflow portions of weirs may contribute to fish turn-around in the transition pools. Elevated temperatures could also create passage deterrents in the pools.

Chinook salmon:

In univariate models, Chinook salmon that first entered the WA-shore transition pool were 1.9-3.4 times more likely (odds ratios, $P < 0.005$) to exit into the tailrace than fish that first entered the OR-shore pool in 1997 and 1998 (Table 52). Exit probabilities did not differ based on transition pool entered in 2000 or 2001. Chinook salmon were significantly ($P < 0.005$) more likely to exit transition pools as migrations progressed in each year. This may have been a function of water temperature, which was strongly positively correlated with date: with every 1º C increase in temperature, Chinook salmon were 1.1 to 1.2 times more likely to exit in all years (Table 52). Time of day was significant ($P < 0.05$) only in 2001, when Chinook salmon were slightly less likely to exit later in the day. Exit probabilities decreased ($P < 0.005$) as flow and spill decreased in the first three years and as tailwater elevation decreased in all years ($P < 0.005$) (Table 52).

In multiple stepwise logistic regression models (Table 53), water temperature was selected first in 1997 and 2001, date was first in 2000, and spill was first in 1998. The transition pool entered was selected second in both 1997 and 1998 (Table 53). When exit probabilities were examined separately for the OR-shore pool, date was the first and only variable selected in 1997 and 1998 and temperature was the only variable in 2000. Tailwater elevation and spill were selected in 2001. For Chinook salmon that first entered the WA-shore pool, water temperature was the only variable selected in 1997 and 2001, while spill was selected in 1998 and 2000 (Table 53).

Table 52. Results of univariate logistic regression models for Chinook salmon, sockeye salmon, and steelhead predicting whether or not fish exited (Y/N) from a transition pool into the tailrace at John Day Dam. Predictor variables were: transition pool entered and date, time of day, flow, spill, tailwater elevation, and temperature at the time each fish entered a transition pool. Odds ratios reflect the difference in the probability of transition pool exit associated with a one-unit change in the predictor variable. Arrows (▲▼) indicate direction of change for continuous variables. Includes fish with telemetry records at all passage points.

			Odds ratios (95% confidence interval)		
Variable (1 unit)	Run	Year	Both transition pools	OR-shore transition pool	WA-shore transition pool
First pool entered (WA vs. OR)	Chinook	1997	**3.35 (2.15-5.21)		
		1998	**1.93 (1.26-2.95)		
		2000	0.95 (0.61-1.47)		
		2001	0.88 (0.62-1.26)		
	Steelhead	1997	**2.11 (1.26-3.52)		
		2000	*1.64 (1.01-2.66)		
		2001	1.05 (0.60-1.84)		
	Sockeye	1997	**2.97 (1.73-3.85)		
Date (1 d)	Chinook	1997	**1.02 (1.01-1.03)▲	**1.02 (1.01-1.03)▲	*1.02 (1.01-1.03)▲
		1998	**1.01 (1.01-1.02)▲	**1.02 (1.01-1.03)▲	1.01 (0.99-1.02)▲
		2000	**1.02 (1.02-1.03)▲	**1.04 (1.02-1.05)▲	**1.02 (1.01-1.03)▲
		2001	**1.02 (1.01-1.03)▲	**1.01 (1.00-1.02)▲	**1.03 (1.01-1.04)▲
	Steelhead	1997	0.99 (0.99-1.00)▼	1.00 (0.99-1.00)▼	1.00 (0.98-1.01)▼
		2000	0.99 (0.99-1.00)▼	*0.99 (0.98-1.00)▼	1.01 (0.99-1.02)▲
		2001	**0.98 (0.98-0.99)▼	**0.98 (0.97-0.99)▼	0.99 (0.97-1.00)▼
	Sockeye	1997	1.01 (0.98-1.04)▲	1.02 (0.98-1.06)▲	1.00 (0.97-1.04)▲
Time (14 min)	Chinook	1997	0.99 (0.98-1.01)▼	1.00 (0.98-1.01)▼	0.99 (0.97-1.01)▼
		1998	1.00 (0.99-1.01)▼	1.00 (0.99-1.02)▲	0.99 (0.97-1.01)▼
		2000	1.00 (0.98-1.01)▼	0.99 (0.97-1.01)▼	1.01 (0.99-1.03)▲
		2001	*0.99 (0.97-1.00)▼	0.99 (0.97-1.00)▼	0.99 (0.97-1.00)▼
	Steelhead	1997	1.01 (1.00-1.02)▲	1.00 (0.99-1.02)▲	1.02 (1.00-1.04)▲
		2000	1.00 (0.99-1.01)▲	1.00 (0.98-1.01)▼	1.01 (0.99-1.03)▲
		2001	1.00 (0.99-1.01)▲	1.01 (1.00-1.03)▲	1.00 (0.98-1.03)▲
	Sockeye	1997	1.01 (1.00-1.02)▼	0.99 (0.97-1.02)▼	1.00 (0.99-1.01)▼
Flow (10 kcfs)	Chinook	1997	**0.94 (0.92-0.97)▼	*0.96 (0.93-0.99)▼	*0.95 (0.92-0.99)▼
		1998	**0.95 (0.92-0.98)▼	0.99 (0.95-1.03)▼	**0.86 (0.81-0.92)▼

		2000	**0.89 (0.85-0.93)▼	**0.84 (0.77-0.92)▼	**0.91 (0.86-0.96)▼
		2001	0.95 (0.88-1.02)▼	0.92 (0.84-1.01)▼	0.99 (0.89-1.11)▼
	Steelhead	1997	1.02 (0.98-1.07)▲	1.02 (0.96-1.08)▲	1.01 (0.94-1.08)▲
		2000	1.02 (0.93-1.11)▲	1.06 (0.94-1.20)▲	0.97 (0.85-1.10)▼
		2001	1.07 (0.92-1.24)▲	1.00 (0.84-1.19)▼	1.31 (0.95-1.81)▲
	Sockeye	1997	0.98 (0.94-1.01)▼	0.94 (0.88-1.01)▼	1.02 (0.97-1.08)▲
Spill (10 kcfs)	Chinook	1997	**0.94 (0.90-0.97)▼	*0.95 (0.91-1.00)▼	*0.95 (0.89-1.00)▼
		1998	**0.88 (0.83-0.94)▼	0.95 (0.87-1.02)▼	**0.75 (0.66-0.84)▼
		2000	**0.82 (0.75-0.91)▼	0.88 (0.77-1.01)▼	**0.77 (0.67-0.88)▼
		2001	*1.72 (1.15-2.58)▲	*1.99 (1.13-3.52)▲	1.41 (0.78-2.57)▲
	Steelhead	1997	1.10 (0.98-1.24)▲	1.10 (0.94-1.29)▲	1.04 (0.86-1.25)▲
		2000	1.03 (0.93-1.14)▲	1.08 (0.93-1.25)▲	0.95 (0.82-1.11)▼
		2001	--	--	--
	Sockeye	1997	*0.93 (0.87-0.99)▼	0.90 (0.80-1.01)▼	0.99 (0.89-1.10)▼
Tailwater (1ft)	Chinook	1997	**0.80 (0.74-0.87)▼	*0.86 (0.77-0.96)▼	**0.81 (0.70-0.94)▼
		1998	**0.83 (0.74-0.93)▼	0.95 (0.82-1.10)▼	**0.58 (0.46-0.75)▼
		2000	**0.69 (0.58-0.82)▼	**0.52 (0.35-0.76)▼	**0.74 (0.61-0.90)▼
		2001	**0.56 (0.39-0.79)▼	**0.44 (0.27-0.71)▼	0.77 (0.45-1.30)▼
	Steelhead	1997	1.12 (0.93-1.36)▲	1.10 (0.86-1.42)▲	1.00 (0.73-1.35)▼
		2000	0.84 (0.57-1.22)▼	0.61 (0.36-1.02)▼	1.37 (0.72-2.62)▲
		2001	1.04 (0.50-2.19)▲	0.83 (0.35-1.98)▼	1.87 (0.45-7.75)▲
	Sockeye	1997	0.91 (0.79-1.05)▼	0.80 (0.62-1.03)▼	1.09 (0.88-1.34)▲
Temperature (1º C)[1]	Chinook	1997	**1.23 (1.15-1.33)▲	**1.17 (1.06-1.29)▲	**1.20 (1.06-1.36)▲
		1998	*1.10 (1.03-1.18)▲	**1.16 (1.06-1.27)▲	1.04 (0.93-1.17)▲
		2000	**1.22 (1.14-1.32)▲	**1.38 (1.19-1.61)▲	**1.17 (1.07-1.28)▲
		2001	**1.15 (1.09-1.22)▲	**1.10 (1.03-1.18)▲	**1.25 (1.13-1.39)▲
	Steelhead	1997	0.99 (0.73-1.34)▼	1.05 (0.69-1.61)▲	1.04 (0.62-1.73)▲
		2000	1.10 (0.80-1.51)▲	0.99 (0.59-1.64)▼	1.17 (0.78-1.74)▲
		2001	1.04 (0.75-1.43)▲	1.18 (0.83-1.69)▲	0.62 (0.25-1.52)▼
	Sockeye	1997	1.04 (0.87-1.23)▲	1.20 (0.90-1.60)▲	0.94 (0.75-1.18)▼

* $P < 0.05$, ** $P < 0.005$

[1] steelhead temperature data only available through mid-September

Table 53. Results of stepwise multiple logistic regression models for Chinook salmon, predicting whether or not fish exited (Y/N) from a transition pool into the tailrace at John Day Dam. Predictor variables were: transition pool entered and date, time of day, flow, spill, tailwater elevation, and temperature at the time each fish entered a transition pool. Odds ratios reflect the difference in the probability of transition pool exit associated with a one-unit change in the predictor variable (see Table 47 for units). Includes fish with telemetry records at all passage points.

	Run	Year	Variable	χ^2	Odds ratio (95% CI)
Both pools	Chinook	1997	Temperature	18.0	**1.18 (1.09-1.28)
			Pool entered	14.9	**2.51 (1.58-4.01)
		1998	Spill	10.7	**0.90 (0.84-0.96)
			Pool entered	11.8	**2.18 (1.40-3.39)
			Date	5.3	*1.01 (1.00-1.02)
		2000	Date	22.8	**1.02 (1.01-1.03)
			Spill	7.7	**0.87 (0.80-0.96)
		2001	Temperature	19.8	**1.14 (1.08-1.21)
			Tailwater	6.2	*0.63 (0.44-0.91)
	Steelhead	1997	Pool entered	8.0	**2.10 (1.26-3.52)
		2000	Pool entered	4.0	*1.64 (1.01-2.66)
		2001	Date	12.8	**0.98 (0.98-0.99)
	Sockeye	1997	Pool entered	15.7	**2.97 (1.73-5.10)
OR-shore pool	Chinook	1997	Date	10.7	**1.02 (1.01-1.03)
		1998	Date	12.4	**1.02 (1.01-1.03)
		2000	Temperature	17.2	**1.38 (1.19-1.61)
		2001	Tailwater	10.6	**0.45 (0.28-0.73)
			Spill	5.0	*1.91 (1.08-3.39)
	Steelhead	1997	n/s	--	--
		2000	Date	6.9	*0.99 (0.98-1.00)
			Tailwater	4.8	*0.53 (0.30-0.93)
		2001	Date	10.5	**0.98 (0.97-0.99)
	Sockeye	1997	n/s	--	--
WA-shore pool	Chinook	1997	Temperature	8.1	**1.20 (1.06-1.36)
		1998	Spill	32.0	**0.75 (0.66-0.84)
		2000	Spill	10.6	**0.80 (0.70-0.91)
			Date	10.4	**1.02 (1.01-1.03)
		2001	Temperature	17.9	**1.25 (1.13-1.39)
	Steelhead	1997	n/s	--	--
		2000	n/s	--	--
		2001	n/s	--	--
	Sockeye	1997	n/s	--	--

* $P < 0.05$, ** $P < 0.005$

Steelhead:

Steelhead that first entered the WA-shore transition pool were significantly more likely to exit to the tailrace than those that first entered the OR-shore pool in 1997 and 2000 (Table 52). Steelhead were less likely to exit later in the year, but this pattern was significant ($P < 0.05$) only in 2001 for both pools combined and in 2000 and 2001 for the OR-shore pool. Time of day, flow, spill, and tailwater elevation were generally not significant in univariate analyses in any year. Water temperature was also non-significant for the smaller sample for which these data were available.

In multivariate stepwise analyses, the first pool entered was the only variable selected in 1997 and 2000 and date was the only variable in 2001 (Table 53). When fish that first entered the OR-shore pool first were considered separately, no variables were selected in 1997 and date was selected in both 2000 and 2001, in both years indicating the exiting was less likely later in the migration. No variables were selected for the WA-shore pool steelhead (Table 53).

Sockeye salmon:

Results for sockeye salmon were generally similar to those for Chinook salmon, though significance levels were lower (Table 52). Sockeye salmon that first entered the WA-shore pool first were about 3 times more likely to exit to the tailrace ($P < 0.005$) than those that first entered the OR-shore pool. Later migrants and those exposed to lower spill and tailwater elevations and higher temperatures tended to be more likely to exit (Table 52).

With both transition pools combined, only the pool sockeye first entered was selected in the multivariate model (Table 53). No variable were selected when fish were considered separately by pool first entered.

Migration Timing of the Most and Least Efficient Passages

In 1997 and 1998, the 10% of radio-tagged spring–summer Chinook salmon that took the longest to pass John Day Dam mostly entered the tailrace in mid-April to early May, significantly earlier in the migration than the 10% that passed the dam the most rapidly in 1997 ($P < 0.001$, K-W χ^2 tests) and 1998 ($P = 0.067$) (Figure 8). The differences in timing between the fastest and slowest groups was greatest in 1997, when a relatively large proportion of radio-tagged fish were fast-moving summer Chinook salmon returning to mid-Columbia River tributaries. The longest passage times in 1997 (and some of the longest recorded in the study) coincided with high flow (> 400 kcfs) and spill (> 250 kcfs) in late April/early May, the highest levels encountered by spring Chinook salmon during the four years. Timing differences were non-significant ($P > 0.05$) in 2000 and 2001 (Figure 8).

Migration timing differences between the fastest and slowest 10% of steelhead were inconsistent between years (Figure 9). In 1997, the fastest 10% passed the dam significantly earlier ($P = 0.022$, K-W χ^2 test), while in 2001 the slowest 10% passed earlier in the year ($P = 0.025$). Timing did not differ in 2000.

As with Chinook salmon in 1997, the fastest 10% of sockeye salmon in 1997 passed later in the migration.

Modeling John Day Dam Passage Times

We used multiple regression analyses (PROC GLM, SAS) to identify which continuous variables (date, time of day, flow, spill, tailwater elevation, temperature) and categorical variables (fishway exit, transition pool first entered, transition pool exit) most influenced John Day Dam passage times. Times modeled were from first tailrace entry to pass over the dam, and were log-transformed to improve normality.

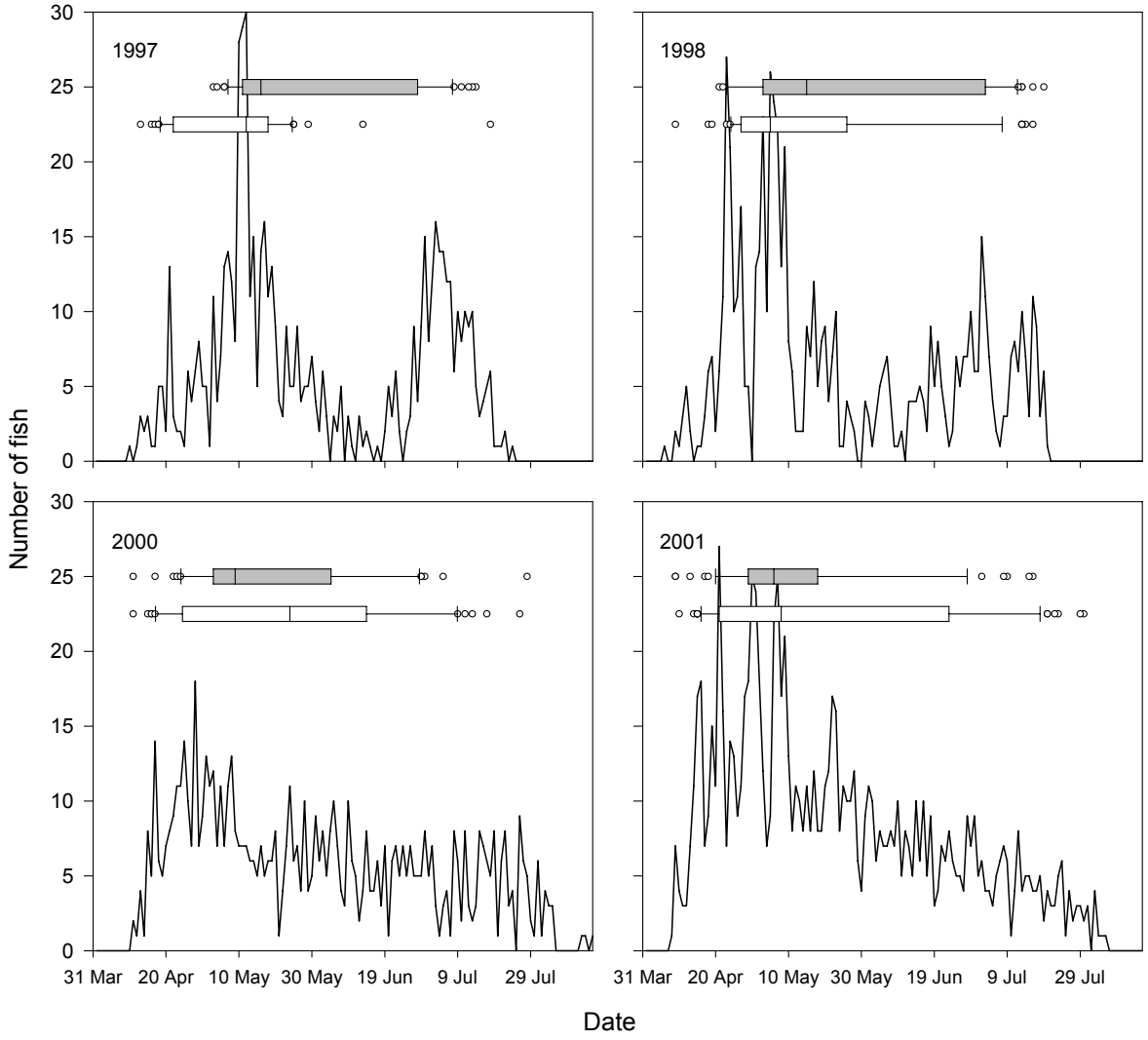

Figure 8. Passage of radio-tagged spring–summer Chinook salmon (lines), with median, quartile, 5th and 95th percentile dates for the 10% that passed the fastest (gray boxplots) and slowest (white boxplots) in each year.

Correlations among predictor variable were high in some cases, particularly among date and temperature and among flow, spill, and tailwater elevation (Table 54). Similarly, the binary term fishway exit was strongly similar to transition pool exit. Nonetheless, all variables were retained and both Type I Type III sums of squares were reported. The latter take into account the variability explained by all other variables in the model.

Chinook salmon:

Multiple regression models were highly significant ($P < 0.001$) for spring–summer Chinook salmon in each year, and the predictor variables explained between 21 and 29% of the variability in passage times (Table 55). When all variables were considered together, an exit from a transition pool into the tailrace of John Day Dam was the most influential variable

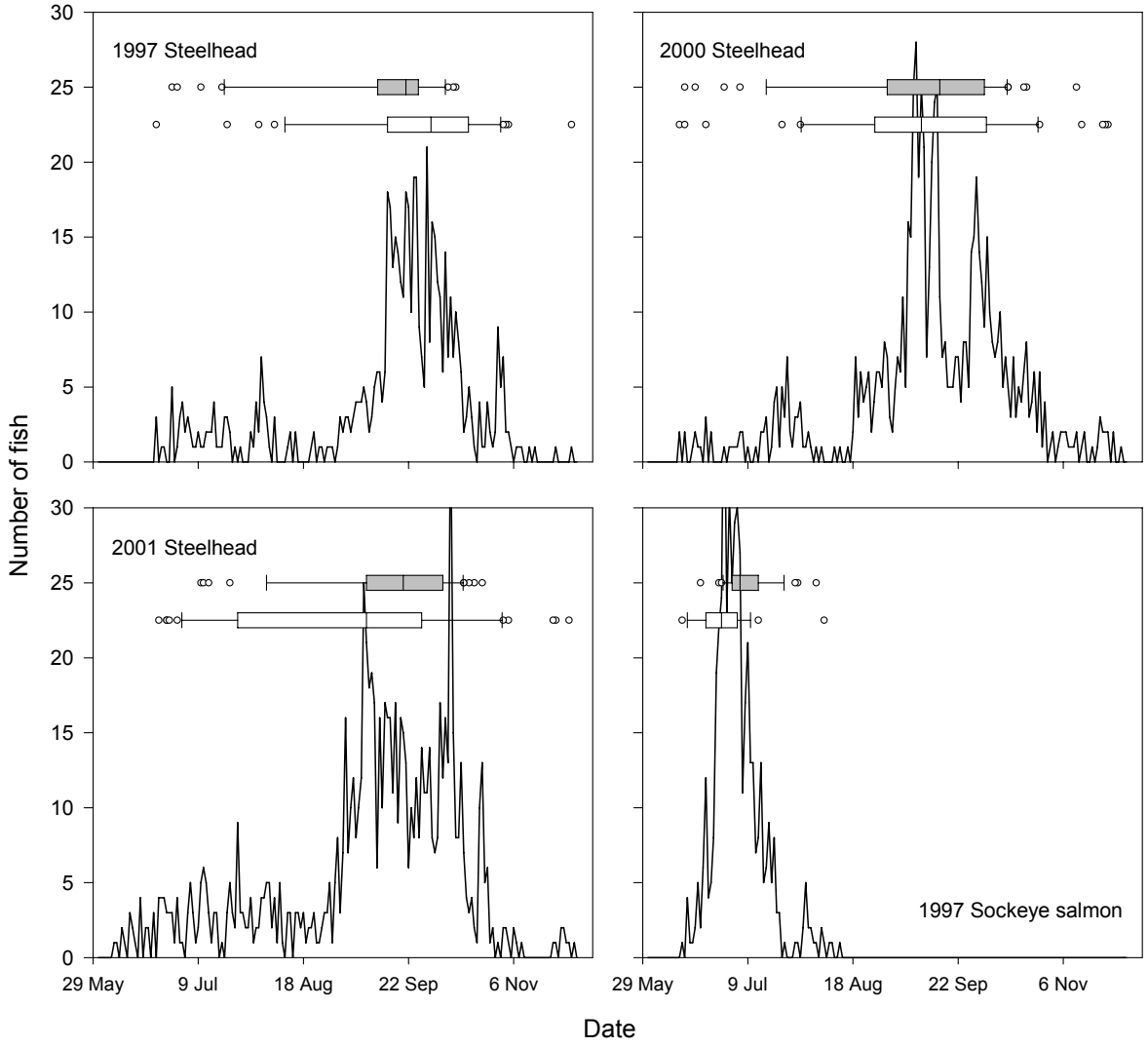

Figure 9. Passage of radio-tagged steelhead and sockeye salmon (lines), with median, quartile, 5th and 95th percentile dates for the 10% that passed the fastest (gray boxplots) and slowest (white boxplots) in each year.

($18 < F < 55$, $P < 0.001$) in all four years. Time of day was also influential in both 1997 and 2001, reflecting longer passage times for salmon the entered the tailrace late in the day and then spent a night in the tailrace or fishway. Date, or the closely related variable water temperature, was significant in 1997, 1998, and 2001. Exit from a fishway (as opposed to exit from a transition pool) was influential in 1998 and 2000 (Table 55).

Steelhead:

Multiple regression models explained 18 to 29% of the variability in steelhead passage times (Table 56). When all variables were considered together, an exit from a transition pool into the tailrace of John Day Dam was the most influential variable in 2000 and 2001, while date was most influential in 1997. Patterns for other variables were less consistent among years than for

spring–summer Chinook salmon. Tailwater elevation and flow (1997), spill and time of day (2000), and transition pool first entered (2001) were all influential variables. The flow, elevation, and spill variables may all have reflected seasonal differences as these variables tend to be higher in summer than fall.

Table 54. Correlation coefficients for environmental variables, date, and time based on the time fish first entered the John Day Dam tailrace. Bold indicates significant ($P < 0.05$) correlation.

		Chinook salmon				Steelhead			SK
Variables		1997	1998	2000	2001	1997	2000	2001	1997
Date	Time	-0.058	-0.016	0.016	**0.121**	0.058	0.016	0.025	**-0.124**
	Flow	**-0.470**	**-0.121**	**-0.890**	**-0.178**	**-0.457**	**-0.648**	**-0.268**	**-0.769**
	Spill	**-0.279**	**-0.277**	**-0.278**	**0.237**	**-0.586**	**-0.812**	**-0.327**	**-0.548**
	Tailwater	**-0.487**	-0.030	**-0.847**	**-0.351**	**-0.426**	**-0.269**	**0.106**	**-0.741**
	Temp.	**0.980**	**0.955**	**0.988**	**0.963**	-	-	-	**0.944**
Time	Flow	-0.074	-0.022	-0.028	0.006	**-0.134**	0.006	0.079	0.063
	Spill	-0.071	-0.026	0.030	**0.117**	-0.100	-0.024	0.021	0.017
	Tailwater	-0.063	-0.035	-0.024	-0.044	**-0.128**	0.029	-0.031	0.068
	Temp.	-0.063	-0.012	0.009	**0.123**	-	-	-	-0.117
Flow	Spill	**0.952**	**0.929**	**0.444**	**0.305**	**-0.201**	**0.694**	**0.328**	**0.869**
	Tailwater	**0.975**	**0.969**	**0.961**	**0.725**	**-0.254**	**0.570**	**0.530**	**0.979**
	Temp.	**-0.474**	**-0.105**	**-0.886**	-0.024	-	-	-	**-0.830**
Spill	Tailwater	**0.925**	**0.872**	**0.586**	-0.083	**0.848**	**0.306**	0.062	**0.835**
	Temp.	**-0.271**	**-0.219**	**-0.283**	**0.280**	-	-	-	**-0.546**
Tailwater	Temp.	**-0.488**	-0.031	**-0.847**	**-0.236**	-	-	-	**-0.807**

Sockeye salmon:

An exit from a transition pool was the most influential predictor of sockeye salmon passage time at John Day Dam ($F = 19$, $P < 0.001$) (Table 56). The other fishway variables (fishway exit, first transition pool entered) were also significant ($P < 0.005$), as were flow and spill ($P < 0.05$). The overall model explained 37% of the passage time variability at the dam (Table 56).

Behavior and Fate of Fish that Did Not Pass the Dam

Chinook salmon:

Between 2.5 (2001) and 5.7% (2000) of the spring–summer Chinook salmon recorded in the tailrace or at John Day Dam did not pass the dam (Table 57). Of those that did not pass, 12 to 25% were only recorded in the tailrace, 8 to 48% were recorded approaching fishway entrances, 2 to 20% were recorded inside fishways (but not in transition pools), and 28 to 52% were recorded inside transition pools. Of those that entered fishways, most (65 to 85%) were last detected in the OR-shore fishway (Table 57).

Table 55. Results of multiple regression analysis, where Chinook salmon times to pass John Day Dam (tailrace to top of ladder, log-transformed) was the dependent variable and independent variables included date, time of day, fishway exit to tailrace (0,1), transition pool first entered, transition pool exit to tailrace (0,1), flow, spill, tailwater elevation, and temperature. Type III sum of squares adjust for all other variables in the model. Only includes fish with records at all passage points.

Year	Source	Type I SS	*F*	*P*	Type III SS	*F*	*P*
1997	Date	7.4	35.0	<0.001	1.5	7.3	0.007
	Time	2.3	10.8	0.001	1.8	8.7	0.003
	Fishway exit	12.7	60.0	<0.001	1.0	4.8	0.029
	First pool entered	1.7	8.2	0.005	0.8	3.6	0.058
	Transition pool exit	3.9	18.4	<0.001	3.9	18.4	<0.001
	Flow	0.9	4.2	0.042	0.4	1.8	0.176
	Spill	0.0	0.1	0.785	0.0	0.0	0.997
	Tailwater elevation	0.4	2.0	0.162	0.4	2.0	0.154
	Temperature	0.2	1.0	0.321	0.2	1.0	0.321
					Model r^2 = 0.269; F = 15.5; P < 0.001		
1998	Date	2.6	17.1	<0.001	0.0	0.1	0.709
	Time	0.4	2.9	0.090	0.4	2.6	0.405
	Fishway exit	10.0	66.1	<0.001	0.9	6.0	0.015
	First pool entered	0.2	1.5	0.218	0.0	0.1	0.779
	Transition pool exit	3.0	20.0	<0.001	2.9	19.0	<0.001
	Flow	0.3	2.2	0.136	0.1	0.9	0.351
	Spill	0.4	2.7	0.100	0.1	0.6	0.426
	Tailwater elevation	0.0	0.0	0.962	0.0	0.1	0.760
	Temperature	0.7	4.5	0.035	0.7	4.5	0.035
					Model r^2 = 0.232; F = 13.0; P < 0.001		
2000	Date	0.0	0.2	0.675	0.1	0.4	0.506
	Time	1.4	9.0	0.003	0.6	3.7	0.055
	Fishway exit	12.0	79.1	<0.001	0.9	6.1	0.014
	First pool entered	0.5	3.3	0.068	0.2	1.1	0.304
	Transition pool exit	7.2	47.4	<0.001	7.1	46.7	<0.001
	Flow	0.0	0.0	0.854	0.2	1.3	0.265
	Spill	0.0	0.0	0.996	0.1	0.5	0.487
	Tailwater elevation	0.2	1.4	0.244	0.2	1.3	0.253
	Temperature	0.0	0.0	0.901	0.0	0.0	0.901
					Model r^2 = 0.290; F = 15.6; P < 0.001		
2001	Date	0.2	1.9	0.171	0.8	6.5	0.011
	Time	1.9	14.8	<0.001	3.1	23.7	<0.001
	Fishway exit	6.3	48.3	<0.001	0.0	0.1	0.727
	First pool entered	0.0	0.1	0.750	0.0	0.0	0.845
	Transition pool exit	7.8	59.5	<0.001	7.1	54.4	<0.001
	Flow	0.5	3.5	0.064	0.1	1.1	0.305
	Spill	0.1	0.5	0.480	0.0	0.0	0.988
	Tailwater elevation	0.3	2.3	0.134	0.3	2.2	0.139
	Temperature	1.3	10.0	0.002	1.3	10.0	0.002
					Model r^2 = 0.206; F = 15.6; P < 0.001		

Table 56. Results of multiple regression analysis, where steelhead (SH) and sockeye salmon (SK) times to pass John Day Dam (tailrace to top of ladder, log-transformed) were the dependent variables and independent variables included date, time of day, fishway exit to tailrace (0,1), transition pool first entered, transition pool exit to tailrace (0,1), flow, spill, tailwater elevation, and temperature[1]. Type III sum of squares adjust for all other variables in the model. Only includes fish with records at all passage points.

Year	Source	Type I SS	*F*	*P*	Type III SS	*F*	*P*
1997	Date	1.0	4.9	0.028	3.3	16.3	<0.001
(SH)	Time	1.2	5.9	0.016	1.2	6.2	0.014
	Fishway exit	14.3	71.2	<0.001	1.1	5.5	0.020
	First pool entered	0.0	0.2	0.686	0.0	0.0	0.862
	Transition pool exit	1.3	6.6	0.011	1.6	7.8	0.006
	Flow	1.6	7.8	0.006	2.3	11.6	0.001
	Spill	1.4	7.0	0.009	0.9	4.5	0.035
	Tailwater elevation	2.5	12.4	0.001	2.5	12.4	0.001
					Model r^2 = 0.287; F = 14.5; P < 0.001		
2000	Date	0.4	2.2	0.140	0.7	4.0	0.047
(SH)	Time	0.5	2.7	0.102	0.9	4.9	0.028
	Fishway exit	11.2	59.6	<0.001	0.0	0.1	0.801
	First pool entered	0.0	0.0	0.873	0.1	0.4	0.540
	Transition pool exit	3.1	16.6	<0.001	3.5	18.7	<0.001
	Flow	0.4	1.9	0.167	0.2	1.2	0.270
	Spill	1.2	6.6	0.011	1.1	6.1	0.014
	Tailwater elevation	0.5	2.5	0.114	0.5	2.5	0.114
					Model r^2 = 0.209; F = 11.5; P < 0.001		
2001	Date	2.0	7.4	0.007	0.5	1.9	0.166
(SH)	Time	1.0	3.8	0.052	0.7	2.5	0.119
	Fishway exit	12.2	44.4	<0.001	0.7	2.7	0.104
	First pool entered	1.1	3.9	0.048	1.3	4.7	0.031
	Transition pool exit	2.0	7.3	0.007	1.4	5.1	0.025
	Flow	2.0	7.3	0.007	0.5	1.7	0.193
	Spill	0.4	1.3	0.254	0.3	1.1	0.296
	Tailwater elevation	0.9	3.3	0.072	0.9	3.3	0.072
					Model r^2 = 0.178; F = 9.8; P < 0.001		
1997	Date	2.2	24.5	<0.001	0.0	0.0	0.926
(SK)	Time	0.0	0.3	0.568	0.1	1.0	0.318
	Fishway exit	8.4	93.3	<0.001	0.9	9.6	0.002
	First pool entered	0.3	3.7	0.054	0.7	7.6	0.006
	Transition pool exit	1.5	16.6	<0.001	1.7	18.7	<0.001
	Flow	0.5	5.6	0.018	0.4	4.2	0.042
	Spill	0.2	2.7	0.101	0.5	5.5	0.019
	Tailwater elevation	0.3	3.2	0.076	0.3	3.7	0.057
	Temperature	0.2	1.7	0.194	0.2	1.7	0.194
					Model r^2 = 0.367; F = 16.8; P < 0.001		

[1] sockeye salmon only

In the first three years, the largest percentages (37 to 52%) of the fish that did not pass the dam were unaccounted for downstream; 36% were unaccounted for in 2001 (Table 57). From

12 to 17% were recaptured in fisheries in the first three years, as were 44% in 2001. In all years, 16 to 24% entered downstream tributaries. The remaining 4 to 32% were known or presumed spit tags, based either on tag recoveries or repeated detections of stationary tags. We note that some of the latter were likely natural mortalities or mortalities associated with active fisheries in the area.

Table 57. Final fate, most upstream point reached at dam, and last fishway detection for radio-tagged fish that did not pass John Day Dam.

	Chinook salmon				Steelhead			Sockeye
	1997	1998	2000	2001	1997	2000	2001	1997
Recorded at dam	654	673	722	994	599	780	910	485
Did not pass dam	25	34	41	25	45	28	41	17
Percent that did not pass dam	3.8%	5.1%	5.7%	2.5%	7.5%	3.6%	4.5%	3.5%
Fate of fish that did not pass:								
Unaccounted for	**52%**	**35%**	**37%**	36%	**42%**	18%	32%	**65%**
Recaptured in fisheries	12%	15%	17%	**44%**	24%	**39%**	**39%**	6%
Entered downstream tributary	20%	18%	24%	16%	24%	32%	17%	18%
Known or presumed spit tags[1]	16%	32%	22%	4%	9%	11%	12%	12%
Most upstream point at dam:								
Tailrace	25%	21%	12%	20%	27%	18%	5%	29%
Approached fishway only	**48%**	21%	27%	8%	7%	14%	2%	6%
Inside fishway, no trans. pool	4%	12%	2%	20%	2%	--	5%	18%
Inside transition pool	28%	**44%**	**59%**	**52%**	13%	**64%**	**83%**	41%
Near top of ladder	--	3%	--	--	**51%**	4%	5%	6%
Last fishway detection[2]:								
OR-shore fishway	**65%**	**67%**	**83%**	**85%**	**67%**	**78%**	**64%**	**83%**
WA-shore fishway	35%	33%	17%	15%	33%	22%	36%	17%

[1] Some may have been mortalities
[2] Percent of those that approached dam

Steelhead:

Between 3.6 (2000) and 7.5% (1997) of the steelhead recorded in the tailrace of John Day Dam or at the dam did not pass (Table 57). Of these, 5 to 27% were only recorded in the tailrace, 2 to 14% were recorded approaching fishway entrances, < 5% were recorded inside fishways (but not in transition pools), and 13 to 83% were recorded inside transition pools. Of those that entered fishways, most (64 to 78%) were last detected in the OR-shore fishway (Table 57).

In the three years, 18 to 42% of the steelhead that did not pass the dam were unaccounted for downstream, 24 to 39% were recaptured in fisheries downstream, and 17 to 32% were last recorded in downstream tributaries (Table 57). An estimated 9 to 12% that did not pass may have regurgitated tags or the fish died and the transmitter was not recovered.

Sockeye salmon:

Seventeen sockeye salmon (3.5%) did not pass John Day Dam in 1997 (Table 57). About a quarter were recorded only in the tailrace, and 59% entered a fishway or transition pool. Most (83%) of the salmon that entered fishways were last recorded in the OR-shore fishway.

The majority (65%) of sockeye salmon that did not pass were unaccounted for downstream. One fish (6%) was recaptured in a fishery, and 3 (18%) entered downstream tributaries (these strays were unsuccessful migrants because no sockeye salmon populations spawn in lower river tributaries). Two sockeye salmon had presumed spit tags and may also have been mortalities.

Discussion

Passage Times: One of the primary objectives of the adult passage project was to identify sources of slowed adult passage at dams (NMFS 2000). In this report, we have summarized passage behaviors—including passage times —through tailrace, fishway, transition pool, and full-project passage segments at John Day Dam. Median full-dam passage times during the study years (1997, 1998, 2000, 2001) were longest for radio-tagged spring–summer Chinook salmon (26 to 36 h), intermediate for steelhead (17 to 20 h) and shortest for sockeye salmon (13 h). Overall, passage times at John Day Dam were among the longest recorded at any of the eight lower Columbia and lower Snake River dams (see Keefer et al. 2004a). These long passage times were attributable, at least in part, to high fishway and transition pool exit rates at John Day Dam. During the study years, adult fish from all runs were far more likely to exit into the tailrace at John Day Dam than were the same fish at The Dalles Dam (Keefer et al. 2003b; Keefer et al. 2007), and exit rates from John Day Dam fishways were higher than those recorded in 1996 at Bonneville, McNary, Ice Harbor, and Lower Granite dams (Keefer et al. 2003a).

As in other adult passage time studies, mean times at John Day Dam were longer than medians for all species/years, because some fish delayed for days or weeks and/or moved downstream temporarily. As a result, all passage time distributions were right-skewed. It is likely that salmonid migration times under pre-dam conditions were also skewed, with some fish migrating slower than the bulk of the run, particularly in areas with natural constrictions like falls and rapids (e.g., Jensen et al. 1989; Gilhousen 1990; Rand and Hinch 1998).

To best determine where fish slowed at John Day Dam, we partitioned passage by radio-tagged fish at John Day Dam into five primary components: 1) first tailrace entry to first fishway approach, 2) first fishway approach to first fishway entry, 3) first fishway entry to first transition pool entry, 4) first transition pool entry to exit a pool into a ladder, and 5) ladder ascension. These passage segments capture the major fish passage environments at the dam, with segment endpoints marking transitions between environments. Some segments, such as transition pools, have been previously identified as sources of confusion or delay for adult migrants at other hydrosystem dams (e.g., Bjornn et al. 1998b; Keefer et al. 2003a). Defining ‘delay’ through any passage segment was an arbitrary decision, because fish may have temporarily stopped upstream migration or moved downstream for a variety of reasons, including nightfall (e.g. Naughton et al. 2005), route-searching behavior, response to environmental change, the number of fish passing a site, or difficult passage conditions at the dam. By way of summary, one measure of delay that was useful for classifying and comparing groups of fish was a time gap of > 24 h through any of the five passage segments listed above.

In all years, the segment with the largest numbers of spring–summer Chinook salmon with passage times > 24 h was from first transition pool entry to exit a pool into a ladder (Figure 10).

Between 26 and 29% of the Chinook salmon took > 24 h between transition pool entry and eventual exit into a ladder. Salmon were generally not inside the transition pools for most of the elapsed time, but instead were in the tailrace or entering and exiting the fishways. The longest transition pool passage times almost always included an exit from a pool into the tailrace. The transition pool segment also had the greatest numbers of steelhead and sockeye salmon with passage times > 24 h (Figure 10), and the circumstances of transition pool 'delay' were similar for these runs. The passage segment from first fishway approach to first fishway entry also included a number of passage times > 24 h, particularly for Chinook salmon in 1997, the year when flow and spill were highest. Ascending ladders, passing from fishway entry to transition pool entry, and even from tailrace entry to first fishway approach were generally efficient for all runs, with less than 10% taking > 24 h to pass these segments in any run-year.

Spring–summer Chinook passage times at John Day Dam tended to decrease as water temperatures warmed each year. This behavior was consistent with dam passage at other dams and migration times through longer hydrosystem reaches (Bjornn et al. 2000a; Keefer et al. 2004a; 2007). Increasing passage rates were likely due to increased metabolic activity at warmer temperatures (Erkinaro 1999; Økland 2001), but may also have been related to increased proportions of fish destined for upriver spawning areas (e.g., Snake and mid-Columbia River tributaries) as migrations processed. Keefer et al. (2004b) also reported increasing passage rates by Chinook salmon as temperatures warmed in unimpounded reaches and tributaries.

Fish of all species that exited a fishway into the tailrace had longer dam passage times than fish that did not exit in almost all months of all years. Increases in passage time associated with exiting a fishway were 13 to > 30 h for spring–summer Chinook, 10 to 16 h for steelhead and 7 to 13 h for sockeye salmon in most individual months. Similar delays were observed for fish that exited transition pools into the tailrace—overlap between fish that exited fishways and those that exited transition pools to the tailrace was extensive, because many fish migrated upstream in fishways to transition pool areas before turning around and exiting fishways.

Behavior in transition pools and fishway exit behavior were very good predictors of overall dam passage times for all runs. Fish that exited transition pools into the tailrace had dam passage times that were significantly longer than times for fish that moved through transition pools without exiting. Similarly, fish that exited fishways took significantly longer than fish that did not exit. Non-uniform flows, lack of sufficient attractive flow, temperature changes, locations of floor diffusers, fishway configuration, or a combination of these or other variables may have contributed to the behaviors we observed in transition pools. Fishway exits not related to transition pools may also have been related to some of the variables described above. These results are consistent with previous studies that showed fishway and transition pool exits were sources of delay for adult migrants (Bjornn et al. 1998a, 1998b; Keefer et al. 2003a). Water temperatures in the fishways and ladders were implicated in adult exit behavior in a more detailed study of temperature effects at John Day Dam that used the 1997 and 1998 data (Keefer et al. 2003b). In that study, fishway exit rates at John Day Dam were strongly positively correlated with mean and maximum water temperatures in the ladders (Keefer et al.

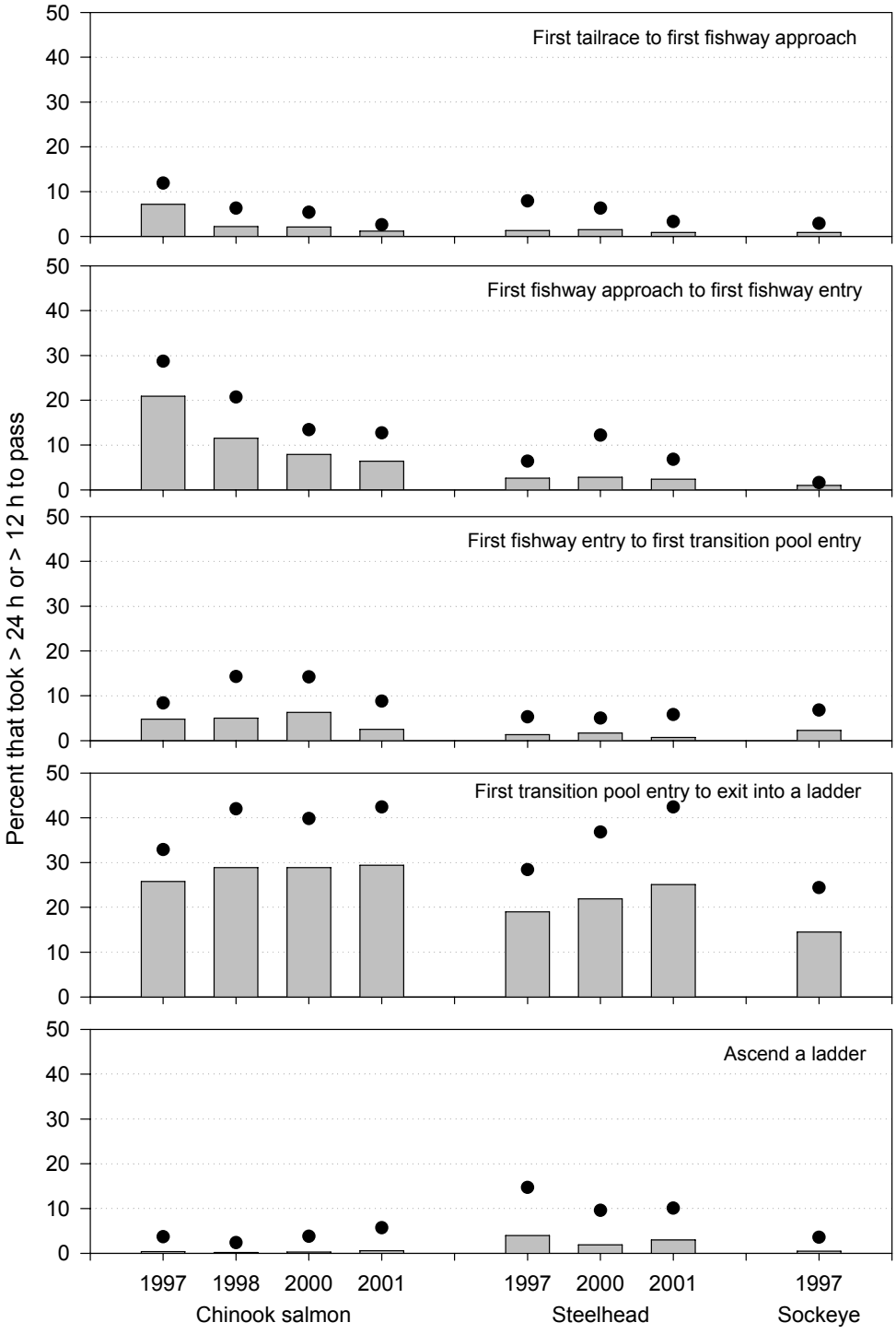

Figure 10. Percent of fish that took > 24 h (gray bars) and > 12 h (black circles) to pass through each John Day Dam passage segment.

2003b). In this study, the likelihood of fish exiting a transition pool into the tailrace was generally higher for fish that first entered the WA-shore pool, was higher for Chinook salmon later in the migration when water temperatures were elevated, and for some steelhead migrating during the warm summer months.

We also note that some variability in passage times and behaviors like fishway and transition pool exits can be attributed to diel cycles. We have observed that adult salmon and steelhead are unlikely to pass dams at night (Keefer et al. 2004a; Naughton et al. 2005). As a result, fish that enter fishways and tailraces late in the day tend to pass the following day, resulting in longer passage times.

The multivariate analyses of complete passage times at John Day Dam (e.g., Table 55) indicated that an exit from a transition pool into the tailrace was the most influential predictor of passage time for all four years of spring–summer Chinook salmon, for sockeye salmon, and for two of three years for steelhead. Time of day was secondary in two years for Chinook salmon, while water temperature and/or date also provided good predictive capabilities for several run years. Fishway exits were also important (in addition to transition pool exits) in some cases. Collectively, these results suggest that how adult fish behaved after entering John Day Dam fishways was the most important determinant of how long fish took to pass the dam. Seasonal and diel effects were also important, reflecting a general aversion to passing dams at night and increasing migration speeds during warmer periods or as spawning times approached.

Our results suggest that the best opportunities for improving adult passage efficiency at John Day Dam include reducing fallout from fishways and transition pools. The overwhelming majority of 'efficient' (i.e., fast) dam passages by all three species were by fish that did not exit. Modifications to transition pool weirs, including increasing hydraulic head at lower weirs and raising velocities through orifices, may increase the proportions of fish that pass directly through transition pool areas. Experimental results at Lower Granite Dam (Naughton and Peery 2003) indicate that these types of transition pool weir modifications can reduce transition pool fallout and lower dam passage times. Other fishway modifications, such as fishway fences, have reduced fishway exit rates at Snake River dams (Bjornn et al. 1999) and could be considered for John Day Dam. The steep thermal gradients that occasionally exist within the John Day fishways may act as a barrier or deterrent to adult migrants (Dalen et al. 1999; Keefer et al. 2003b). Providing cooler water in the fishway, from the tailrace or other sources, may alleviate some passage delay during warm periods.

Closure of orifice gates at John Day Dam may also lower fishway exit rates. Earlier studies of orifice gate closures at Priest Rapids and Wanapum dams (Bjornn et al. 1997; Peery et al. 1998) were equivocal in terms of adult passage. Currently, analyses of the effects of orifice gate closure tests at Bonneville Dam are underway. At John Day Dam, more explicit experimental testing of orifice gate closures is recommended before this strategy is permanently employed to reduce fishway fallout.

Fishway Use: Telemetry coverage at John Day Dam in all study years was less complete than at other Lower Columbia River dams in this study (see Keefer et al. 2003a). Therefore, interpretation of fish approach and entry behavior at fishway entrances, movements in collection channels and ladders and fine-scale movements in transition pools were limited by the location and number of antennas. We don't believe the limitations detract from the major conclusions of this report, but some behaviors such as use of orifice gates, ladder backdown, and exact locations for fish turn-around in fishways could not be monitored.

Fish from all runs approached fishway entrances multiple times. Average numbers of approaches were 15 to 26 for spring–summer Chinook salmon and 9 to 19 times for steelhead. Sockeye approached less frequently (mean = 5 times). The high numbers of approaches may have indicated that some fish had difficulty locating or entering fishways. Alternately, the high numbers of approaches may have been a function of high fishway exit rates at the dam, as fish that exited had to re-approach and re-enter fishways. In some cases this behavior was repeated multiple times. At The Dalles Dam, some spring–summer Chinook salmon took a long time to pass from first fishway approach to first fishway entry (Keefer et al. 2007) and the longest passage times through this segment occurred during high flow and spill conditions, particularly in the high-flow year 1997. The same was true at John Day Dam. However, fish from all runs were recorded approaching fishways at John Day Dam more often in 2000 and 2001 than in the high-flow 1997, probably reflecting higher fishway exit rates in later years.

In general, fish from all runs were more likely to approach at the South Ladder Entrance (SLE) under most conditions. Use of the North Ladder Entrance (NLE) increased when spill was occurring, probably because spill provided attractive flow to that fishway. Not surprisingly, fish were most likely to approach at the NLE in 1997, the study year with the highest Columbia River discharge, and least likely to approach there in low-flow 2001. Steelhead, which passed mostly after spill had stopped, strongly favored the SLE, while sockeye salmon approached the NLE and SLE about equally.

On average, adult fish entered fishways between 4 and 9 times (3 times for sockeye salmon). The distributions of entrances used were similar to those for approach sites. The South Ladder Entrance (ELE) was favored by Chinook salmon and particularly steelhead, while sockeye salmon used the NLE more frequently. Sockeye salmon may orient toward the north shoreline because the majority of the run enters the mid-Columbia, which enters from the north at the Snake-Columbia River confluence. Fish from all runs tended to first enter a fishway at the site where they first approached, but preferred shoreline entrances as has been observed at other dams (Bjornn et al. 1998a; Keefer et al. 2003a). Use of the North Powerhouse Entrance (NPE) was more limited, though as many as 21% of spring–summer Chinook salmon first entered there.

Fishway exit percentages were very high at John Day Dam for all runs and years. Between 56 and 83% of spring–summer Chinook salmon, 67 to 85% of steelhead, and 70% of sockeye salmon exited a fishway into the tailrace at least once. Exit percentages tended to increase as migrations progressed each year for Chinook salmon, and may have been related to increasing temperatures. Exit percentages were highest for steelhead during summer months. The highest numbers of total exits were from the South Ladder Entrance (SLE) for all runs in all years, closely followed by the North Powerhouse Entrance (NPE). Many fish from all runs migrated upstream in the fishways to the transition pool areas before turning around and exiting fishways. Smaller proportions exited to the tailrace after entering ladders upstream from transition pools, and almost no fish backed down ladders after being recorded at top-of-ladder sites.

Under most operational conditions, radio-tagged fish were more likely to pass John Day Dam via the OR-shore fishway. This was especially true for steelhead, 61 to 82% of which passed the dam via this route. The OR-shore route preference was most likely related to flow patterns in the tailrace, the location of the Powerhouse near the OR-shore, and possibly inconsistent attraction flows to the WA-shore fishway associated with spillway operation. Attractive flow along the Oregon shoreline, particularly when spill was not occurring, appeared to guide fish to the Powerhouse and away from the spillway and WA-shore fishway. Increasing

spill volumes attracted increasing proportions of fish to the WA-shore fishway, though even during relatively high flow use was still mostly at the OR-shore fishway.

***Dam Conversion*:** In all years, some fish that approached or entered fishways at John Day Dam did not pass the dam. Percentages that did not pass ranged from 3 to 6% for all runs. Identifying fates of non-passing fish is of particular interest to managers who wish to partition the incidence of tributary overshoot and mainstem harvest from dam-related mortality. In this study, a mixture of fates was associated with non-passing fish. Harvest in downstream fisheries averaged 22% for spring–summer Chinook salmon and 34% for steelhead, and was 6% for sockeye salmon. On average, 20% of Chinook salmon and 24% of steelhead entered downstream tributaries. At a minimum, 40% of Chinook salmon, 31% of steelhead and 65% of sockeye salmon could not be accounted for and were presumed mortalities. These should be considered minimums because another 4 to 32% of the fish that did not pass John Day Dam had known or presumed regurgitated transmitters. It was likely that some of the latter category were also mortalities or unreported harvest. Causes for losses could not be identified.

***Fallback*:** The behaviors and passage times described here were for first passages of radio-tagged fish at John Day Dam only. Fallback rates at the dam were more than 10% in some years (Boggs et al. 2004) and majorities of fallback fish reascended fishways. At Bonneville Dam, fallback Chinook salmon passed more quickly on their second passage, with fewer fishway and transition pool entrances and exits (Keefer et al. 2003a). The behavior at Bonneville Dam may have been related to fallback routes (most fish fell back over the spillway and subsequently entered WA-shore fishway entrances), or to familiarity with passage routes. Most fallback at John Day Dam also occurs via the spillway, which would tend to favor second passages via the WA-shore fishway given its proximity to the spillway. Additional details on fallback at John Day dam are provided in Bjornn et al. 2000b.

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