Technical Report 2007-2

ADULT SALMON AND STEELHEAD PASSAGE THROUGH FISHWAYS AND TRANSITION POOLS AT THE DALLES DAM, 1997-2001

A 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 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 The Dalles 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 The Dalles 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 the dam 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 2.5 to 5.3 h (*medians*); median times to first enter a fishway were 2.5 h for sockeye salmon, 6.1 to 6.8 h for steelhead and 6.2 to 16.1 h for Chinook salmon. Median dam passage times, from first tailrace record to exit from the top of a ladder, were 7.9 h for sockeye salmon, 13.3 to 16.4 h for steelhead and 20.4 to 31.2 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 fishways more often (*median* = 4 to 6 times, *mean* = 6 to 8 times) than steelhead (*median* = 2 to 3 times, *mean* = 4 to 6 times) or sockeye salmon (*median* = 1 time, *mean* = 2 times). Fish from all species approached all fishway entrances. Chinook salmon and steelhead tended to first approach shoreline entrances, and Chinook salmon increasingly approached the North Ladder Entrance (NLE) as spill increased. Steelhead approached the NLE two to four times more frequently during periods of spill, and preferred the East Ladder Entrance (ELE) or South Spillway Entrance (SSE) during periods of no-spill. The majority of sockeye salmon first approached the NLE, followed by the ELE.

All species entered fishways a median of one time; means were 2 to 4 times for Chinook salmon, 2 to 3 times for steelhead, and 1.5 times for sockeye salmon. Chinook salmon and steelhead mostly entered the ELE at low spill levels, and increasingly entered the NLE and SSE as spill increased. Sockeye salmon mostly entered the NLE first, followed by the ELE.

In all years, 30 to 54% of the fish from all species exited a fishway into the tailrace. The percentage of Chinook salmon that exited increased as migrations progressed each year while exit rates for steelhead tended to be lower in fall than in summer months. Fish that exited fishways had significantly longer passage times than those that did not exit. An exit typically resulted in dam passage delays of 8 to 20 h 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 SSE, and were at the NLE and West Powerhouse Entrance (WPE) 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 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 61% of Chinook and sockeye salmon and > 85% of steelhead passed via the OR-shore.

Most fish of all species entered transition pools almost immediately after entering fishways. Median times to first enter a pool were < 3 min for all species in all years; medians were 0.3 to 2.3 h for fish that entered the OR-shore pool via the SSE or WPE entrances.

Fish behavior in transition pools fell 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. Fourteen to 21% of Chinook salmon, 22 to 49% of steelhead and 29% of sockeye salmon moved straight through, while 32 to 57% of Chinook and sockeye salmon and 22 to 32% of steelhead delayed. Two to 8% of all species exited to the OR-shore collection channel. Between 22 and 49% of Chinook salmon, 26 to 45% of steelhead and 24% 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, 0.4 to 2.1 h for fish that delayed, 2.0 to 5.2 h for fish that exited into the collection channel, and 8.4 to 23.4 h for fish that exited into the tailrace. Steelhead and sockeye salmon times tended to be lower than Chinook salmon times. Between 18 and 53% 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. Tailwater elevation was a secondary predictor of transition pool exit rates.

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. Dam passage times for Chinook salmon and steelhead that exited transition pools into the tailrace were 9 to 22 h longer than those for fish that did not exit; delays for sockeye salmon that exited were 5 to 9 h longer than fish that moved straight through or delayed in a pool.

Fish of all species ascended ladders relatively quickly throughout the migrations. Median times were 1.6 to 2.4 h, with sockeye salmon and steelhead ascending ladders slightly faster than Chinook salmon.

The fastest-migrating Chinook salmon passed the dam mostly during June and July, significantly later than those fish that passed the dam slowest. The longest Chinook salmon passage times occurred in spring 1997, coincident with the highest flow and spill levels recorded during the study. While flow and spill may affect dam passage times, water temperature and migration timing appeared to be more important factors for Chinook salmon. Environmental conditions and date of passage for the fastest- and slowest-migrating steelhead were similar, except in 2001 when the slowest-migrating fish tended to pass the dam in summer and faster fish passed in fall. Flow and spill were significantly lower for the fastest-passing sockeye salmon. Chinook and sockeye salmon—but not steelhead— that passed the dam fastest tended to first approach and first enter the dam at the NLE.

The fastest-migrating fish were far less likely to exit from fishways or transition pools into the tailrace. Significantly fewer of the fastest Chinook salmon exited fishways in all years except 1997, and significantly fewer exited from transition pools in all years. Among steelhead, 81 to 91% of the slowest fish exited fishways compared to 11 to 13% of the fastest fish. The proportions of the slowest steelhead that exited transition pools were 7 to 18 times higher than the proportions of the fastest fish. Just four percent of the fastest sockeye salmon exited either a fishway or transition pool, compared to 86% and 61% of the slowest fish, respectively.

Orifice gate entrances were open and unmonitored at the dam in 1997 and 1998 and closed in 2000 and 2001. We did not experimentally test for differences in fish behavior with gates open and closed, but made retrospective comparisons between years. Total dam passage times for Chinook salmon were longer in most months of 1997 than in 2000 and 2001, though in-river conditions (near record low flow in 2001, very high flow in 1997) may have affected passage times more than orifice gate closures. Chinook passage times in 1998 were longer

than in 2001 but not 2000. Conversely, steelhead dam passage times were significantly shorter in 1997 (gates open) than in 2000 or 2001; differences were inconsistent between individual months.

In each year, 3.6 to 8.9% of Chinook salmon, 2.5 to 3.4% of steelhead and 2.8% of sockeye salmon recorded at the dam did not pass. Pooling across years, 32% of Chinook salmon, 56% of steelhead and 79% of sockeye salmon that did not pass were recaptured in fisheries near the dam or downstream in the Bonneville pool. Twenty-five percent of Chinook salmon and 13% of steelhead that did not pass were last recorded in tributaries downstream from the dam; 33% of Chinook, 28% of steelhead and 21% of sockeye 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. Accurately monitoring movements at the dams of fish outfitted with transmitters was significantly enhanced with the development of digital spectrum processors (DSP), which, when combined with SRX radio receivers (SRX/DSP units), allowed simultaneous monitoring of all transmitter frequencies. SRX/DSP radio receivers were first used to monitor entrance use by steelhead at Lower Granite Dam in fall 1992 (Bjornn et al. 1994).

Monitoring of fishway entrance use and movements within fishways by adult salmon and steelhead at all four of the lower Snake River dams began in spring 1993 and continued through 1994. Antennas connected to SRX/DSP receivers were placed near entrances to fishways, within fishways, and at the top of the ladders at all four lower 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. (1995) and in Part III of Bjornn et al. (1998a). Fishway use behaviors by spring–summer Chinook salmon at Bonneville, McNary, Ice Harbor and Lower Granite dams were reported in Keefer et al. (2003a).

Objectives at The Dalles Dam in 1997, 1998, 2000, and 2001 included monitoring fishway entrance use, documenting fish movements in fishways and transition pools, and determining times fish required to enter fishways and pass the 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.

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 The Dalles 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 The Dalles Dam was a breakdown of the time fish required to pass the dam. Analytical emphasis was placed on determining passage times from the tailrace to first approach fishway entrances at the dam, to first recorded entry into a fishway, and total time to pass over the dam. Start times were the times fish were first recorded at tailrace receivers (3.2 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.

All fishway entrances were monitored at The Dalles Dam in 2000 and 2001 when orifice gate entrances were closed; in 1997 and 1998, orifice gates were open but not monitored

(Figure 1). As a result, we likely overestimated the time some fish took to first approach or enter a fishway entrance in 1997 and 1998 because some fish likely first approached or entered at unmonitored orifice gates. In all years, from 3 to 13% of adult salmon and steelhead with transmitters were recorded inside fishways before they were recorded approaching an antenna outside the fishway (except sockeye salmon = 20%). 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 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 7 to 22% of Chinook salmon and steelhead (sockeye salmon = 31%); percentages with unknown entrances were lower in 2000 and 2001 when orifice gates were closed. In the first two years, many unknown first entrances were likely via unmonitored orifice gates. In the majority of unknown first entrances in 2000 and 2001, entry locations were known but the exact time was uncertain. Fish with unknown approach or entrance times were excluded from passage time analyses, but were included in fishway use summaries if the entrance location was known.

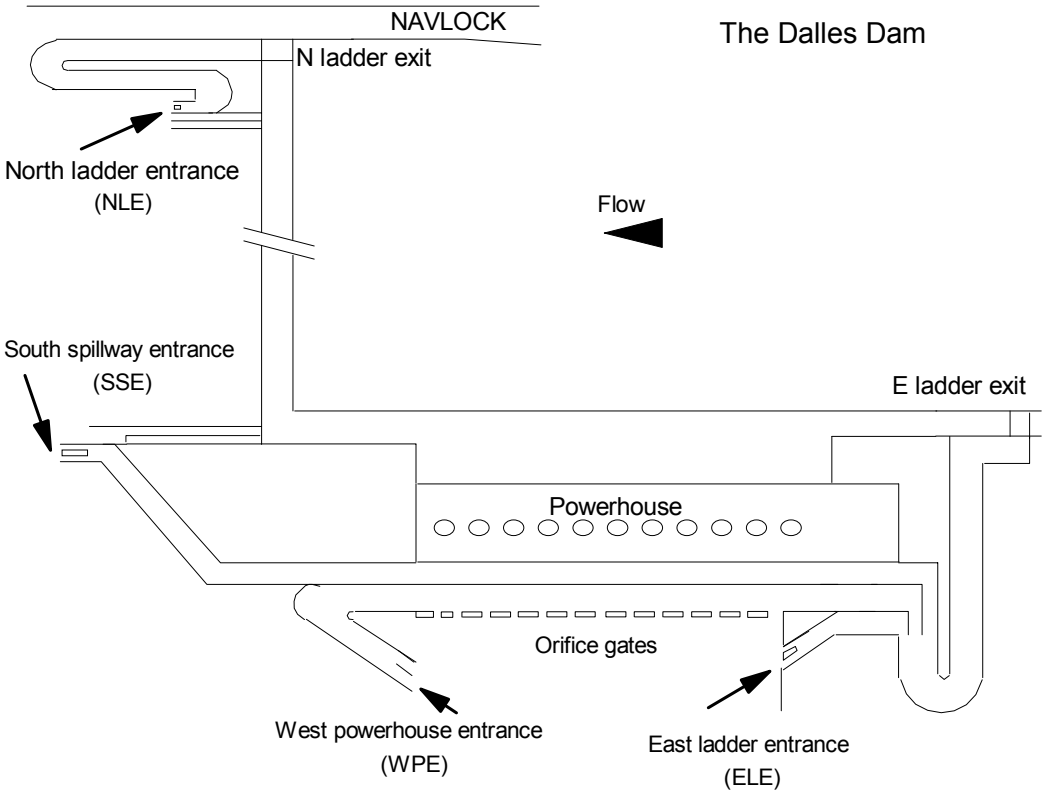

Figure 1. Locations of fishway entrances and ladders at The Dalles Dam.

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 91 and 97% of all fish recorded at The Dalles Dam eventually passed the dam. Between 57 and 70% of Chinook salmon in all years, 69% of steelhead in 2000, and 72% of steelhead in 2001 had known times

and locations at all passage points. In comparison, 27% of steelhead in 1997 and 48% of sockeye salmon in 1997 had known times and locations at all points (Table 1). The distribution of fish with unknown first tailrace, first approach and first fishway entry records are summarized in Figures 2, 3, and 4. The largest data loss occurred during September 1997, when the Washington-shore tailrace receiver was not scanning properly and many steelhead migrating along that shoreline were not detected. In addition, about 40% of steelhead released in 1997 had smaller, lower transmission 3-volt transmitters with lower detection rates than 7-volt tags. All sockeye salmon released in 1997 had the smaller, 3-volt transmitters, which may explain lower detection rates for sockeye at some sites. In 2001, 70 spring–summer Chinook salmon (7% of the fish recorded at the dam) 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 The Dalles 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	784	816	907	1,027	707	910	989	506
Known to pass dam	714	763	844	990	683	871	964	492
Percent known to pass dam	91%	93%	93%	96%	97%	96%	97%	97%
Recorded first tailrace passage	625	572	614	825	321	703	849	435
Recorded first fishway approach[1]	717	777	835	1,006	596	862	938	397
Recorded first fishway entrance[1]	567	676	772	990	455	823	881	341
Recorded first transition pool entry	690	760	834	980	662	876	969	451
Recorded transition pool exit	635	753	799	927	589	834	893	375
Recorded ladder exit	704	755	830	958	661	843	954	484
Recorded all passage points	408	450	496	685	181	600	697	234
Percent with all passage points[2]	57%	59%	59%	69%	27%	69%	72%	48%

[1] Some fish likely approached or entered at unmonitored sites prior to being recorded in 1997 and 1998
[2] Percent of all fish known to pass dam

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.

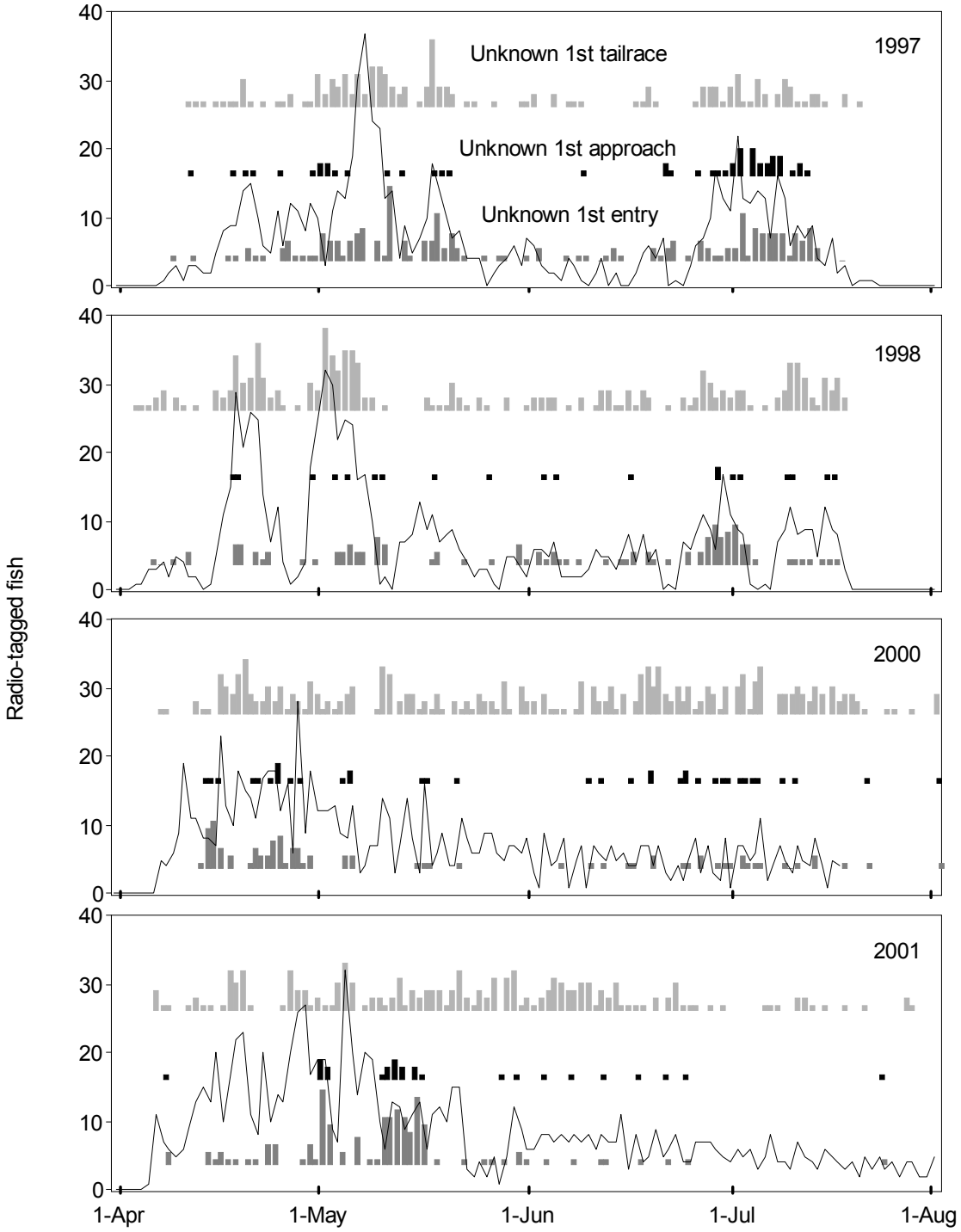

Figure 2. Distributions of first arrival by all radio-tagged spring–summer Chinook salmon at The Dalles Dam (lines), with dates of fish with unknown times in the tailrace, at first fishway approach and at first fishway entry (bars).

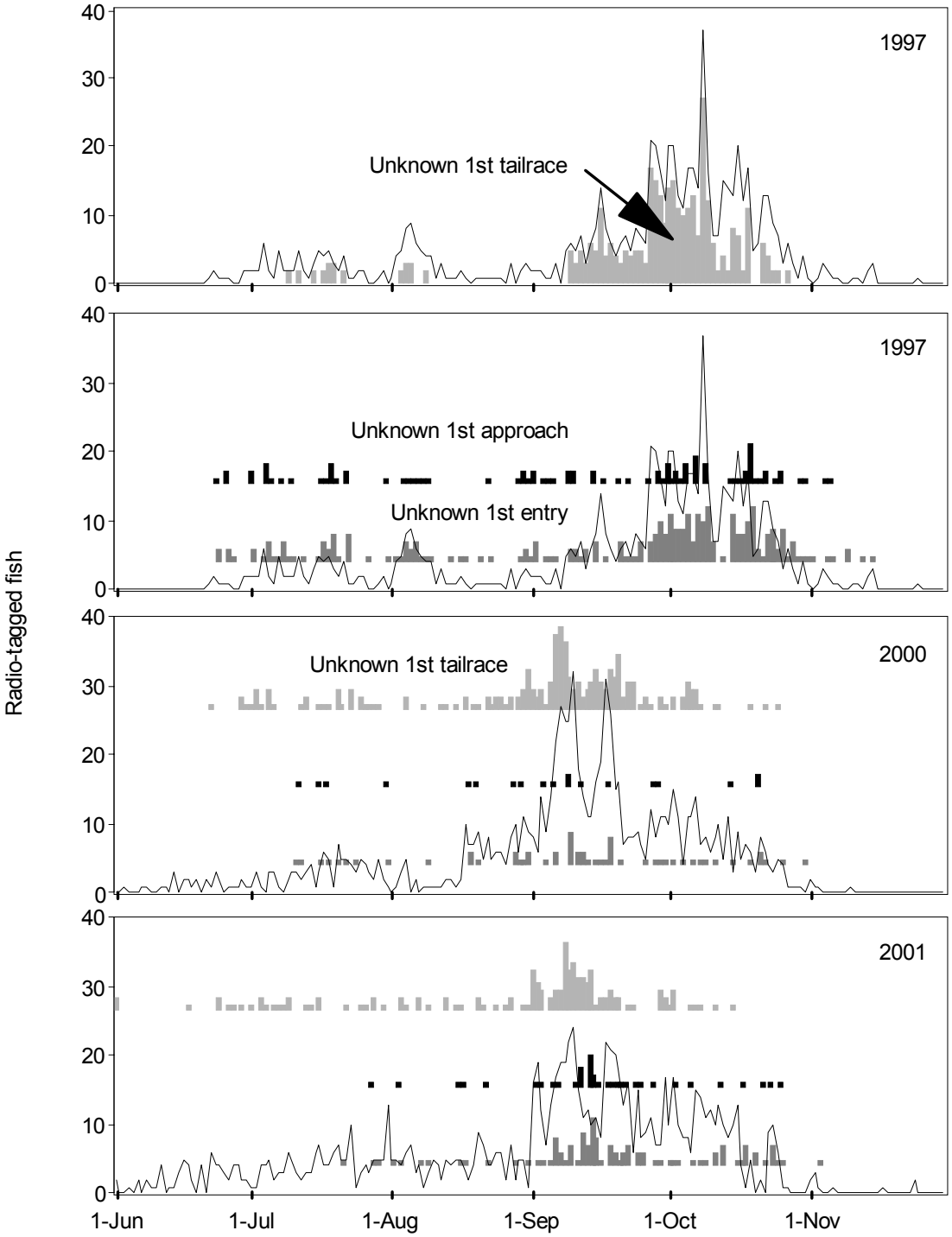

Figure 3. Distributions of first arrival by radio-tagged steelhead at The Dalles Dam (lines), with dates of fish with unknown times in the tailrace, at first fishway approach and at first fishway entry (bars).

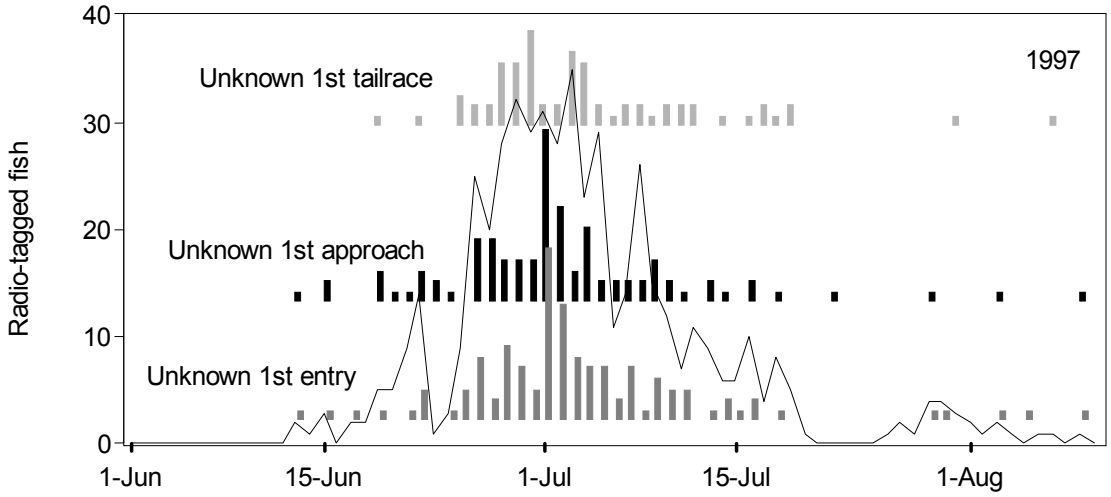

Figure 4. Distribution of first arrival by radio-tagged sockeye salmon at The Dalles Dam (line), with dates of fish with unknown times in the tailrace, at first fishway approach and at first fishway entry (bars).

Fishway Use

With the antenna/receiver setups at The Dalles 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. The Dalles Dam has two fishways, one for the north ladder adjacent to the Washington shore and one that leads to the east ladder adjacent to the Oregon shore. Fish can enter the east ladder via four routes: from the entrance at the south end of the spillway, from the entrance at the west end of the powerhouse, from orifice gates along the face of the powerhouse (closed during 2000 and 2001), or from the east ladder entrance at the base of the east ladder (Figure 1).

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 from 1997, 1998 and 2000 were coded once, checked, and then double-checked in the context of each fishes' entire migration. The 2001 data were coded and checked once, but had not yet received a final check in the context of the entire migration. Although technically incomplete, we believe errors in the 2001 data were minor and did not affect results or conclusions.

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 Washington-shore fishway, the transition pool extended from just inside the fishway entrance upstream to the first unsubmerged weir in the ladder (Figure 5). In the Oregon-shore fishways, the transition pool extended from the upper end of the powerhouse collection channels upstream to the first unsubmerged weirs (Figure 5). 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.

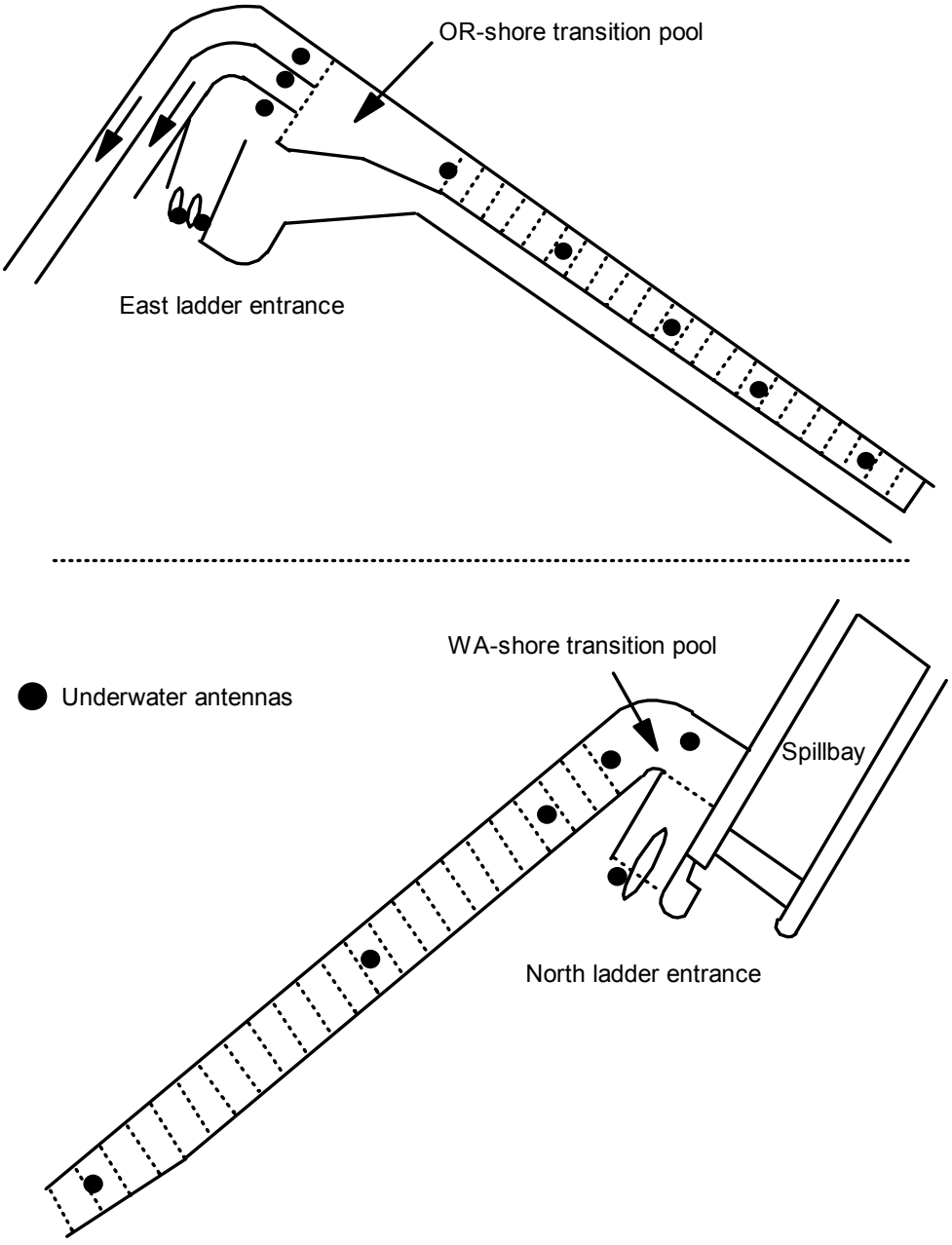

Figure 5. Location of underwater antennas in relation to fishway entrances (NLE and ELE) and OR- and WA- shore transition pools at The Dalles Dam.

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 Oregon-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 in 1997 and 1998.)

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

Environmental Conditions

Flow and spill at The Dalles 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 > 500 kcfs and peak spill was > 350 kcfs; in comparison, peak flows were ~ 425 kcfs briefly in 1998, < 400 kcfs in 2000 and < 200 kcfs in 2001 (Figure 6). In all years except 2001, spill was continuous from early to mid-April through 1 September. Spill was limited in 2001 to two periods, one from mid-May to mid-June and another from late July to 1 September. Peak temperatures at the dam were between 20 and 24° C in all years, with the highest levels in 1998; temperatures were typically lower throughout the migrations in 1997 and 2000 than in 1998 and 2001 (Figure 7). 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 7).

Results

Passage Times

Chinook salmon:

Median times for all spring–summer Chinook salmon to pass from the tailrace receiver (3.2 km downstream from The Dalles Dam) to their first recorded approach at a fishway entrance ranged from 3.5 to 5.3 h in the four study years (Table 2). At least 75% first approached a fishway entrance in < 12 h each year, and most fish first approached in < 8 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, 4% 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 6.2 h in 2001, the year with the lowest flow and spill, to 16.1 h in 1997 (Table 2). One to 3% took > 5 d to first enter a fishway in the latter three years, and 18% took > 5 d in 1997. The percentages that took more than 3 d to first enter were 24% (1997), 6% (1998), 8% (2000) and 1% (2001).

Median times from first fishway approach to first fishway entry ranged from 1.3 h in 2001 to 3.2 h in 1997 (Table 2). Time to first enter after first approach was quite variable: 25% of the fish entered a fishway within 0.3 h (18 min) of first approaching in all years, while 25% took more than 15 h in 1998 and 2000 and 25% took more than 43 h in 1997.

Median times from first tailrace record to exit from the top of a ladder were 31.2 h in 1997, 23.9 h in 1998, 22.3 h in 2000, and 20.4 h in 2001 (Table 2). In each year, about 12% of the fish passed the dam in < 12 h. Six to 30% passed in > 3 d and 2 to 26% passed in > 5 d. As with time salmon took to first approach and first enter a fishway, the proportions that passed the dam in > 3 and > 5 d were highest in 1997 and lowest in 2001 (Table 2).

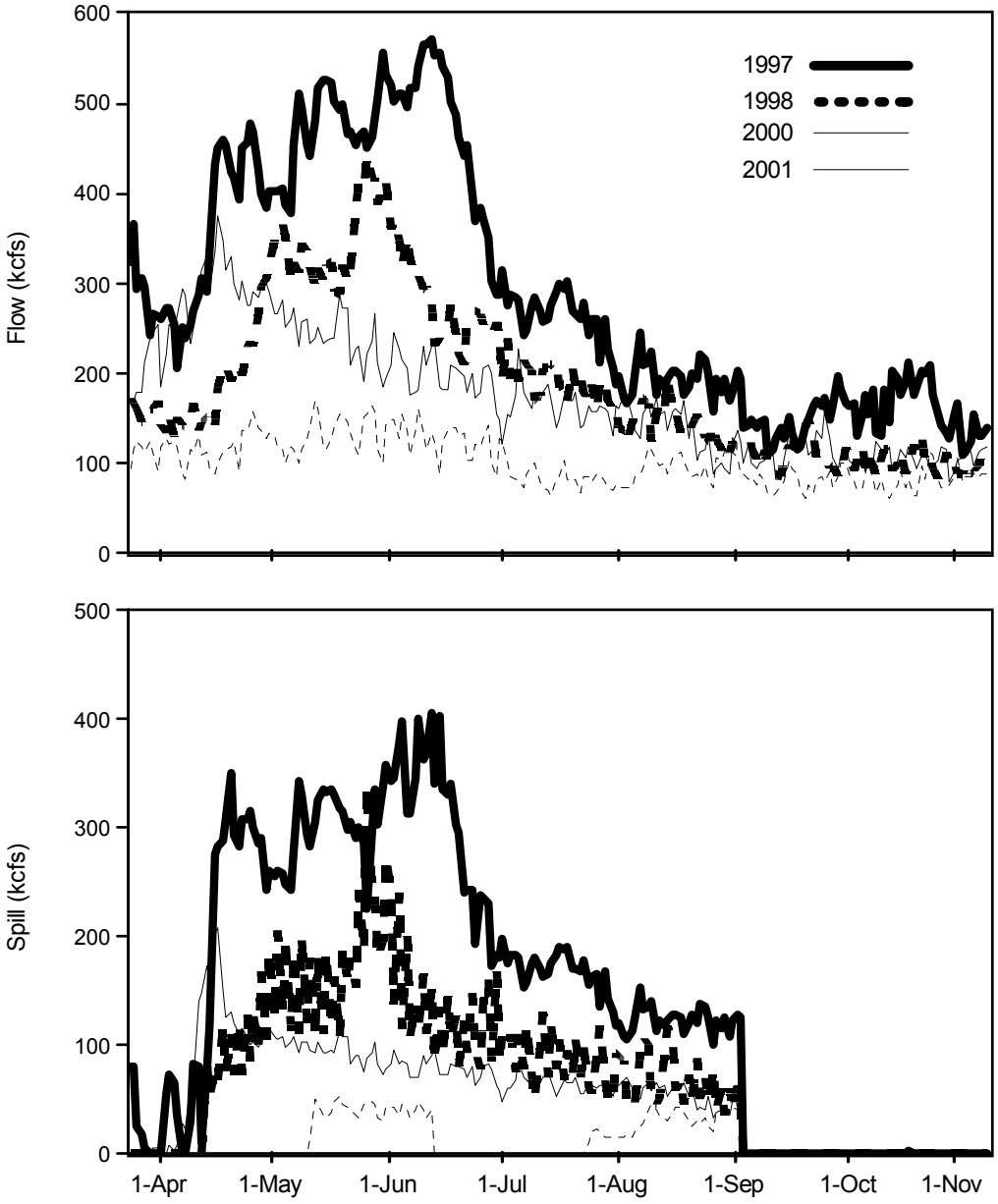

Figure 6. Mean daily flow and spill (kcfs) at The Dalles Dam in 1997, 1998, 2000, and 2001.

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 migrating up and down powerhouse collection channels, exiting and reentering fishways

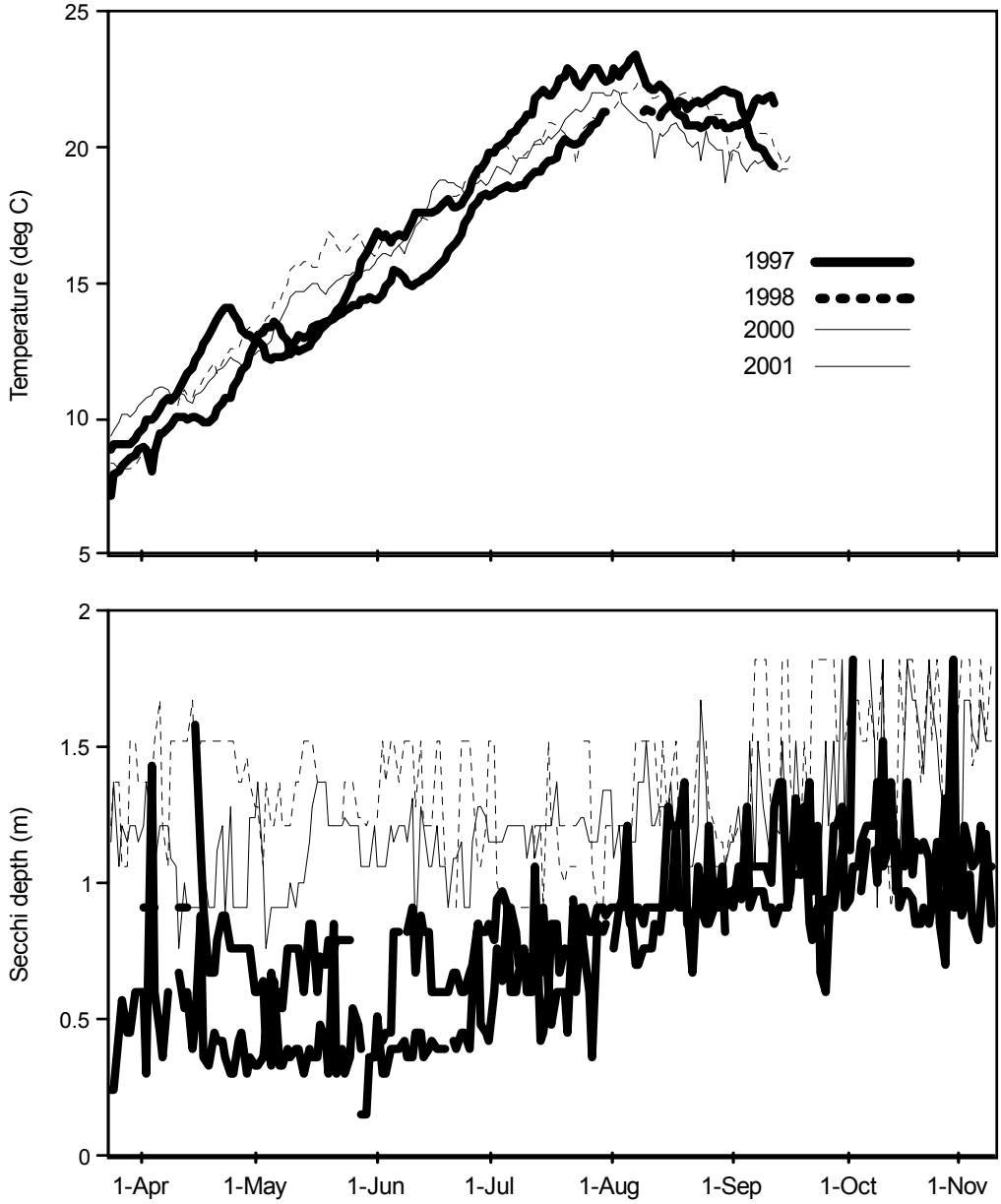

Figure 7. Mean daily water temperature (ºC) and Secchi disk visibility (m) at The Dalles Dam in 1997, 1998, 2000, and 2001.

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 decreased each month from April through July, except in 2001 when times increased slightly between June and July (Table 3). Median times to pass the dam decreased from 5 to 45 h (20 to 53%) from April to May in the four years, with the largest decreases in 1997 (45.1 h) and 1998 (25.1 h). Between May and June, median times to pass the dam decreased 5 to 35 h (23 to 66%) in 1997, 2000 and 2001 and about 2 h (8%) in 1998. Between June and July, time to pass the

Table 2. 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 The Dalles 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	572	543	562	788	266	668	809	337
1st Quartile (h)	2.8	2.1	3.2	2.5	2.6	3.1	2.7	1.3
Median (h)	**5.3**	**3.5**	**4.8**	**3.5**	**4.3**	**4.2**	**4.0**	**2.5**
3rd Quartile (h)	11.6	8.2	9.1	6.3	8.2	7.3	7.3	5.3
Percent > 5 d	2%	<1%	<1%	<1%	<1%	<1%	<1%	0%
Percent > 3 d	4%	<1%	<1%	<1%	<1%	<1%	<1%	0%
First tailrace to first entry								
N	455	465	522	712	202	636	764	290
1st Quartile (h)	4.4	3.4	5.4	3.5	4.1	4.5	3.9	1.3
Median (h)	**16.1**	**10.5**	**11.7**	**6.2**	**6.8**	**6.3**	**6.1**	**2.5**
3rd Quartile (h)	67.4	24.5	28.2	14.8	13.2	11.6	11.9	5.5
Percent > 5 d	18%	2%	3%	1%	1%	<1%	<1%	0%
Percent > 3 d	24%	6%	8%	1%	1%	<1%	<1%	0%
First tailrace to pass dam								
N	555	530	559	782	302	657	818	417
1st Quartile (h)	13.3	11.1	11.5	11.6	8.9	9.4	10.2	4.6
Median (h)	**31.2**	**23.9**	**22.3**	**20.4**	**13.3**	**15.9**	**16.4**	**7.9**
3rd Quartile (h)	91.2	47.6	44.5	29.3	21.6	25.0	24.5	15.1
Percent > 5 d	26%	5%	4%	2%	2%	2%	2%	<1%
Percent > 3 d	30%	12%	13%	6%	4%	5%	5%	<1%
First approach to first entry								
N	561	676	771	877	455	823	881	341
1st Quartile (h)	0.2	0.2	0.3	0.2	0.0	0.1	0.1	0.0
Median (h)	**3.2**	**2.7**	**2.6**	**1.3**	**0.6**	**0.8**	**0.7**	**0.0**
3rd Quartile (h)	43.6	18.0	15.8	5.7	2.5	3.4	3.3	0.1
Percent > 5 d	14%	2%	2%	<1%	1%	<1%	<1%	0%
Percent > 3 d	18%	4%	4%	1%	1%	<1%	<1%	0%

dam decreased about 6 h (30%) in 1997 and 1998, increased about 2 h (20%) in 2000 and decreased 0.5 h (3%) in 2001 (Table 3). Median dam passage times in July were 10 to 86 h shorter than in April.

Passage times from first tailrace to first fishway approach, first fishway entrance and to pass the dam were significantly longer in April than in May, June or July in all years ($P < 0.005$, K-W χ^2 tests) (Table 3). Passage times for all segments in May were significantly longer than in June and July in 1997, 2000 and 2001 ($P < 0.05$). In 1998, time to first fishway entrance and to pass the dam were longer in May than in July ($P < 0.005$), but differences between May and June were not significant ($P > 0.30$). Times to first fishway entrance and to pass the dam in June were significantly longer ($P < 0.005$) than in July in 1997 and 1998; time to first fishway approach was longer ($P < 0.002$) in June than in July 1997, but not in 1998 ($P = 0.09$).

Table 3. Number of adult radio-tagged spring–summer Chinook salmon and median times to pass from first tailrace record to first fishway approach, to first fishway entrance, and to pass The Dalles Dam, and from first fishway approach to first fishway entry 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	125	**11.6**	147	**5.2**	199	**7.1**	295	**4.2**
May	242	**6.2**	229	**3.1**	210	**4.3**	238	**3.7**
June	87	**3.6**	100	**3.7**	96	**3.4**	136	**2.8**
July	118	**2.6**	67	**2.5**	54	**3.2**	114	**2.7**
First tailrace to first entry								
April	101	**71.1**	132	**20.0**	172	**22.8**	271	**13.8**
May	186	**33.8**	203	**10.1**	200	**12.1**	186	**6.8**
June	68	**5.5**	72	**8.8**	94	**5.2**	136	**4.1**
July	100	**3.1**	58	**4.1**	53	**5.3**	114	**3.6**
First tailrace to pass dam								
April	118	**98.2**	141	**47.1**	198	**34.1**	290	**24.7**
May	221	**53.1**	222	**22.0**	205	**22.3**	238	**19.7**
June	83	**18.1**	98	**20.3**	96	**12.8**	138	**15.1**
July	133	**12.7**	69	**14.3**	55	**15.2**	111	**14.6**
First approach to first entry								
April	101	**41.2**	133	**8.6**	172	**11.4**	271	**4.1**
May	186	**21.0**	203	**3.6**	200	**5.6**	186	**1.6**
June	68	**0.5**	72	**0.2**	94	**0.5**	136	**0.2**
July	99	**0.2**	58	**0.0**	53	**0.4**	114	**0.3**

Differences in passage times for all segments in June and July in 2000 and 2001 were non-significant ($P > 0.20$).

Median times from first fishway approach to first fishway entry followed similar patterns: times were significantly longer in April and May than in later months (Table 3).

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 when fish passed the tailrace had r^2 values < 0.08 when we included all fish in each year/month separately. Results were similar when we only included fish that passed the dam in < 5 or < 3 d.

Behavior by spring–summer Chinook salmon in fishways explained much of the variability in passage times at the dam compared to flow and spill rates. 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 4.0 to 4.3 h (Table 2). At least 75% first approached within 9 h, and most fish first approached in < 8 h. Less than 1% took more than 3 d to first approach. Median times to first enter a fishway ranged from 6.1 to 6.8 h (Table 2). At

least 75% first entered within 14 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 13.3 h in 1997, 15.9 h in 2000, and 16.4 h in 2001 (Table 2). In each year, about a quarter of the steelhead passed the dam in < 10 h and another quarter passed in > 21 h. About 2% passed in > 5 d and 4 to 5% passed in > 3 d (Table 2).

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 2).

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) (Table 4). Steelhead first approached a fishway more quickly in September than in October or November in 2000 ($P < 0.05$), and first approached more slowly in June than September ($P = 0.04$) in 2001. No between-month differences were significant in 1997. We found more significant differences in median times from first tailrace to first fishway entrance (Table 4). Median time to first enter a fishway was 1.7 to 4.2 h shorter in August than in July, September or October in 1997 ($P < 0.04$). In 2000, median time to first entry was 1.5 to 3.2 h shorter in June than in August, September and October ($P < 0.05$). In 2001, median time to first entry was shorter in September than in July ($P = 0.04$) or October ($P = 0.02$).

Median time to pass the dam, from first tailrace record, was longer in October than in September in 1997 ($P = 0.01$) (Table 4). In 2000, median dam passage time was longer in August than in June ($P = 0.05$). In 2001, dam passage times generally decreased through the migration: median June passage times were significantly longer than in September and October ($P < 0.03$), July times were longer than in September and October ($P < 0.001$), and August times were longer than September and October times ($P < 0.03$).

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 The Dalles Dam were 2.5 h, and > 75% first approached and entered within 5.5 h after first passing the tailrace receiver (Table 2). No sockeye salmon took > 3 d to first approach or first enter a fishway. Median time between first fishway approach and first fishway entry was < 6 min (0.1 h) for almost all fish. Median passage time from the tailrace over the dam was 7.9 h; 25% passed in < 4.6 h and 25% passed in > 15.1 h. Less than 1% took more than 3 d to pass over the dam (Table 2).

About 35% of sockeye salmon first approached and entered fishways and passed the dam in June, compared to ~63% in July and ~2% in August (Table 4). Differences in June and July median times to first approach and first entry were < 0.4 h (25 minutes). Sockeye passed the

Table 4. Number of adult radio-tagged steelhead and sockeye salmon and median times to pass from first tailrace record to first fishway approach, to first fishway entrance, and to pass The Dalles 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	5	**2.4**	20	**4.2**	56	**4.2**	120	**2.4**
July	41	**4.4**	58	**4.3**	115	**4.4**	211	**2.7**
August	30	**3.7**	101	**4.1**	113	**4.0**	6	**3.5**
September	82	**4.4**	314	**3.9**	319	**3.8**		
October	105	**4.5**	170	**4.8**	196	**4.0**		
November	3	**14.9**	5	**8.6**	10	**4.7**		
First tailrace to first entry								
June	2	**13.5**	20	**4.7**	55	**6.3**	104	**2.4**
July	27	**8.5**	55	**6.2**	112	**7.0**	181	**2.7**
August	27	**4.3**	97	**7.9**	108	**6.3**	5	**3.5**
September	64	**6.0**	298	**6.5**	298	**5.4**		
October	79	**7.4**	161	**6.1**	182	**6.2**		
November	3	**15.4**	5	**11.3**	9	**7.6**		
First tailrace to pass dam								
June	7	**11.5**	16	**11.1**	52	**19.2**	152	**9.3**
July	49	**14.1**	56	**16.1**	112	**21.3**	258	**7.3**
August	40	**13.7**	100	**17.3**	113	**17.6**	7	**7.7**
September	88	**11.0**	308	**15.3**	327	**15.2**		
October	115	**14.7**	172	**16.5**	203	**15.1**		
November	3	**17.4**	5	**23.3**	10	**12.8**		

dam more rapidly in July (*median* = 7.3 h) than in June (*median* = 9.3 h), a difference that approached significance ($P = 0.08$, K-W χ^2 test). Individual sockeye salmon passage times were very weakly correlated with spill at the dam, with longer passage times during high spill ($r^2 < 0.05$ for all fish, and for June and July fish separately).

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 four major fishway entrances at The Dalles Dam: the north ladder entrance (NLE), the south spillway entrance (SSE), the west powerhouse entrance (WPE) and the east ladder entrance (ELE). The NLE was the only entrance into the Washington-shore fishway, while the SSE, WPE and ELE were part of the Oregon-shore fishway (Figure 1). Orifice gate entrances were not monitored in any year, but fish could enter them undetected in 1997 and 1998; orifice gate entrances were closed in 2000 and 2001. The NLE had one and the SSE had two open entrances, each about 4.6 m wide. The WPE and ELE each had two open entrances about 2.6

m wide. Approximate discharges under most tailwater conditions were 800 cfs at the NLE and 1,600 to 2,000 cfs at the SSE, WPE and ELE (USACE, personal communication).

Between 766 and 1,007 Chinook salmon were known to have approached fishways each year, 724 to 990 were known to have entered fishways, and 245 to 508 exited fishways (Table 5). In each year, 95 to 98% of fish that approached fishways subsequently entered and 34 to 51% of the fish that entered eventually exited into the tailrace. Salmon approached fishways a median of 4 to 6 times (*means* = 6.1 to 8.1 times), entered a median of 1 time in the first three years and 2 times in 2001 (*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* = 2.4 to 3.1). The median numbers of exits for all fish that entered a fishway were 0 in the first three years and 1 in 2001 (*means* = 0.8 to 1.6 exits/fish that entered). Mean and median numbers of exits for all fish that exited were higher (Table 5) than for all fish that entered fishways. Because orifice gate entrances were closed in 2000 and 2001, entrance use summaries for those years have the lowest error rate. In 1997 and 1998, some fish approached, entered and exited through orifice gates undetected, and so behavior summaries in these years were less precise.

Table 5. Number of radio-tagged spring–summer Chinook salmon that approached, entered and exited fishway entrances at The Dalles Dam, and the median (Med) and mean (Avg) 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	766	4	6.6	797	5	7.6	872	6	8.1	1,007	4	6.1
Entered	724	1	1.8	781	1	4.2	852	1	1.9	990	2	2.6
Exited	245	1	2.5	362	2	2.4	298	2	2.7	508	2	3.1
Percentage of those that approached that subsequently entered												
	94.5%			98.0%			97.7%			98.3%		
Percentage of those that entered that subsequently exited												
	33.8%			46.4%			35.0%			51.3%		

Approaches to fishways - Chinook salmon first approached fishways at The Dalles Dam at all monitored entrances (Table 6). About a third of the fish first approached at the NLE in 1997 and 1998, compared to 23% in 2000 and 16% in 2001. Spillway discharge provides attraction flow along the Washington shoreline and to NLE, and Chinook salmon first approached NLE less frequently during periods of no spill. In 1998, 75 fish first approached on days with zero spill and 19% of those first approached the NLE. In comparison, 33% of 710 fish first approached the NLE on days with spill, a significantly higher percentage ($P = 0.01$, Z test). In 2001, 9.5% of 741 fish first approached the NLE on days with zero spill, compared to 34% of 275 fish that first approached on days with spill ($P < 0.0001$). Fewer than 10 fish first approached on days with zero spill in 1997 and 2000.

Between 13 and 16% of tagged salmon first approached at the SSE in the first three years, as did 26% in 2001 (Table 6). Between 28 and 30% first approached SSE on days with no spill in both 1998 and 2001, significantly higher than the 12 to 16% that approached there on days with spill ($P < 0.0001$).

Table 6. Location of first and total[1] approaches to fishway entrances by radio-tagged spring–summer Chinook salmon at The Dalles 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	254	**33.2**	249	**31.2**	201	**23.1**	163	**16.2**
South Spillway Entrance	125	**16.3**	103	**12.9**	137	**15.7**	263	**26.1**
West PH Entrance	204	**26.6**	211	**26.5**	140	**16.1**	204	**20.3**
East Ladder Entrance	143	**18.7**	222	**27.9**	392	**50.0**	375	**37.3**
Unknown	41	**5.2**	12	**1.5**	2	**0.2**	1	**0.1**
Total	767		797		872		1,006	
Total approaches								
North Ladder Entrance	809	**15.9**	904	**14.9**	660	**9.4**	665	**10.8**
South Spillway Entrance	936	**18.4**	873	**14.4**	1,186	**16.9**	1,287	**20.8**
West PH Entrance	1,924	**37.8**	2,257	**37.1**	2,292	**32.6**	1,693	**27.4**
East Ladder Entrance	1,173	**23.0**	1,862	**30.6**	2,875	**40.9**	2,531	**40.9**
Unknown	251	**4.9**	182	**3.0**	8	**0.1**	5	**0.1**
Total	5,093		6,078		7,021		6,181	

[1] Totals differ from Table 5 because includes unknown approaches

About 27% first approached at the WPE in 1997 and 1998, and 16 to 20% first approached there in 2000 and 2001 (Table 6). Differences in proportions on days with and without spill in 1998 and 2000 were not significant ($P > 0.45$).

The percentages that first approached at the ELE were the most variable for all entrance sites (Table 6). Nineteen percent first approached at the ELE in 1997, 28% in 1998, 50% in 2000 and 37% in 2001. Differences in percentages on days with and without spill were not significant in 1998 ($P = 0.38$); a significantly higher percentage first approached the ELE on days with spill (39%) than on days without spill (31%) in 2001 ($P = 0.01$).

Site preferences for first fishway approaches varied with spill volume, but few strong patterns emerged across years. In 2001, 73% of first approaches were on days with zero spill: (39%) at the ELE, with 31% at SSE, and 21% at WPE (Table 7). When spill was between 1 and 49 kcfs in 2001, 35% first approached at the NLE and 31% approached at the ELE; only 11 fish first approached at spill between 50 and 99 kcfs. In 2000, the highest percentages (38 to 68%) of first approaches were at the ELE at all spill levels (Table 7). The second-highest proportions in 2000 tended to be at the NLE or SSE at low spill levels and at WPE at spill levels > 150 kcfs. In 2000, about 38% first approached at the ELE when spill was 50-100 kcfs and 51% first approached there when spill was 100-150 kcfs, a difference that was significant ($P = 0.0004$). About 29% first approached at the NLE when spill was 50-100 kcfs, compared to 19% when spill was 100-150 kcfs in 1998 ($P = 0.002$). In 1997, the highest proportions of first approaches were at the NLE or WPE at most spill levels. Relatively higher proportions first approached the SSE at intermediate spill levels and more fish first approached the ELE when spill was between 200 and 300 kcfs in 1997. In 1998, few patterns other than the tendency not to approach the NLE during zero spill were evident (Table 7). First approaches for all years were combined in Figure 8.

Table 7. Percentage of first and total approaches to fishway entrances by radio-tagged spring–summer Chinook salmon at The Dalles 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 excluded.

Chinook salmon - 1997										
		% of first approaches					% of total approaches			
Spill	N	NLE	SSE	WPE	ELE	N	NLE	SSE	WPE	ELE
0	7	**86**	14	0	0	48	23	**38**	**38**	2
1-49	14	**50**	29	21	0	35	29	**46**	26	0
50-99	29	31	**45**	21	3	100	28	**43**	24	5
100-149	8	25	25	**38**	13	33	21	30	**45**	3
150-199	173	**45**	10	27	19	726	**34**	17	27	22
200-249	100	**37**	22	16	25	624	16	26	**31**	27
250-299	199	26	22	**27**	26	1,570	13	21	**40**	26
300-349	170	**35**	11	27	18	1,537	12	13	**49**	26
>350	26	15	19	**54**	12	169	15	17	**49**	20
Chinook salmon - 1998										
0	75	19	28	**29**	24	52	9	10	**44**	37
1-49	-	-	-	-	-	-	-	-	-	-
50-99	272	**33**	14	28	25	261	19	15	**37**	30
100-149	253	32	9	25	**34**	262	14	13	**38**	36
150-199	142	**32**	11	29	29	217	15	18	**39**	28
200-249	32	**47**	13	19	22	58	18	21	**39**	22
250-299	5	20	20	**60**	0	12	13	31	**44**	13
300-349	6	**50**	17	17	17	11	21	29	**34**	16
Chinook salmon - 2000										
0	6	17	17	17	**50**	55	9	13	29	**49**
1-49	55	11	22	16	**51**	390	8	13	32	**48**
50-99	464	29	18	15	**38**	3,208	13	18	31	**38**
100-149	275	19	14	16	**51**	2,644	6	17	34	**43**
150-199	37	14	0	19	**68**	433	10	8	38	**44**
200-249	33	15	3	24	**58**	283	11	19	**35**	**35**
Chinook salmon - 2001										
0	741	9	31	21	**39**	4,581	9	23	27	**42**
1-49	264	**35**	16	19	31	1,501	16	16	29	**39**
50-99	11	**27**	**27**	18	**27**	84	12	17	**37**	35

Distributions of combined first and subsequent approaches at fishway entrances (total approaches) differed from those for first approaches (Table 6). The highest percentages of total fishway approaches were 38% at the WPE in 1997, 37% at the WPE in 1998, and 41% at the ELE in both 2000 and 2001. Between 14 and 21% of total approaches were at the SSE and 9 to 16% were at the NLE in all years.

In 1997, the highest percentages of total approaches were at the NLE or SSE when spill was < 100 kcfs and were at the WPE when spill was > 200 kcfs (Table 7). The percentage at the ELE increased from < 6% when spill was < 150 kcfs to between 22 and 27% when spill was >150 kcfs. In 1998, the highest percentages of all approaches were at the WPE at all spill levels; the second-highest proportions tended to be at the ELE when spill was < 200 kcfs and at the SSE when spill was > 200 kcfs (Table 7). In 2000 and 2001, the highest proportions of first approaches were at the ELE at almost all spill levels, with the second-highest proportions at the WPE. Proportions may have been higher at the ELE in 2000 and 2001 because with the orifice gates closed, more attractive flow was probably present along the Oregon-shoreline downstream from the ELE.

Mean daily spill during the time radio-tagged salmon were passing the dam in 2000 averaged 244 kcfs in 1997, 114 kcfs in 1998, 83 kcfs in 2000 and 12 kcfs in 2001; these between-year differences in spill encountered by fish also probably affected the distribution of fishway approaches with fish favoring the ELE when spill rates were lower.

When all approaches from all years were combined, spring–summer Chinook salmon tended to approach most often at the ELE at lower spill levels and at the WPE at higher spill levels (Figure 8).

Entries to fishways - Chinook salmon first entered fishways at The Dalles Dam at all monitored entrances (Table 8). Between 37 and 47% first entered at the NLE in 1997, 1998 and 2000, compared to 13% in 2001. In all years, 5 to 9% first entered at the WPE and 13 to 23% first entered at the SSE. The percentage that first entered at the ELE varied most between years: 13% in 1997, 20% in 1998, 40% in 2000 and 68% in 2001. In 1998, 53 fish first entered on days with zero spill and 42% of those first approached the ELE. In comparison, 20% of 637 fish first approached the ELE on days with spill, a significantly lower percentage ($P = 0.0004$, Z test). Percentages that first entered at the NLE, WPE and SSE increased when spill was occurring in 1998, but not significantly ($P > 0.05$). In 2001, 73% of 738 fish first entered the ELE on days with zero spill, compared to 54% of 250 fish that first entered on days with spill ($P < 0.0001$). Significantly higher percentages first entered the NLE ($P < 0.0001$) and the SSE ($P = 0.04$) on days with spill in 2001. Fewer than 10 fish first entered fishways on days with zero spill in 1997 and 2000.

In 1997 and 1998, when orifice gates were open but unmonitored, 12 to 19% of first and 15 to 22% of total entrances were at unknown sites and times; many of these entrances were likely via orifice gates. In comparison, < 2% of first and subsequent entrances were unknown in 2000 and 2001 (Table 8; also see Figure 2).

Site preferences for first fishway entrances varied with spill volume and between years (Table 9). In 1997 and 1998, the highest proportions of first entrances were at the NLE under almost all spill conditions; in those instances when the NLE did not have the highest percentages, the SSE had the highest first entrance use. In 2000, 40 to 75% of first entrances were at the ELE when spill was < 150 kcfs and 40 to 68% were at the NLE when spill was > 150 kcfs (Table 9). In 2001, when most fish first entered fishways on days with zero spill, the highest proportions entered the ELE at all spill levels. Few spring–summer Chinook salmon first entered the WPE under any spill conditions in all years. In each year, the proportions that first entered the SSE tended to be higher when spill was at intermediate or high levels. When we combined first entrances from all years, the proportion of first entrances was highest at

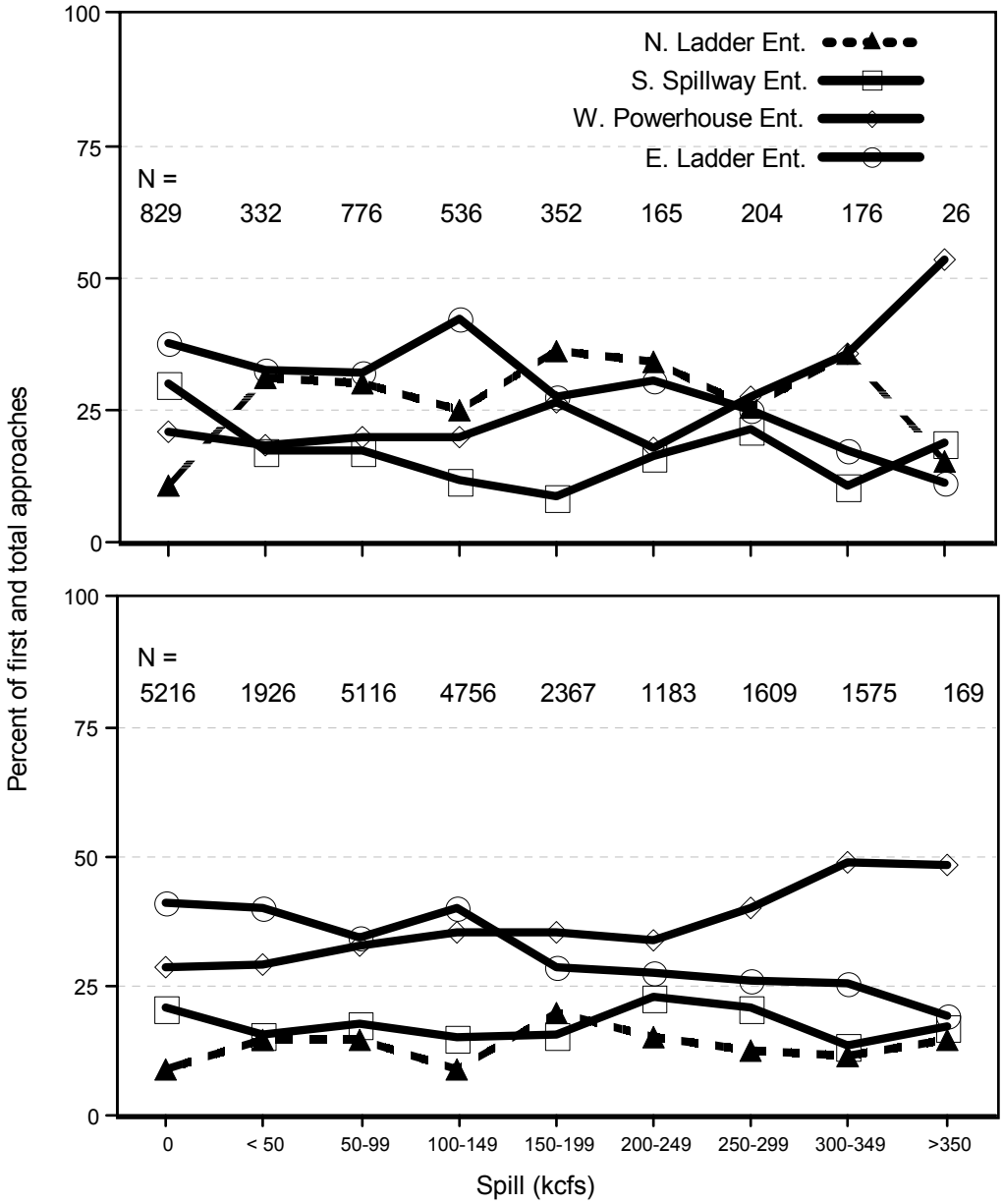

Figure 8. Percent of first (top panel) and total (bottom panel) fishway approaches at each site based on mean daily spill on the date spring–summer Chinook salmon approached; all years combined.

ELE at zero spill and decreased at that site as spill increased; the proportions at the NLE and SSE increased as spill increased (Figure 9).

The distributions of first and subsequent fishway entrances (total entrances) in relation to spill levels were very similar to those for first entrances (Table 9). When total entrances for all years were combined, the proportion of total entrances was highest at ELE at zero spill and decreased at that site as spill increased; the proportions at the NLE and SSE increased as spill increased, in patterns very similar to first entrance distributions (Figure 9).

Table 8. Location of first and total[1] fishway entrances by radio-tagged spring–summer Chinook salmon at The Dalles 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	280	**38.6**	370	**47.4**	304	**37.0**	128	**12.9**
South Spillway Entrance	166	**22.9**	100	**12.8**	127	**15.5**	131	**13.2**
West PH Entrance	47	**6.5**	68	**8.7**	46	**5.6**	54	**5.5**
East Ladder Entrance	94	**13.0**	152	**19.5**	330	**40.1**	675	**68.2**
Unknown	139	**19.2**	90	**11.5**	15	**1.8**	2	**0.2**
Total	725		780		822		990	
Total fishway entrances								
North Ladder Entrance	471	**36.0**	641	**39.3**	511	**31.0**	433	**17.0**
South Spillway Entrance	270	**20.6**	246	**15.1**	226	**13.7**	312	**12.3**
West PH Entrance	101	**7.7**	167	**10.2**	170	**10.3**	183	**7.2**
East Ladder Entrance	178	**13.6**	339	**20.8**	722	**43.9**	1,606	**63.2**
Unknown	289	**22.1**	238	**14.6**	17	**1.0**	6	**0.2**
Total	1,309		1,631		1,646		2,540	

[1] Totals differ from Table 5 because includes unknown entries

Exits from fishways – The highest percentages of first and subsequent fishway exits by spring–summer Chinook salmon were via the NLE entrance in 1997 and 1998 (31 to 40%) and were via the SSE in 2000 and 2001 (46 to 61%) (Table 10). Nine to 23% of first and subsequent exits were via the WPE and 9 to 22% were via the ELE in all years. In 1997 and 1998, when orifice gates were open but unmonitored, 8 to 18% of first exits and 7 to 15% of total exits were at unknown sites and times; many of these exits were likely via orifice gates. In comparison, < 1% of first and total exits in 2000 and 2001 had unknown sites and times (Table 10).

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 11). Relatively sparse telemetry coverage in some portions of fishways, particularly in the collection channel and in ladders upstream from transition pools, limited resolution in this analysis. Each year, 20 to 35% were recorded at antennas inside the SSE and WPE entrances and less than 5% were recorded inside the NLE (downstream from the first transition pool weir) before exiting to the tailrace. The largest percentages (47 to 59%) first turned around in the submerged-weir portions of transition pools each year, and another 12 to 24% were recorded at antennas just upstream from transition pools in the overflow-weirs at the bottom of ladders. 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 actually 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 telemetry records also indicated that many fish were further downstream.

Table 9. Percentage of first and total entrances to fishways by radio-tagged spring–summer Chinook salmon at The Dalles 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 excluded.

Chinook salmon - 1997										
		% of first entrances					% of total entrances			
Spill	N	NLE	SSE	WPE	ELE	N	NLE	SSE	WPE	ELE
0	5	**40**	**40**	20	0	6	**33**	**33**	**33**	0
1-49	8	**88**	13	0	0	8	**88**	13	0	0
50-99	25	**72**	16	0	12	28	**68**	21	0	11
100-149	3	**67**	33	0	0	3	**67**	33	0	0
150-199	154	**40**	21	13	25	421	**46**	20	13	21
200-249	96	**59**	24	7	9	118	**55**	25	9	12
250-299	154	**47**	41	3	9	188	**46**	39	3	12
300-349	126	**41**	25	12	21	220	**38**	28	13	21
>350	16	**44**	**44**	0	13	28	**43**	36	7	14
Chinook salmon - 1998										
0	53	**49**	6	4	42	87	**45**	6	5	**45**
1-49	-	-	-	-	-	-	-	-	-	-
50-99	224	**60**	16	11	13	511	**46**	19	12	24
100-149	236	**47**	12	11	30	464	**43**	16	15	26
150-199	130	**55**	19	8	18	245	**51**	20	11	18
200-249	36	**64**	11	6	19	68	**56**	18	7	19
250-299	7	43	**57**	0	0	8	38	**63**	0	0
300-349	4	**75**	0	25	0	10	30	**40**	20	10
Chinook salmon - 2000										
0	4	25	0	0	**75**	4	25	0	0	**75**
1-49	40	28	8	5	**60**	58	26	7	7	**60**
50-99	460	31	15	7	**47**	1,148	28	14	13	**45**
100-149	262	**40**	16	4	**40**	343	35	15	4	**46**
150-199	41	**68**	7	2	22	44	**71**	7	2	21
200-249	30	**60**	27	3	10	32	**59**	28	3	9
Chinook salmon - 2001										
0	738	9	13	5	**73**	1,780	15	12	6	**66**
1-49	243	25	13	8	**54**	723	21	12	9	**58**
50-99	7	0	29	14	**57**	23	13	17	4	**65**

Therefore, percentages reported first turning in transition pools (Table 11) should be considered minimums: maximum percentages that first turned around within the transition pools ranged from 60% in 1997 to 79% in 2001. Less than 1% moved to the top of ladders before turning around and exiting to the tailrace, except in 1998 when 4.7% were recorded at the top of the WA-shore ladder.

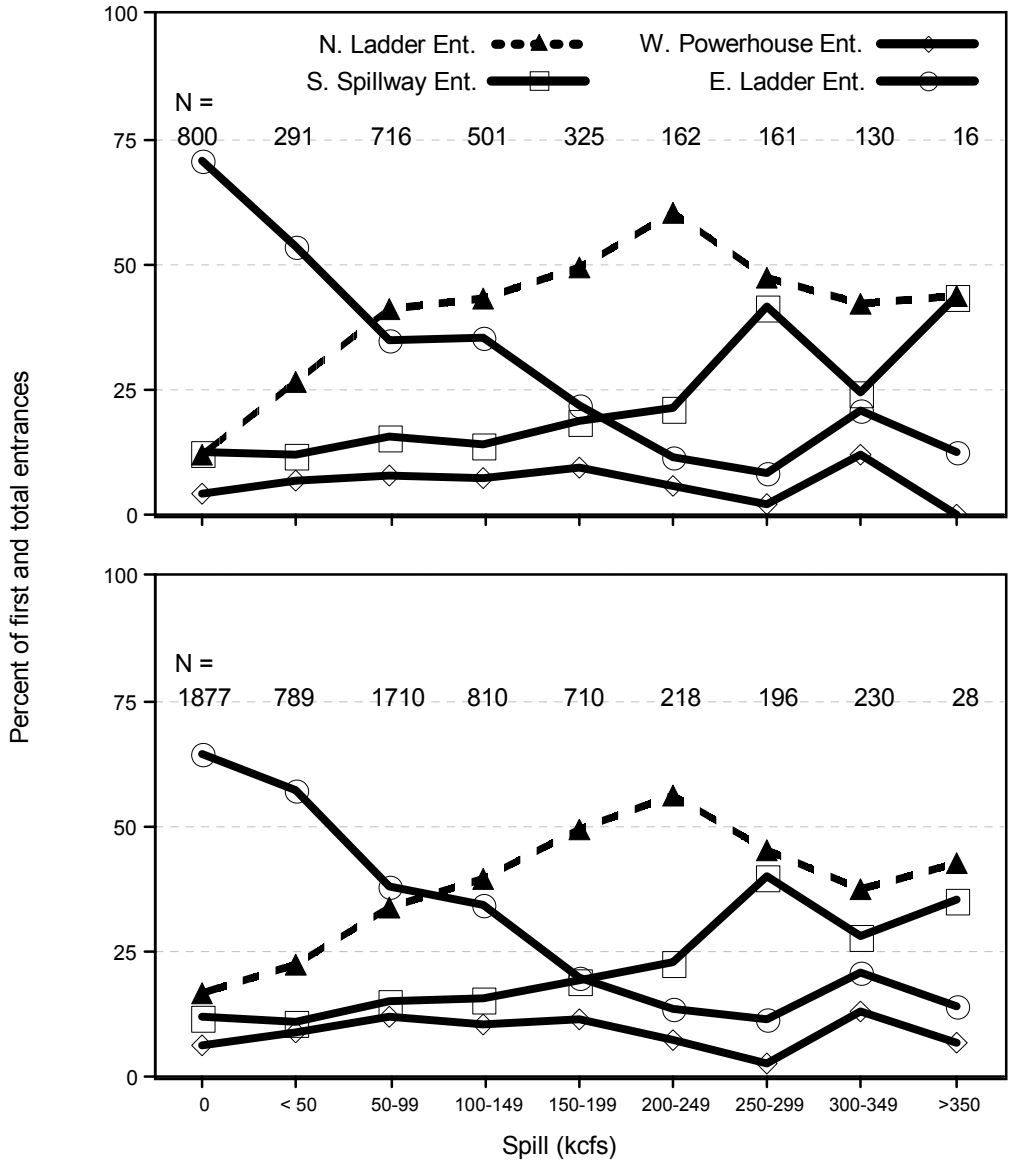

Figure 9. Percent of first (top panel) and total (bottom panel) fishway entrances at each site based on mean daily spill on the date spring–summer Chinook salmon entered; all years combined.

There appeared to be two basic turn-around behaviors for fish that first turned in transition pools. The first included fish that turned at or near the first submerged weir in the pool, and the second included fish that appeared to turn near the transition between the submerged-weirs of the pool and the overflow-weir portion of the lower ladders. With all spring–summer Chinook salmon included, percentages of fish that appeared to turn at or near the first WA-shore transition pool weir decreased steadily as tailwater elevation increased from > 90% at the lowest elevations to < 20% at the highest elevations. Percentages that first turned near the first OR-shore transition pool weir tended to increase (from ~40% to ~70%) until tailwater elevations were near 85 ft then decreased to ~30 to ~40% as levels rose further. Percentages that turned at the uppermost antenna in the submerged-weir portion of the pools increased as

Table 10. Location of first and total[1] fishway exits by radio-tagged spring–summer Chinook salmon at The Dalles 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	82	**33.5**	146	**40.3**	69	**23.2**	71	**14.0**
South Spillway Entrance	50	**20.4**	79	**21.8**	139	**46.6**	309	**60.8**
West PH Entrance	45	**18.4**	72	**20.0**	26	**8.7**	54	**10.6**
East Ladder Entrance	25	**10.2**	38	**10.5**	64	**21.5**	71	**14.0**
Unknown	43	**17.6**	27	**7.5**	0	**0.0**	3	**0.6**
Total	245		362		298		508	
Total fishway exits								
North Ladder Entrance	198	**32.8**	270	**31.1**	160	**19.8**	259	**16.4**
South Spillway Entrance	138	**22.9**	228	**26.3**	369	**45.7**	901	**57.2**
West PH Entrance	123	**20.4**	201	**23.2**	110	**13.6**	182	**11.6**
East Ladder Entrance	52	**8.6**	112	**12.9**	168	**20.8**	224	**14.2**
Unknown	92	**15.3**	56	**6.5**	1	**0.1**	9	**0.6**
Total	603		867		808		1,575	

[1]Totals differ from Table 5 because they include unknown exits

Table 11. Most upstream point reached in fishways before spring–summer Chinook salmon first exited into the tailrace.

	Chinook salmon							
	1997		1998		2000		2001	
Antenna location	N	**Percent**	N	**Percent**	N	**Percent**	N	**Percent**
Inside SSE	41	**16.7**	30	**8.3**	59	**19.8**	80	**15.7**
Inside WPE	45	**18.4**	63	**17.5**	15	**5.0**	23	**4.5**
OR transition pool	63	**25.7**	98	**27.1**	126	**42.3**	223	**43.9**
Above OR pool[1]	12	**4.9**	21	**5.8**	29	**9.7**	111	**21.9**
Top of OR ladder	--	**--**	--	**--**	--	**--**	--	**--**
Inside NLE	11	**4.5**	4	**1.1**	2	**0.7**	4	**0.8**
WA transition pool	52	**21.2**	105	**29.1**	51	**17.1**	56	**11.0**
Above WA pool[1]	19	**7.8**	23	**6.4**	14	**4.7**	11	**2.2**
Top of WA ladder	2	**0.1**	17	**4.7**	2	**0.7**	--	**--**
Total OR fishway	161	**65.7**	212	**58.7**	229	**76.8**	437	**86.0**
Total WA fishway	84	**34.3**	149	**41.3**	69	**23.2**	71	**14.0**

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

tailwater elevations increased. The strong tendency for fish to move further upstream in transition pools as tailwater elevations increased suggests that some fish turn around in response to unfavorable conditions near the submerged-overflow weir transition. Alternately, because the telemetry data is not accurate enough to identify fish location at the level of specific weirs, it is also possible that turns in this area may be a response to transition pool hydraulics (e.g., lack of attractive flow through orifices) or other confusing conditions within the upper several transition pool weirs just downstream from the transition into ladders.

Fishway entrance effectiveness - In each year some fishway entrances had more exits than entries for both first and total entries by spring–summer Chinook salmon (Table 12). In 1997 and 1998, the WPE was the least effective entrance for both first and total net entries, while the NLE was the most effective. The second most effective entrance was the SSE in 1997 and was the ELE in 1998. The relatively high proportion of unknown entrances and exits in 1997 and 1998 raises some uncertainty about the absolute values of net entry rates in those years. In 2000 and 2001, net entry rates were negative (more exits than entries) at the SSE for both first and total entries. In both years, the ELE was the most effective entrance and the NLE was second most effective (Table 12).

Table 12. Net first and total fishway entrances and exits by radio-tagged spring–summer Chinook salmon at The Dalles 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
North Ladder Entrance	198	273	224	371	235	351	57	174
South Spillway Entrance	116	132	21	18	**-12**	**-143**	**-178**	**-589**
West PH Entrance	2	**-22**	**-4**	**-34**	20	60	0	1
East Ladder Entrance	69	126	114	227	266	554	604	1,382
Unknown	95	197	63	182	15	16	**-1**	**-3**

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 WPE in 1997 and 1998, but between 3 and 4% of spring–summer Chinook salmon last used the WPE just prior to passing the dam (Table 13). Net entry rates were also negative at the SSE in 2000 and 2001, but between 8% and 10% used that entrance just prior to passing the dam in those years. Between 39 and 48% used the NLE as their last fishway entrance prior to passing the dam in 1997, 1998 and 2000; 18% used the NLE last in 2001, when spill was limited. Fifteen to 21% used the SSE last and 14 to 22% used the ELE last in 1997 and 1998 (Table 13). In 2000 and 2001, 42 and 71% used the ELE last. Based on eventual passage via the Oregon-shore ladder, another 22% of Chinook salmon in 1997 and 12% in 1998 likely used orifice gate entrances last or entered monitored Oregon-shore fishway entrances (SSE, WPE, ELE) undetected. Two percent or less last entered at unknown locations in 2000 and 2001 (Table 13).

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. In all years,

Table 13. Last fishway entrance used by radio-tagged spring–summer Chinook salmon at The Dalles 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**
North Ladder Entrance	277	**39.3**	364	**48.1**	349	**41.7**	176	**18.3**
South Spillway Entrance	147	**20.9**	115	**15.2**	83	**9.9**	73	**7.6**
West PH Entrance	25	**3.6**	24	**3.2**	37	**4.4**	29	**3.0**
East Ladder Entrance	99	**14.1**	166	**21.9**	350	**41.9**	685	**71.1**
Unknown[1]	156	**22.2**	88	**11.6**	17	**2.0**	0	**0.0**
Dam passage route								
OR-shore ladder	428	**60.7**	393	**51.5**	487	**57.7**	787	**80.4**
WA-shore ladder	277	**39.3**	364	**47.7**	349	**41.4**	176	**18.0**
Passed unknown[2]	1	**0.1**	6	**0.8**	8	**0.9**	16	**1.6**

[1] All unknown last entrances were at entrances to the OR-shore fishway
[2] Likely passage via navigation lock, or with malfunctioning transmitter

fishway exit rates exceeded 100% at some flow levels for the WPE and SSE (Figure 10). Rates could exceed 100% at those sites because fish could enter the ELE, SSE or WPE, travel upstream to the OR-shore transition pool and then move back downstream and exit out of any of the three entrance sites (see Figure 1). Exit rates were typically lowest at the ELE under all flow conditions, in part because fish could enter the ELE and exit elsewhere.

In each year, more spring–summer Chinook salmon first passed The Dalles Dam via the OR- than the WA-shore ladder: 52 to 61% passed the OR-shore ladder in 1997, 1998 and 2000, while 80% passed there in 2001 (Table 13). Less than 2% passed via unknown routes (most likely via the navigation lock) in each year, with the highest number of unknown-route passages in 2001. It is possible that fish that migrated along the WA-shore in the tailrace in 2001 were attracted to outflow from the navigation lock in that year, particularly during no-spill conditions.

Movement between fishways - In all years, Chinook salmon moved between entrances and between fishways at high rates before passing the dam. Twenty to 47% of the fish that first approached the dam at the NLE (WA-shore) made their first fishway entrance into the OR-shore fishway (Table 14). After first approaching OR-shore fishway entrances, 7 to 37% (SSE), 5 to 34% (WPE) and 3 to 27% (ELE) migrated through the tailrace to first enter at the NLE entrance to the WA-shore fishway. In some years, large percentages (> 60%) that first approached at the SSE and WPE entrances subsequently first entered at other OR-shore fishway entrances. Fish that first approached at the NLE and ELE tended to first enter at those sites in all years (Table 14). Of those that first approached at the SSE, the highest proportions subsequently entered at the SSE in 1997 and 2000, at the NLE in 1998 and at the ELE in 2001. Of those that first approached at the WPE, the highest proportions subsequently entered at the NLE in 1997 and 1998 and at the ELE in 2000 and 2001 (Table 14).

Despite considerable movement between fishways, Chinook salmon tended to pass the dam via the fish ladder adjoining the fishway they first approached: 50 to 67% of fish that first approached the NLE eventually passed the dam via the WA-shore ladder, and 54 to 85% that first approached OR-shore entrances eventually passed the dam via that fishway (Table 14).

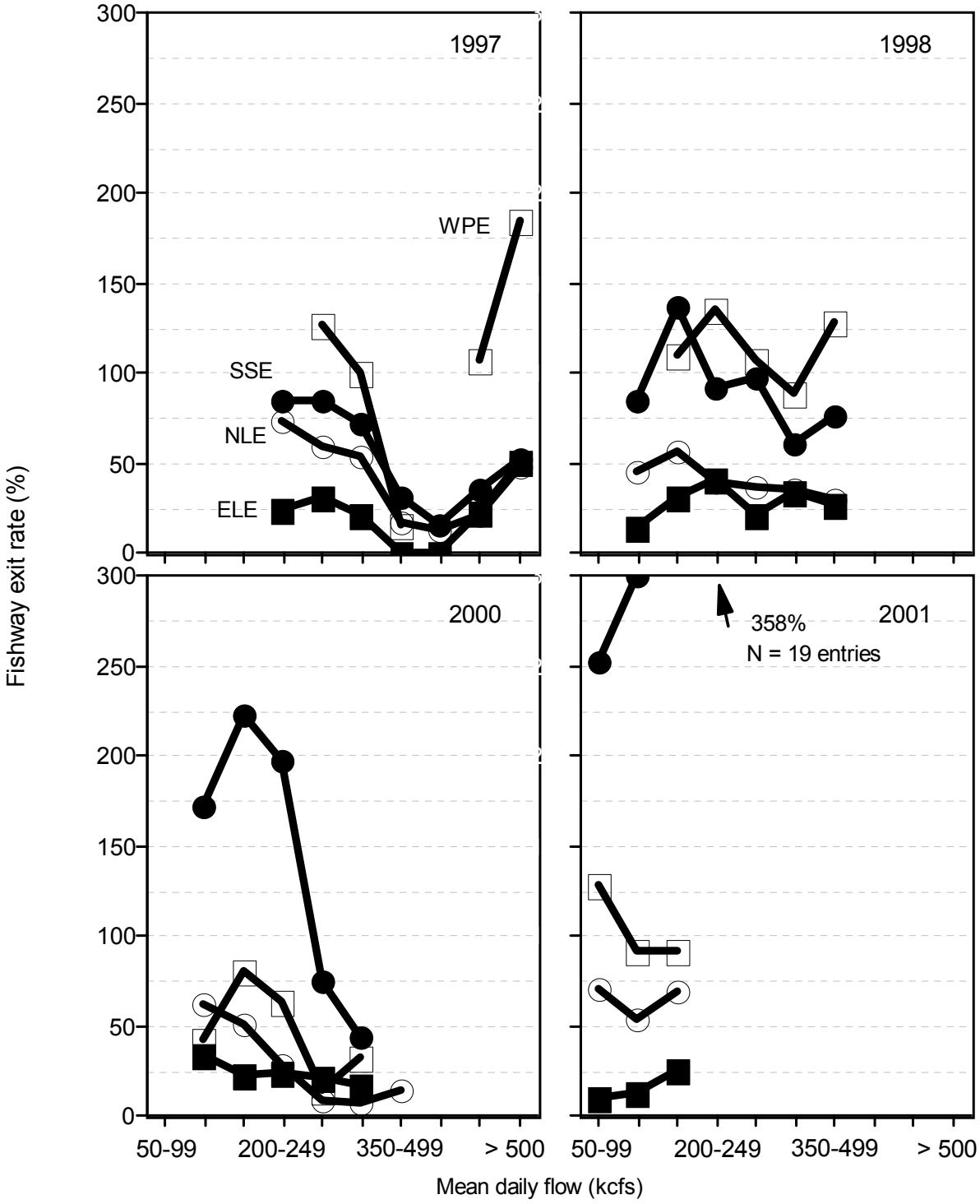

Figure 10. Fishway exit rates [(total exits/total entrances)*100] for each monitored fishway entrance at The Dalles Dam, by mean daily flow.

Table 14. Location of first fishway entrances and ladders passed by radio-tagged spring–summer Chinook salmon at The Dalles 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	Pass	Did not
First approach NLE	N	NLE	SSE	WPE	ELE	Unk	OR	WA	Pass
1997	254	**63**	17	2	6	7	43	**50**	7
1998	249	**80**	8	4	5	2	33	**61**	4
2000	168	**74**	11	2	11	1	32	**67**	2
2001	163	**53**	15	2	29	0	29	**65**	5
First approach SSE									
1997	125	27	**44**	1	9	14	**59**	34	6
1998	103	**37**	29	0	23	10	**54**	42	4
2000	137	20	**39**	4	20	1	**61**	32	7
2001	263	7	30	4	**59**	0	**79**	19	2
First approach WPE									
1997	204	**25**	22	17	11	18	**57**	32	9
1998	211	**34**	16	22	14	11	**52**	42	6
2000	139	28	9	12	**45**	5	**61**	35	4
2001	204	5	7	13	**70**	<1	**75**	14	5
First approach ELE									
1997	143	21	16	6	**33**	18	**65**	25	7
1998	222	27	15	5	**38**	18	**60**	36	5
2000	391	20	10	5	**61**	1	**65**	30	2
2001	375	3	4	4	**88**	0	**85**	13	1

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

Some Chinook salmon that approached The Dalles 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 pool and turned around when they reached The Dalles Dam, died, or were recaptured in fisheries near the dam after first approaching

Fishway exits and dam passage time – Spring–summer Chinook salmon that exited a fishway into the tailrace one or more times at The Dalles Dam had longer dam passage times than fish that did not exit in all months of all years (Table 15). Exit fish had significantly longer passage times ($P < 0.005$, K-W χ^2 tests) than non-exiting fish in 12 of 16 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 11 to 22 h in 1998, 2000 and 2001. The delay was 72 h in April 1997 (Table 15). Median delays for fish that exited were 12 to 21 h in May, 11 to 18 h in June, and 9 to 12 h in July in all years.

The percentage of fish that exited a fishway into the tailrace tended to increase each month through the migration in each year (Figure 11), particularly in 1997 and 2000. Ten to 13% of the fish with known dam passage times exited a fishway in April 1997 and 2000 versus 37 to 45% in April 1998 and 2001. By July, 47 to 64% of the fish exited a fishway into the

Table 15. Number of adult radio-tagged spring–summer Chinook salmon, and median times (h) to pass from first tailrace record to pass The Dalles 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	106	**95.2**	78	**34.0**	172	**31.9**	184	**22.0**
May	171	**51.5**	132	**13.8**	153	**19.2**	123	**13.1**
June	42	**11.1**	52	**12.3**	50	**8.5**	54	**9.2**
July	71	**9.5**	29	**8.4**	22	**9.3**	39	**7.5**
Exited fishway one or more times								
April	12	**167.0**	63	****55.8**	26	**45.9**	106	****32.9**
May	50	**72.3**	90	****31.8**	52	****31.6**	115	****28.3**
June	41	****29.4**	46	***24.6**	46	****21.9**	84	****19.9**
July	62	****17.1**	40	****18.0**	33	****19.2**	72	****19.0**

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

tailrace before passing the dam in all years (Figure 11). Between-month differences in exit percentages were all significant ($P < 0.005$, Z tests) in 1997 and 2000, except between June and July ($P > 0.15$). All between-month differences in exit percentages were significant in 2001 ($P < 0.05$), except between June and July ($P = 0.52$). In 1998, the exit percentage in May (41%) was significantly lower than in July (58%) ($P = 0.01$). No other between-month differences were significant in 1998.

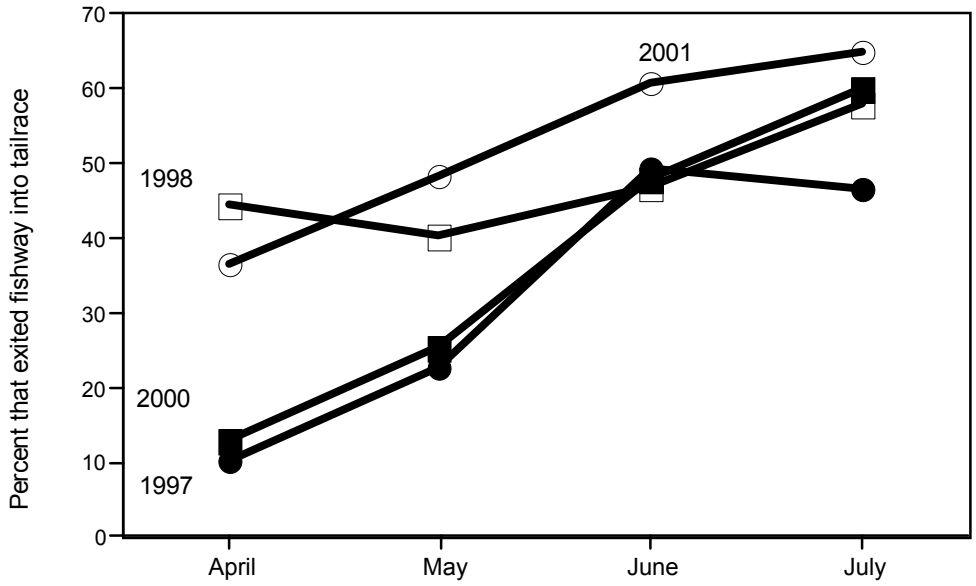

Figure 11. Percent of spring–summer Chinook salmon that exited fishways into the tailrace at The Dalles Dam by month each fish first entered the tailrace. Only includes fish with known dam passage times and known fishway exit information - summarized in Table 15.

Steelhead:

In all years, steelhead were monitored as they approached and entered four major fishway entrances at The Dalles Dam: the north ladder entrance (NLE), the south spillway entrance (SSE), the west powerhouse entrance (WPE) and the east ladder entrance (ELE) (see Figure 1). Orifice gate entrances were not monitored in any year, but fish could enter them undetected in 1997; orifice gate entrances were closed in 2000 and 2001.

Between 684 and 976 steelhead were known to have approached fishways each year, 675 to 971 entered fishways, and 250 to 494 exited fishways (Table 16). In each year, > 98.5 of fish that approached fishways subsequently entered fishways and 37 to 53% of the fish that entered eventually exited into the tailrace. Steelhead approached fishways a median of 2 to 3 times (*means*= 3.6 to 5.6 times), entered a median of one time in 1997 and twice in 2000 and 2001 (*means* = 2.1 to 3.3 times). Fish that exited fishways exited a median of 2 times in all years (*means* = 3.0 to 4.5 times). The median numbers of exits for all fish that entered a fishway were 0 in 1997 and 1 in 2000 and 2001 (*means* = 1.1 to 2.3 exits/fish that entered). Because orifice gate entrances were closed in 2000 and 2001, entrance use summaries for those years have the lowest error rate. Behavior summaries were less precise in 1997, when some fish used unmonitored orifice gates.

Table 16. Numbers of radio-tagged steelhead and sockeye salmon that approached, entered and exited fishway entrances at The Dalles 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.

	Steelhead									Sockeye		
	1997			2000			2001			1997		
	N	Med	Avg	N	Med	Avg	N	Med	Avg	N	Med	Avg
Approached	684	2.0	3.6	885	3.0	5.6	976	3.0	5.6	495	1.0	1.8
Entered	675	1.0	2.1	882	2.0	2.9	971	2.0	3.3	495	1.0	1.5
Exited	250	2.0	3.0	471	2.0	3.6	494	2.0	4.5	147	1.0	1.8
Percentage of those that approached that subsequently entered												
		98.7%			99.7%			99.5%			100%	
Percentage of those that entered that subsequently exited												
		37.0%			53.4%			50.9%			29.7%	

Approaches to fishways – Steelhead first approached fishways at all monitored entrances (Table 17). Nineteen to 22% first approached at the NLE, but approaches were 2.3 to 3.5 times more frequent during periods of spill: 39 to 44% first approached at the NLE during spill compared to 11 to 18% during no spill in all years ($P < 0.0001$, Z tests). Most steelhead (72 to 80%) first approached the dam during spill conditions in each year.

Between 21 and 32% of tagged steelhead first approached at the SSE, 17 to 23% first approached at the WPE and 24 to 37% first approached at the ELE in each year (Table 17). In each year, more steelhead approached all three sites on days with no spill than on days with spill. Between 25 and 34% first approached SSE on days with no spill in both 1998 and 2001, versus 17 to 21% that approached there on days with spill ($P < 0.0001$ in 2000 and 2001; P = 0.43 in 1997). From 18 to 27% first approached the WPE on days with no spill, versus 10 to 21% on days with spill ($P < 0.02$ in 2000 and 2001; $P = 0.11$ in 1997). Thirty to 39% first

approached the ELE on days with no spill, versus 17 to 34% on days with no spill (P = 0.002 in 1997; P ~ 0.11 in 2000 and 2001).

About 10% of steelhead first approaches were at unknown sites in 1997, when orifice gates were open but unmonitored, compared to < 0.7% at unknown sites in 2000 and 2001 (Table 17).

Table 17. Location of first and total[1] approaches to fishway entrances by radio-tagged steelhead and sockeye salmon at The Dalles 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	142	**20.8**	165	**18.6**	211	**21.6**	229	**46.3**
South Spillway Entrance	146	**21.3**	221	**25.0**	307	**31.5**	17	**3.4**
West PH Entrance	159	**23.2**	163	**18.4**	163	**16.7**	45	**9.1**
East Ladder Entrance	166	**24.3**	331	**37.4**	292	**29.9**	141	**28.5**
Unknown	71	**10.4**	5	**0.6**	3	**0.3**	63	**12.7**
Total	684		885		976		495	
Total approaches								
North Ladder Entrance	372	**15.3**	583	**11.7**	870	**15.8**	298	**33.5**
South Spillway Entrance	435	**17.9**	891	**17.9**	1,387	**25.2**	49	**5.5**
West PH Entrance	594	**24.4**	1,079	**21.7**	1,043	**19.0**	107	**12.0**
East Ladder Entrance	857	**35.2**	2,405	**48.4**	2,193	**39.9**	288	**32.4**
Unknown	174	**7.2**	9	**0.2**	7	**0.1**	147	**16.5**
Total	2,432		4,967		5,500		889	

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

Site preferences for first fishway approaches varied with spill volume (Table 18). On days with zero spill, steelhead first approached most frequently at the ELE in 1997 (30%) and 2000 (39%) and at the SSE (34%) in 2001. On days with spill < 100 kcfs, steelhead first approached most frequently at the SSE (67%) in 1997 and at the NLE (39 to 44%) in 2000 and 2001. More than 50% of steelhead first approached at the NLE on days with spill > 150 kcfs (1997 only) (Table 18).

Distributions of combined first and subsequent approaches at fishway entrances (total approaches) differed from those for first approaches (Table 17). The highest percentages of total fishway approaches were at the ELE in all years, and ranged from 35% in 1997 to 48% in 2000. Twelve to 16% were at the NLE, 18 to 25% were at the SSE and 19 to 24% were at the WPE in all years.

In 1997, the highest proportions of total approaches were at the ELE at zero spill and spill < 50 kcfs and were at the NLE when spill was between 100 and 200 kcfs (Table 18). In 2000 and 2001, the highest proportions were at the ELE under all reported spill levels. The remaining approaches were distributed fairly evenly among the other monitored fishway entrances each year.

Table 18. Percent of first and total approaches to fishway entrances by radio-tagged steelhead and sockeye salmon at The Dalles 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 excluded.

Steelhead - 1997										
		% of first approaches					% of total approaches			
Spill	N	NLE	SSE	WPE	ELE	N	NLE	SSE	WPE	ELE
0	476	18	25	27	**30**	1,807	14	19	27	**41**
1-49	6	0	**67**	33	0	30	3	20	27	**50**
50-99	-	-	-	-	-	-	-	-	-	-
100-149	66	**33**	20	21	26	231	**29**	23	24	25
150-199	58	**53**	21	17	9	182	**32**	22	26	19
200-249	4	**50**	0	**50**	0	6	33	0	**50**	17
250-299	-	-	-	-	-	-	-	-	-	-
300-349	2	**50**	0	0	**50**	2	**50**	0	0	**50**
Steelhead - 2000										
0	634	11	28	22	**39**	3,616	10	17	22	**51**
1-49	62	**39**	21	6	34	362	17	24	18	**41**
50-99	183	**39**	16	12	33	980	17	18	22	**43**
Steelhead - 2001										
0	777	16	**34**	18	31	4,202	14	25	21	**41**
1-49	195	**44**	20	11	25	1,289	22	28	14	**37**
Sockeye salmon - 1997										
100-149	19	**63**	5	21	11	27	**52**	11	15	22
150-199	300	**52**	4	11	34	504	39	6	15	**40**
200-249	83	**55**	5	8	31	146	**43**	8	14	36
250-299	9	**56**	11	0	33	14	**50**	7	0	43
300-349	16	**56**	0	0	44	36	36	6	14	**44**
>350	6	**33**	0	**33**	**33**	15	27	7	20	**47**

Entries to fishways – Steelhead first entered fishways at The Dalles Dam at all monitored entrances (Table 19). More then 50% first entered at the ELE in 2000 and 2001 and 35% first entered there in 1997. Ten to 15% first entered the NLE, 11 to 28% first entered the SSE and 6 to 14% first entered the WPE in each year. Almost 30% first entered at unknown sites in 1997, most likely through open, unmonitored orifice gates. Less than 1.5% of first entrances were unknown in 2000 and 2001. In all years, steelhead first entered the NLE at significantly higher rates when spill was occurring ($P < 0.0001$, Z test). Between 24 and 33% first entered the NLE on days with spill compared to 10 to 12% on days with no spill. Fish first entered the SSE at significantly higher rates during spill in 1997 (25% versus 14%; $P = 0.004$), but not in subsequent years ($P > 0.08$). Percentages that first entered the WPE did not differ between spill and no-spill periods ($P > 0.30$). Significantly higher percentages first entered the ELE on days with no spill in all years ($P < 0.005$). Between 55 and 64% first entered the ELE on days with no spill compared to 25 to 46% on days with spill.

Table 19. Location of first and total[1] fishway entrances by radio-tagged steelhead and sockeye salmon at The Dalles 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	71	**10.5**	136	**15.4**	136	**14.0**	212	**42.8**
South Spillway Entrance	77	**11.4**	141	**16.0**	269	**27.7**	17	**3.4**
West PH Entrance	95	**14.1**	84	**9.5**	56	**5.8**	36	**7.3**
East Ladder Entrance	233	**34.5**	510	**57.8**	507	**52.2**	122	**24.6**
Unknown	199	**29.5**	11	**1.2**	3	**0.3**	108	**21.8**
Total	675		882		971		495	
Total fishway entrances								
North Ladder Entrance	197	**13.9**	435	**17.1**	518	**16.4**	258	**34.6**
South Spillway Entrance	170	**12.0**	405	**15.9**	700	**22.2**	39	**5.2**
West PH Entrance	173	**12.2**	231	**9.1**	252	**8.0**	68	**9.1**
East Ladder Entrance	472	**33.3**	1,467	**57.5**	1,678	**53.1**	193	**25.9**
Unknown	406	**28.6**	12	**0.5**	12	**0.4**	188	**25.2**
Total	1,418		2,550		3,160		746	

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

Site preference for first fishway entrances varied with spill volume. In 2000 and 2001, mean daily spill was < 100 kcfs for all radio-tagged steelhead at The Dalles Dam. In those years, fish first entered the ELE most frequently with 64% and 55% first entering there on days with zero spill and 42 to 48% first entering there on days with spill (Table 20). The second most-used entrance tended to be the NLE or SSE, with < 13% first entering at the WPE under all conditions. Steelhead encountered a wider range of spill levels in 1997. At zero spill, 56% first entered at the ELE and 10 to 21% first entered at the other sites. The highest proportions tended to first enter at the NLE during spill, followed by the SSE or ELE (Table 20).

The distribution of first and subsequent fishway entrances (total entrances) by steelhead was similar to that for first entrances, both in aggregation (Table 19) and in relation to spill levels (Table 20).

Exits from fishways – The highest percentages of first and subsequent fishway exits by steelhead were via the SSE in all years (Table 21). The percentages of first exits via the SSE were 31% (1997), 55% (2000) and 64% (2001); percentages of total exits were similar. Between 16 and 18% first exited via the NLE, and 12 to 17% first exited via the ELE in all years. The percentage that first exited via the WPE was the most variable: 21% in 1997, 12% in 2000 and 7% in 2001. Percentages of total fishway exits followed similar patterns (Table 21). In 1997, when orifice gates were open but unmonitored, 12 to 14% of first and total exits were at unknown sites and times; most were likely via orifice gates.

Table 20. Percent of first and total entrances to fishways by radio-tagged steelhead and sockeye salmon at The Dalles 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 excluded.

		Percent of first entries					Percent of total entries			
Spill	N	NLE	SSE	WPE	ELE	N	NLE	SSE	WPE	ELE
Steelhead - 1997										
0	371	10	14	21	**56**	766	14	14	18	**54**
1-49	4	25	0	**50**	25	16	13	6	25	**56**
50-99	-	-	-	-	-	-	-	-	-	-
100-149	56	**29**	21	21	**29**	137	**36**	22	20	23
150-199	39	**41**	36	5	18	87	**39**	35	8	18
200-249	3	**33**	0	**33**	**33**	3	**33**	0	**33**	**33**
250-299	-	-	-	-	-	-	-	-	-	-
300-349	1	0	0	**100**	0	1	0	0	0	**100**
Steelhead - 2000										
0	625	10	18	9	**64**	1,842	14	16	8	**62**
1-49	62	31	21	7	**42**	186	24	26	8	**43**
50-99	183	31	10	12	**48**	509	26	12	14	**48**
Steelhead - 2001										
0	772	12	28	5	**55**	2,364	15	22	8	**55**
1-49	195	24	26	7	**43**	781	20	24	8	**48**
Sockeye salmon - 1997										
100-149	17	**71**	6	12	12	21	**67**	5	9	19
150-199	267	**54**	4	10	33	380	**46**	7	13	35
200-249	75	**55**	5	9	31	110	**46**	7	13	35
250-299	8	**63**	13	0	25	12	**58**	8	0	33
300-349	15	**53**	0	0	47	25	40	8	4	**48**
>350	4	**50**	0	25	25	10	**40**	10	10	**40**

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 22). 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, 22 to 28% were recorded at antennas inside the SSE and WPE entrances and less than 10% were recorded inside the NLE (downstream from the first transition pool weir) before exiting to the tailrace. The largest percentages (46 to 56%) first turned around in the submerged-weir portions of transition pools each year, and another 7 to 25% were recorded at antennas just upstream from transition pools in the overflow-weirs at the bottom of ladders. 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 actually still in the transition pool. As with Chinook salmon, relatively few steelhead were recorded for extended periods at the upper antennas before being recorded at downstream sites, suggesting few fish moved far up the ladder. Therefore,

Table 21. Location of first and total[1] fishway exits by radio-tagged steelhead and sockeye salmon at The Dalles 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	42	**16.8**	85	**18.0**	80	**16.2**	59	**40.1**
South Spillway Entrance	78	**31.2**	261	**55.4**	318	**64.4**	8	**5.4**
West PH Entrance	52	**20.8**	58	**12.3**	36	**7.3**	35	**23.8**
East Ladder Entrance	42	**16.8**	66	**14.0**	58	**11.7**	16	**10.9**
Unknown	36	**14.4**	1	**0.2**	2	**0.4**	29	**19.7**
Total	250		471		494		147	
Total fishway exits								
North Ladder Entrance	145	**19.4**	273	**16.6**	399	**18.1**	68	**26.0**
South Spillway Entrance	263	**35.2**	889	**54.0**	1,266	**57.4**	35	**13.4**
West PH Entrance	135	**18.0**	175	**10.6**	205	**9.3**	82	**31.3**
East Ladder Entrance	112	**15.0**	304	**18.5**	322	**14.6**	24	**9.2**
Unknown	93	**12.4**	4	**0.2**	12	**0.5**	53	**20.2**
Total	748		1,645		2,204		262	

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

Table 22. 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 SSE	12	**4.8**	68	**14.4**	113	**22.9**	2	**1.4**
Inside WPE	58	**23.3**	36	**7.6**	19	**3.8**	39	**26.5**
OR transition pool	121	**48.6**	193	**41.0**	167	**33.8**	27	**18.4**
Above OR pool[1]	16	**6.4**	89	**18.9**	115	**23.3**	19	**12.9**
Top of OR ladder	--	**--**	--	**--**	--	**--**	--	**--**
Inside NLE	21	**8.4**	3	**0.6**	10	**2.0**	9	**6.1**
WA transition pool	19	**7.6**	64	**13.6**	58	**11.7**	29	**19.7**
Above WA pool[1]	2	**0.8**	18	**3.8**	9	**1.8**	22	**15.0**
Top of WA ladder	--	**--**	17	**3.6**	3	**0.6**	--	**--**
Total OR fishway	207	**83.1**	386	**82.0**	414	**83.8**	87	**59.2**
Total WA fishway	42	**16.9**	85	**18.0**	80	**16.2**	60	**40.8**

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

percentages reported first turning in transition pools (Table 22) should be considered minimums: maximum percentages that first turned around within the transition pools ranged

from 63% in 1997 to 77% in 2000. Between 0 and 3.6% moved to the top of ladders before turning around and exiting to the tailrace.

Unlike the spring–summer Chinook runs, steelhead passed The Dalles Dam under a narrow range of tailwater elevations: about 90% passed when elevations were between 75 and 77 feet. About 85% of steelhead that first turned around in the WA-shore transition pool appeared to do so at or near the first submerged weir in the pool. For those that first turned in the OR-shore pool, about 66% appeared to turn near the first submerged weir when tailwater elevation was 75 feet and 51% turned there when elevations were 76 and 77 feet. Most of the remainders (both transition pools) appeared to turn near the transition between the submerged-weirs of the pool and the overflow-weir portion of the lower ladders.

Fishway entrance effectiveness - In each year the SSE had more exits than entries for both first and total entries by steelhead, and the ELE was the most effective entrance (Table 23). The second most effective entrance was the NLE, followed by the WPE in all years. The relatively high proportion of unknown entrances and exits in 1997 raises some uncertainty about absolute values of net entry rates that year, but rates were likely similar to 2000 and 2001.

Table 23. Net first and total fishway entrances and exits by radio-tagged steelhead and sockeye salmon at The Dalles 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	52	51	162	56	119	153	190
South Spillway Entrance	**-1**	**-93**	**-120**	**-484**	**-49**	**-566**	9	4
West PH Entrance	43	38	26	56	20	47	1	**-14**
East Ladder Entrance	191	360	444	1,163	449	1,356	106	169
Unknown	163	313	1	4	1	0	79	135

Negative net entry rates at the SSE do not mean that the entrance did not produce dam passages. Twelve to 19% of steelhead last used the SSE just prior to passing the dam in all years (Table 24). Seven to 13% last used the NLE and 5 to 8% last used the WPE before passing the dam. In 1997, 40% last used the ELE and 63 to 69% last used the ELE in 2000 and 2001. Thirty-two percent last entered at unknown sites (likely orifice gates) in 1997 (Table 24).

In each year, > 85% of tagged steelhead first passed The Dalles Dam via the OR-shore ladder and 8 to 13% passed via the WA-shore ladder (Table 24). Between 0.2 and 2.3% 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 34 and 62% of fish that first approached the dam at the NLE (WA-shore) made their first fishway entrance at the OR-shore fishway (Table 25). After first approaching OR-shore fishway entrances, 6 to 8% (SSE) and 1 to 4% (WPE, ELE) migrated through the tailrace to first enter at the NLE entrance to the WA-shore

Table 24. Last fishway entrance used by radio-tagged steelhead and sockeye salmon at The Dalles 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**
North Ladder Entrance	51	**7.6**	109	**12.7**	119	**12.4**	193	**39.8**
South Spillway Entrance	85	**12.7**	100	**11.7**	183	**19.1**	21	**4.3**
West PH Entrance	52	**7.8**	53	**6.2**	43	**4.5**	28	**5.8**
East Ladder Entrance	264	**39.5**	589	**68.6**	607	**63.3**	147	**30.3**
Unknown[1]	216	**32.3**	7	**0.8**	7	**0.7**	96	**19.8**
Dam passage route								
OR-shore ladder	616	**90.2**	749	**86.0**	836	**87.1**	292	**59.3**
WA-shore ladder	51	**7.5**	109	**12.5**	122	**12.7**	193	**39.2**
Passed unknown[2]	16	**2.3**	13	**1.5**	2	**0.2**	7	**1.4**

[1] All unknown last entrances were at entrances to the OR-shore fishway
[2] Likely passage via navigation lock, or with malfunctioning transmitter

Table 25. Location of first fishway entrances and ladders passed by radio-tagged steelhead and sockeye salmon at The Dalles 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 Pass	Pass	Did not
First approach NLE	N	NLE	SSE	WPE	ELE	Unk	OR	WA	Pass
Steelhead 1997	142	**38**	14	15	16	16	**75**	22	2
Steelhead 2000	165	**66**	10	3	21	-	**66**	32	2
Steelhead 2001	211	**49**	25	3	22	-	**71**	27	2
Sockeye 1997	229	**93**	-	< 1	5	2	20	**77**	3
First approach SSE									
Steelhead 1997	146	8	**33**	8	26	22	**92**	5	4
Steelhead 2000	221	6	42	8	**43**	< 1	**89**	9	2
Steelhead 2001	307	7	**61**	2	29	-	**86**	12	2
Sockeye 1997	17	-	94	-	-	6	**88**	12	-
First approach WPE									
Steelhead 1997	159	2	4	**36**	28	29	**94**	4	2
Steelhead 2000	163	2	9	26	**61**	1	**91**	7	1
Steelhead 2001	163	4	10	18	**67**	-	**93**	5	2
Sockeye 1997	45	-	-	**64**	11	24	**96**	4	-
First approach ELE									
Steelhead 1997	166	1	1	3	**77**	18	**95**	3	2
Steelhead 2000	331	3	5	5	**85**	1	**88**	8	3
Steelhead 2001	292	2	4	4	**90**	-	**92**	7	1
Sockeye 1997	141	-	1	4	**75**	20	**96**	4	-

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

fishway. Thirty to 50% of fish that first approached at the WPE and SSE subsequently first entered at other OR-shore fishway entrances. In comparison, 75% or more of fish that first approached at the ELE also first entered there (Table 25). Thirty-eight to 66% of the fish that first approached at the NLE first entered there. More than 60% of fish that first approached at the WPE first entered at the ELE in 2000 and 2001.

Regardless of the entrance first approached or first entered, steelhead tended to pass the dam via the OR-shore ladder (Table 25). Between 22 and 32% of fish that first approached at the NLE eventually passed the dam via the WA-shore fishway: 66 to 75% crossed the tailrace and passed the dam via the OR-shore fishway. More than 86% of fish that first approached the SSE, 91 to 94% that first approached the WPE, and 88 to 95% that first approached the ELE passed the dam via the OR-shore ladder.

Some steelhead that approached The Dalles Dam did not pass the dam (Table 25). Where fish first approached, however, did not appear to be related to unsuccessful passage.

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 26). Exiting fish had significantly longer passage times ($P < 0.005$, K-W χ^2 tests) than non-exiting fish in August, September and October of all years, in July of 2000 and in June and July of 2001. Based on median times in 2000 and 2001, delays associated with exiting a fishway into the tailrace were 8 h in June and 11 to 18 h in July. Delays for fish that exited were 11 to 14 h in August, 10 to 12 h in September, and 9 to 11 h in October in all years (Table 26).

Table 26. Number of adult radio-tagged steelhead and sockeye salmon, and median times (h) to pass from first tailrace record to pass The Dalles 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	7	**10.6**	8	**8.0**	20	**15.4**	104	**6.3**
July	31	**14.1**	20	**11.7**	40	**13.6**	193	**6.0**
August	19	**9.8**	48	**12.5**	45	**11.6**	5	**6.1**
September	61	**9.5**	144	**10.7**	166	**11.6**		
October	84	**13.8**	87	**11.2**	127	**12.8**		
November	2	**13.3**	5	**23.3**	9	**13.4**		
Exited fishway one or more times								
June	1	**27.0**	8	**15.9**	32	****23.1**	48	****18.5**
July	18	**15.7**	36	****22.9**	72	****31.1**	65	****15.0**
August	21	****20.4**	52	****24.2**	68	****26.0**	2	**50.0**
September	27	****25.6**	164	****20.7**	161	****22.2**		
October	31	****22.2**	85	****22.4**	76	****22.5**		
November	1	**28.3**	--	--	1	**11.1**		

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

Exit rates were highest (~ 65%) in July of 2000 and 2001 and in August of 1997 (53%) (Figure 12). In all years, the proportion that exited fishways decreased from summer into the fall and exit rates were lowest in October. The percentage that exited in August 1997 (53%) was significantly higher than in September (31%) and October (27%) ($P < 0.02$, Z tests). No other between-month differences were significant ($P > 0.15$) in 1997. No between-month differences in exit percentages were significant in 2000 ($P > 0.05$), but the rate in July (64%) was marginally higher than in October (49%) ($P = 0.053$). In 2001, the percentage that exited in October (37%) was significantly lower than in all other months ($P < 0.002$) and the percentage that exited in September (49%) was significantly lower than in July (64%; $P = 0.006$) and August (60%; $P = 0.045$). 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.

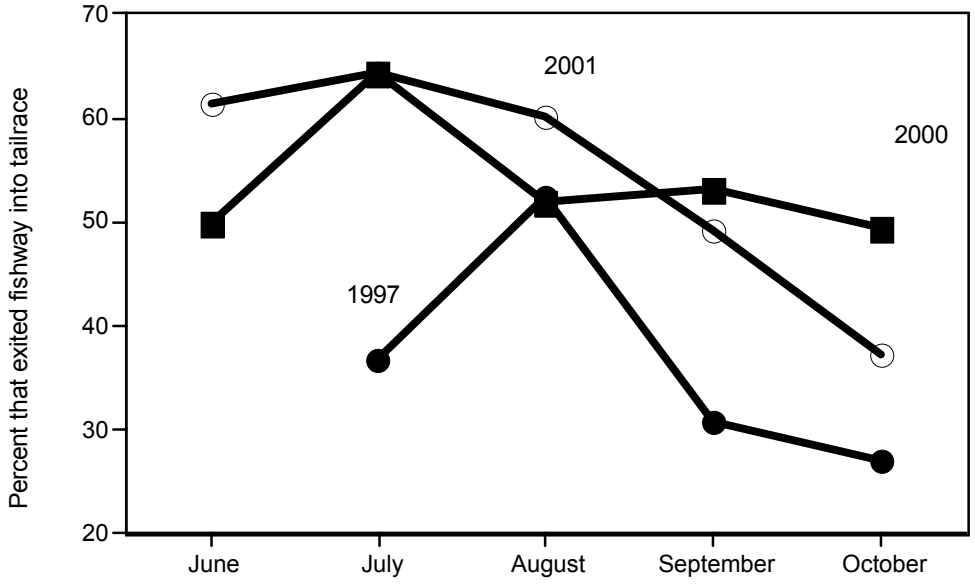

Figure 12. Percent of steelhead that exited fishways into the tailrace at The Dalles Dam by month each fish first entered the tailrace. Only includes fish with known dam passage times and known fishway exit information - summarized in Table 26.

Sockeye salmon:

Sockeye salmon were monitored in 1997 as they approached and entered four major fishway entrances at The Dalles Dam: the north ladder entrance (NLE), the south spillway entrance (SSE), the west powerhouse entrance (WPE) and the east ladder entrance (ELE) (see Figure 1). Orifice gate entrances were open but unmonitored in 1997.

All 495 sockeye salmon that approached fishways subsequently entered and 147 (30%) exited fishways (Table 16). Sockeye salmon approached fishways a median of 1 time (*mean* = 1.8 times) and entered a median of 1 time (*mean* = 1.5 times). Fish that exited fishways exited a median of 1 time (*mean* = 1.8 times). The median number of exits for all fish that entered was 0 (*mean* = 0.5 times). About 13% of tagged fish approached, 22% entered and 6% exited at unknown locations (most likely via orifice gates) and some fish likely approached, entered and exited undetected so estimates above are minimums.

Approaches to fishways – Sockeye salmon first approached fishways at The Dalles Dam at all monitored entrances, but favored the NLE (46%) and ELE (29%) (Table 17). Three percent first approached at the SSE, 9% first approached at the WPE and 13% first approached at unknown locations. The distribution of total approaches to fishways was similar to first approaches except the percentage at the NLE dropped (34%) while percentages increased slightly at other sites (Table 17).

Mean daily spill during the sockeye salmon migration ranged from about 100 to > 350 kcfs (Table 18). Between 52 and 63% first approached at the NLE at all spill levels except > 350 kcfs, when 33% first approached there. The second-highest percentages (31 to 44%) of first approaches were at the ELE at all spill levels except 100-149 kcfs, when more fish approached at the WPE (21%). The distribution of total approaches was similar to first approaches, but percentages were lower at the NLE at all spill levels (Table 18).

Entries to fishways – Sockeye salmon first entered fishways at all monitored entrances, but favored the NLE (43%) and the ELE (25%) (Table 19). Three percent first entered the SSE and 7% first entered the WPE. The distribution of total entries to fishways was similar to first entries except the percentage at the NLE dropped (35%) and percentages increased slightly at other sites (Table 19).

At all spill levels the highest percentages (50 to 71%) of sockeye salmon first entered the NLE (Table 20); the highest percentage (71%) first entered the NLE at spill between 100 and 149 kcfs, and the lowest percentages entered the NLE when spill was > 300 kcfs. The ELE was the second most-used first entry site at all spill levels. No fish first entered the SSE when spill was > 300 kcfs and only 1 of 27 (4%) first entered the WPE when spill was > 250 kcfs. The distribution of total entries was similar to first entries, but percentages were lower at the NLE and slightly higher at all other sites at all spill levels (Table 20).

Exits from fishways – The highest percentage of first exits by sockeye salmon was at the NLE (40%), followed by the WPE (24%), ELE (11%) and SSE (5%) (Table 21). About 20% of first and total exits were at unknown locations (most likely orifice gates). Approximately 31% of total exits were at the WPE, 26% were at the NLE and 13% were at the SSE (Table 21).

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 22). As with the other runs, resolution was somewhat limited in this analysis. The largest percentage (27%) was recorded at antennas inside the WPE entrance, less than 2% were inside the SSE and 6% were inside the NLE. Thirty-eight percent first turned around in the submerged-weir portions of transition pools, and another 28% were recorded at antennas just upstream from transition pools in the overflow-weirs at the bottom of ladders. Given the detection range of antennas, it was likely that some fish recorded at antennas upstream from the submerged-weir were actually still in the transition pool. Therefore, percentages reported first turning in transition pools (Table 22) should be considered minimums. No sockeye salmon moved to the top of ladders before first turning around and exiting to the tailrace.

Fishway entrance effectiveness – All fishway entrances had more net first entrances than exits for sockeye salmon (Table 23). The NLE had the highest number of net first and total entrances, followed by the ELE. Net first entrance rates were < 10 at the SSE and WPE and were 4 and –14 for total entries and exits, respectively. About 40% of sockeye salmon used the NLE just prior to passing the dam. The ELE was the last entrance used for 30% of the fish, and 4 to 6% last used the SSE or WPE (Table 24). About 20% last entered at unknown sites, most likely orifice gates.

Fifty-nine percent of sockeye salmon first passed The Dalles Dam via the OR-shore ladder and 39% first passed via the WA-shore ladder. Less than 2% passed by an unknown route, most likely via the navigation lock.

Movement between fishways – Sockeye salmon moved between fishways much 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 25). None of the fish that first approached at the SSE, WPE or ELE subsequently made their first entrance at the WA-shore fishway. Ninety-three and 94% of the fish that first approached at the NLE and SSE made their first entries at those sites, while 64% that first approached at the WPE first entered there and 75% that first approached at the ELE first entered there. Twenty-four percent that first approached at the WPE and 20% that first approached at the ELE made their first entry at an unknown location (orifice gates likely) (Table 25).

Sockeye salmon tended to pass The Dalles Dam via the fishway they first approached (Table 25). About 77% that first approached the NLE eventually passed the dam via the WA-shore ladder, 88% that first approached the SSE and 96% that first approached both the WPE and ELE passed via the OR-shore ladder. Seven sockeye salmon that approached The Dalles Dam did not pass.

Fishway exits and dam passage time – Sockeye salmon that exited a fishway into the tailrace one or more times at The Dalles Dam had longer median dam passage times than fish that did not exit in all months (Table 26). 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 12 h in June and 9 h in July (Table 26). Thirty-two percent exited in June and 25% exited in July, a non-significant difference ($P = 0.16$, Z test).

Movements Through Fishways and Transition Pools

Chinook salmon:

Transition pool selection and behavior in pools -- We analyzed behavior of 408 to 685 Chinook salmon with complete passage histories as they moved into fishways, through transition pools and up ladders at The Dalles Dam in four years; another 33 to 83 fish had complete tailrace, transition pool and top-of-ladder histories but were not recorded on their first fishway entry (Table 27). 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.

Most fish (82 to 89%) passed the dam via the same transition pool they first entered, while the remainders (11 to 18%) exited the first transition pool they entered, crossed the tailrace and passed the dam via the other fishway (Figure 13). Between 37 and 56% first entered the transition pool at the bottom of the OR-shore ladder and passed the dam via the OR-shore ladder in 1997, 1998 and 2000. In 2001, a year with limited or zero spill during much of the spring–summer Chinook salmon migration, 74% first entered the OR-shore pool and passed the OR-shore ladder. Thirty-one to 45% first entered the pool at the bottom of the WA-shore ladder and passed via the WA-shore ladder in the first three years; 13% first entered and passed via the WA-shore in 2001. Four to 9% 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. Four to 13% first entered the WA-shore transition pool, but passed the dam via the OR-shore ladder (Figure 13).

Table 27. Transition pool behavior by adult radio-tagged spring–summer Chinook salmon at The Dalles 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	408		450		496		685	
Moved straight through pool	76	**18.6**	65	**14.4**	95	**19.2**	141	**20.6**
Moved downstream, but didn't exit	234	**57.4**	203	**45.1**	268	**54.0**	217	**31.7**
Exited pool to collection channel	11	**2.7**	12	**2.7**	12	**2.4**	29	**4.2**
Exited pool to tailrace	87	**21.3**	170	**37.8**	121	**24.4**	298	**43.5**
All records except fishway entry								
N	83		64		33		78	
Moved straight through pool	30	**36.1**	20	**31.2**	2	**6.1**	21	**26.9**
Moved downstream, but didn't exit	30	**36.1**	16	**25.0**	23	**69.7**	14	**17.9**
Exited pool to collection channel	4	**4.8**	4	**6.3**	-	**-**	4	**5.1**
Exited pool to tailrace	19	**22.9**	24	**37.5**	8	**24.2**	39	**50.0**

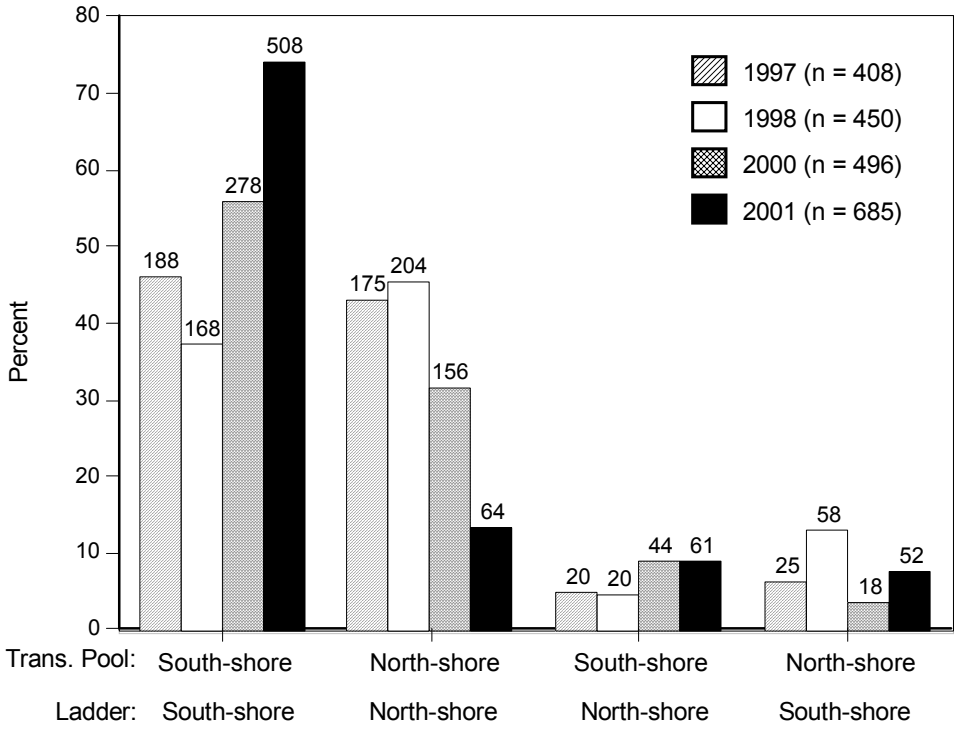

Figure 13. Number of Chinook salmon with telemetry records at all passage points that passed The Dalles Dam, the transition pool first entered, and the ladder used to pass the dam.

Fourteen to 21% of fish with complete passage histories moved straight through a transition pool and entered a ladder with no downstream movement (Table 27). Thirty-two to 57% 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 4% 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: 21% in 1997, 38% in 1998, 24% in 2000 and 44% in 2001 (Table 27).

More fish first entered the OR- than WA-shore transition pool in 1997 (51%), 2000 (65%) and 2001 (83%). More fish first entered the WA-shore pool in 1998 (58%). In the first three years, nineteen to 33% of the fish that first entered the OR-shore pool and 16 to 40% that first entered the WA-shore pool exited into the tailrace (Table 28). Higher percentages (42 and 51%) exited into the tailrace from both transition pools in 2001. Higher percentages (25 to 31%) moved straight through the OR-shore transition pool than through the WA-shore pool (1 to 9%) in all years, although antenna configurations in the WA-shore pool may have led to underestimates of straight-through behavior. Transition pool delay was the most common behavior in both fishways in the first three years, with 34 to 45% delaying in the OR-shore pool and 53 to 75% delaying in the WA-shore pool. Exiting into the tailrace was the most common behavior at both fishways in 2001 (Table 28).

Table 28. Transition pool behavior by adult radio-tagged spring–summer Chinook salmon at The Dalles 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	208		188		322		569	
Moved straight through pool	65	**31.3**	48	**25.5**	80	**24.8**	140	**24.6**
Moved downstream, but didn't exit	93	**44.7**	63	**33.5**	137	**42.5**	161	**28.3**
Exited pool to collection channel	11	**5.3**	12	**6.4**	12	**3.7**	29	**5.1**
Exited pool to tailrace	39	**18.8**	62	**33.0**	93	**28.9**	239	**42.0**
First entered WA-shore pool								
N	200		262		174		116	
Moved straight through pool	11	**5.5**	17	**6.5**	15	**8.6**	1	**0.9**
Moved downstream, but didn't exit	141	**70.5**	140	**53.4**	131	**75.3**	56	**48.3**
Exited pool to collection channel	--	**--**	--	**--**	--	**--**	--	**--**
Exited pool to tailrace	48	**24.0**	105	**40.1**	28	**16.1**	59	**50.9**

As with fishway exits, the proportion that exited the OR-shore transition pool into the tailrace tended to increase as migrations progressed each year (Figure 14). Increases were slight in 1997 and 1998. More than twice as many fish exited the OR-shore transition pool in June and July than in April and May 2000, while the exit percentages increased from 30% in April to 54% in July 2001 (Figure 14). Proportions that exited the WA-shore transition pool were 3 to 6 times higher in June and July than in April and May in 1997 and 2000. In 2001, the proportion that exited the WA-shore pool more than doubled from April and May to July, when > 90% exited. No clear pattern emerged for the WA-shore pool in 1998, although the highest exit rate was in

July (Figure 14). Monthly summaries may be less precise for 1997 and 1998 because fish could exit and re-enter one fishway undetected via orifice gates.

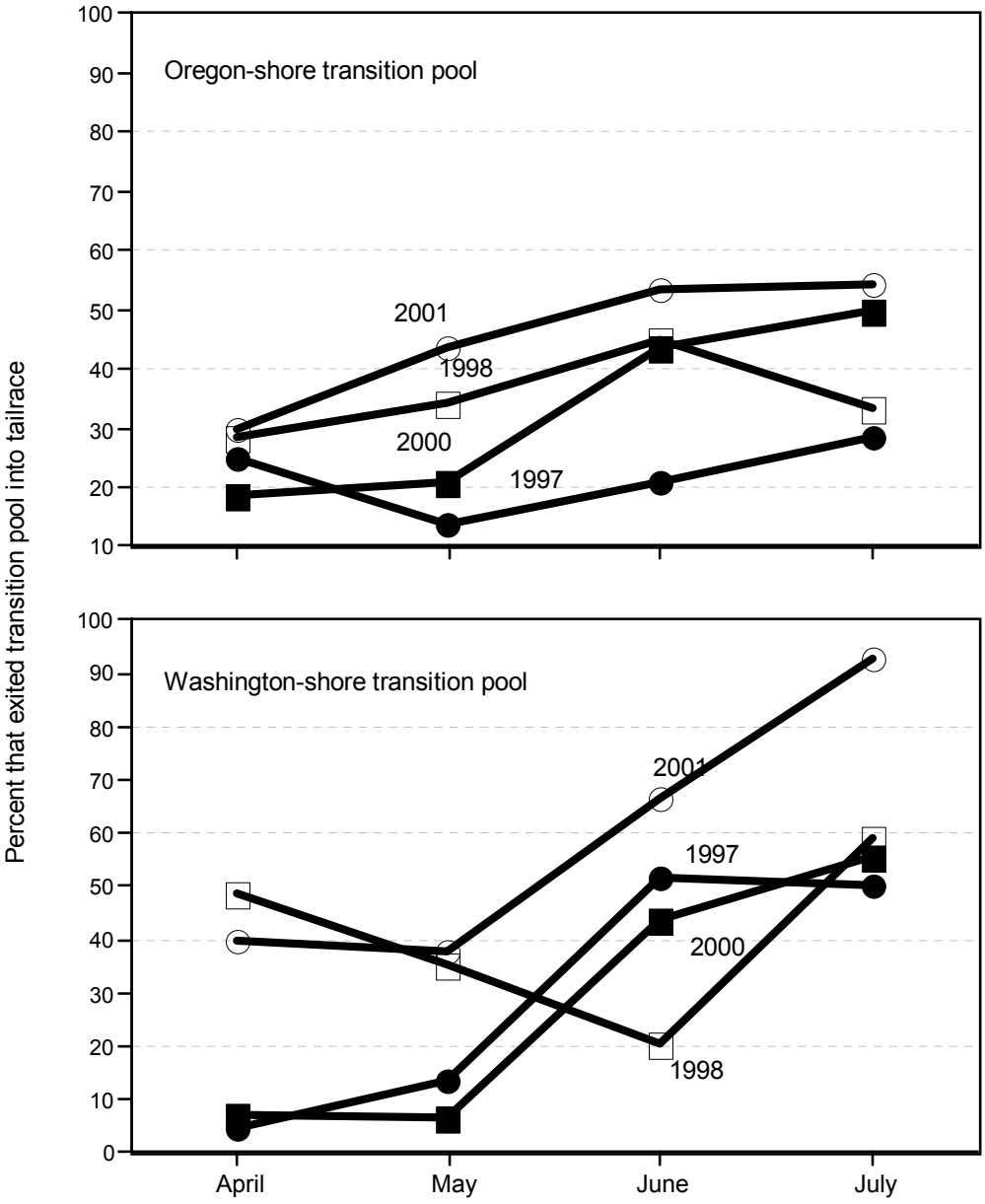

Figure 14. Percent of spring–summer Chinook salmon that exited transition pools into the tailrace at The Dalles Dam by month each fish first entered a transition pool. Only includes fish with complete dam passage histories.

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 were < 1 min (0.03 h) in 1998, 2000 and 2001 and 1.18 h in 1997 (Table 29). Median times were very low to enter the OR-

shore pool in 1998, 2000 and 2001 because most fish (53 to 79%) first entered the fishway at the ELE just downstream from the transition pool. In 1997, 33% first entered the ELE, 54% first entered the SSE and 13% first entered the WPE and times to enter the transition pool were therefore longer. Median times from first entry at the SSE to first pool entry ranged from 1.2 to 2.0 h in all years. Median times from first entry at the WPE ranged from 0.3 to 1.9 h. Less than 2.5% of fish took more than 24 h from first fishway entry to first transition pool entry at either fishway (Table 29).

Table 29. 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 The Dalles Dam.

	OR-shore fishway				WA-shore fishway			
First fishway entry to first pool	1997	1998	2000	2001	1997	1998	2000	2001
N	208	188	322	569	200	262	174	116
1st Quartile (h)	0.03	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Median (h)	**1.18**	**0.03**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.01**
3rd Quartile (h)	2.15	1.15	0.60	0.01	0.01	0.01	0.01	0.02
Percent that took > 24 h	2.4%	2.1%	1.2%	0.5%	0.5%	1.9%	1.7%	0.9%

	Both fishways combined			
First fishway entry to first pool	1997	1998	2000	2001
N	408	450	496	685
1st Quartile (h)	0.01	0.01	0.00	0.00
Median (h)	**0.02**	**0.01**	**0.01**	**0.01**
3rd Quartile (h)	1.37	0.07	0.02	0.02
Percent that took > 24 h	1.5%	2.0%	1.4%	0.6%

Salmon behavior in transition pools (pass straight through, delay, exit) was not a good predictor of differences in time to first enter a pool. Tests of median times from first fishway entry to first pool entry between behavior groups produced some significant ($P < 0.05$) results, but differences were generally < 5 min and were probably not biologically significant.

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 0.5 to 1.8 h for both ladders combined; medians were similar for each pool separately (Table 30). Fish that moved straight through a transition pool on their first attempt, with no recorded downstream movements, had median passage times < 0.25 h (15 min) (Table 31). 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 0.4 to 0.6 h through both transition pools in 1998, 2000 and 2001. In 1997, median times for delayed fish were 0.9 h through the OR-shore and 2.1 h through the WA-shore pools (Table 31). Fish that delayed in the OR-shore pool and exited into the collection channel—but not into the tailrace—had median times of 2.5 to 5.2 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 11.4 to 21.4 h from first pool entry to exit into the ladder; median times for those that exited the WA-shore pool into the tailrace were 11.5 to 23.4 h (Table 31). Between 21 and 49% of fish that exited a pool into the tailrace took > 24 h

Table 30. 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 The Dalles 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	208	188	322	569	200	262	174	116
1st Quartile (h)	0.28	0.21	0.22	0.31	0.32	0.35	0.33	0.58
Median (h)	**0.89**	**0.95**	**0.49**	**1.57**	**0.66**	**0.88**	**0.55**	**2.05**
3rd Quartile (h)	2.54	4.62	4.80	15.06	4.42	18.15	0.93	14.94
Percent that took > 24 h	9%	10%	9%	12%	11%	20%	3%	14%
	Both fishways combined							
First pool to last pool	1997	1998	2000	2001				
N	408	450	496	685				
1st Quartile (h)	0.29	0.28	0.25	0.34				
Median (h)	**0.72**	**0.89**	**0.53**	**1.75**				
3rd Quartile (h)	3.02	9.87	2.33	15.06				
Percent that took > 24 h	13%	16%	7%	12%				

Table 31. 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 The Dalles 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	65	48	80	140	11	17	15	1
1st Quartile (h)	0.11	0.10	0.11	0.17	0.13	0.10	0.17	0.10
Median (h)	**0.20**	**0.16**	**0.16**	**0.24**	**0.19**	**0.14**	**0.21**	**0.10**
3rd Quartile (h)	0.45	0.22	0.23	0.34	0.21	0.20	0.24	0.10
Moved downstream, didn't exit	93	63	137	161	141	140	131	56
1st Quartile (h)	0.41	0.25	0.25	0.30	1.80	0.28	0.34	0.38
Median (h)	**0.89**	**0.39**	**0.41**	**0.42**	**2.09**	**0.48**	**0.52**	**0.57**
3rd Quartile (h)	1.64	1.10	0.71	0.78	2.67	0.75	0.70	1.04
Exited pool to collection chan	11	12	12	29	N/A			
1st Quartile (h)	1.86	1.88	1.38	2.37				
Median (h)	**2.54**	**2.85**	**3.35**	**5.21**				
3rd Quartile (h)	8.86	4.14	11.77	15.30				
Exited pool to tailrace	39	65	93	239	48	105	28	59
1st Quartile (h)	11.09	3.50	4.85	4.82	6.09	9.10	5.59	5.46
Median (h)	**21.39**	**11.39**	**13.39**	**17.14**	**21.14**	**23.43**	**11.48**	**14.42**
3rd Quartile (h)	39.47	30.48	26.38	25.50	47.30	50.85	21.81	24.26
Percent that took > 24 h	46%	28%	30%	29%	44%	49%	21%	27%

to pass through a pool into a ladder (Table 31); in comparison, < 2% of all fish that did not exit took > 24 h to pass through a pool. In 1997 and 1998, ~25% of fish that exited the WA-shore pool into the tailrace took more than 2 d to pass into the ladder.

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 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 ($P < 0.001$, K-W χ^2 tests). (Only one fish moved through the WA-shore transition pool in 2001 with no downstream movement, so no tests were run.)

Passage time to ascend a ladder – After exiting transition pools into ladders, Chinook salmon ascended ladders relatively quickly at The Dalles Dam in all years. Median times to ascend both the OR- and WA-shore ladders were 1.8 to 2.3 h (Table 32). More than 75% of the fish ascended in < 3 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 straight through the pool took ~ 15 min longer than fish that exited to the tailrace or delayed in the pool ($P < 0.03$, K-W χ^2 test), a difference probably due to higher proportions passing straight through in April and May, when fish were migrating more slowly overall. Similarly, behavior in the WA-shore pool did not appear to significantly affect ladder ascension times in any year ($P > 0.05$).

Table 32. 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 The Dalles 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	208	188	322	569	200	262	174	116
1st Quartile (h)	1.76	1.58	1.52	1.89	1.77	1.64	1.60	1.71
Median (h)	**2.19**	**1.94**	**1.84**	**2.33**	**2.06**	**1.96**	**1.84**	**2.26**
3rd Quartile (h)	2.87	2.45	2.42	3.32	2.63	2.44	2.19	2.96
Percent that took > 24 h	0.5%	0.5%	0.0%	0.4%	0.5%	0.4%	0.0%	0.0%

	Both fishways combined[1]			
Last pool record to pass dam	1997	1998	2000	2001
N	408	450	496	685
1st Quartile (h)	1.76	1.61	1.55	1.86
Median (h)	**2.11**	**1.96**	**1.84**	**2.32**
3rd Quartile (h)	2.71	2.45	2.32	3.20
Percent that took > 24 h	0.5%	0.4%	0.0%	0.3%

[1] includes fish that passed via either ladder

In a separate analysis, we compared ladder ascension times for all fish with records exiting a transition pool into a ladder and exiting from the top of a ladder. These criteria included 33 to 88 more fish than in Table 32. Median ladder ascension times for the OR-shore ladder ranged from 1.7 to 2.6 h for all months of all years, and were 1.8 to 2.7 h for the WA-shore ladder. Differences in medians between ladders were never > 30 min (0.5 h) in any month of any year.

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 The Dalles 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 a transition pool in 1998 and 2001 ($P < 0.0001$, K-W χ^2 tests), and in 2000 ($P = 0.02$); the difference approached significance in 1997 ($P = 0.07$). Fish that exited to the tailrace also took significantly longer than fish that delayed in a transition pool in 1998 and 2001 ($P < 0.0001$). Differences in median times between exit fish and those that moved straight through a transition pool ranged from 4.5 h in 2000 to 18.0 h in 1998 (Table 33). Exiting fish took longer than fish that delayed, with median differences of 19.1 h in 1998, 9.2 h in 2001, and < 4 h in 1997 and 2000.

Table 33. Number of adult radio-tagged Chinook salmon, and median times (h) to pass from first tailrace record to pass The Dalles 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	17	**98.4**	18	**45.5**	32	**36.1**	74	**21.7**
May	31	**34.2**	27	**19.3**	35	**21.1**	28	**13.0**
June	17	**15.7**	12	**16.6**	15	**7.0**	23	**11.4**
July	11	**9.3**	8	**11.0**	12	**11.9**	16	**7.8**
All months	76	**23.8**	65	**18.7**	94	**19.9**	141	**17.1**
Moved downstream, no tailrace[1]								
April	71	**121.0**	56	**32.9**	106	**33.0**	108	**21.7**
May	118	**55.7**	103	**14.6**	126	**19.7**	68	**15.7**
June	26	**10.3**	33	**20.2**	36	**12.3**	39	**7.0**
July	30	**10.0**	23	**9.4**	11	**10.2**	30	**9.1**
All months	245	**34.8**	215	**17.6**	279	**21.2**	245	**16.2**
Exited pool to tailrace								
April	8	**162.9**	55	**58.6**	20	**41.0**	81	**37.8**
May	29	**74.2**	69	**29.9**	34	**26.3**	69	**28.3**
June	21	**37.6**	21	**28.9**	41	**22.5**	80	**21.4**
July	29	**19.0**	25	**16.5**	25	**18.7**	64	**20.3**
All months	87	**35.5**	170	**36.7**	120	**24.4**	294	**25.4**

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

Because the proportion of salmon that exited transition pools into the tailrace tended to increase through the migration (Figure 14), relationships between passage time and pool behavior were compared separately for each month. For each transition pool behavior, passage times were longest in April of all years and tended to be shortest in July (Table 33). 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 all months of all years (Table 33; Figure 15). To facilitate statistical comparisons, fish that exited a pool into the collection channel were combined with those that delayed in a pool for Table 33 and Figure 15.

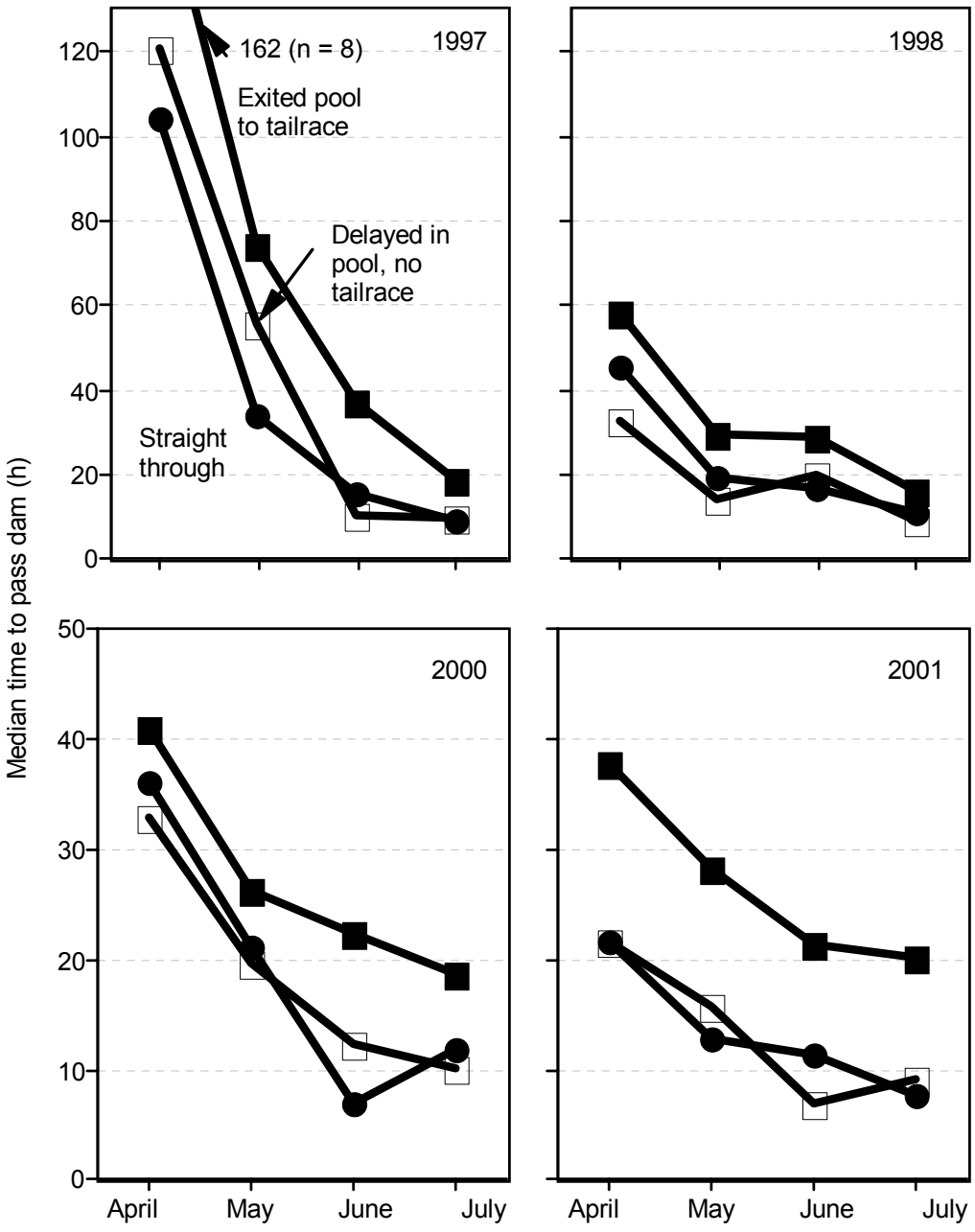

Figure 15. Median time for spring–summer Chinook salmon to pass from the first tailrace record over The Dalles Dam, based on transition pool behavior. Sample sizes in Table 33.

In April, fish that exited to the tailrace had significantly longer median dam passage times than those that moved straight through or delayed in 2001 ($P < 0.001$) and than those that delayed ($P = 0.0006$) or moved straight through ($P = 0.07$) in 1998. Fish that exited had longer median times than fish that moved straight through in May 1998 and 2001 ($P < 0.005$), but not in 1997 or 2000 ($P \sim 0.15$). Fish that exited had longer medians than those that delayed in 1998 and 2001 ($P < 0.0001$) and 2000 ($P = 0.03$). Fish that moved straight through in May took about 1 h longer than those that delayed ($P = 0.03$). No other differences were significant in May of any year ($P > 0.25$).

In June, fish that exited had longer median times than those that moved straight through or delayed in all years ($P < 0.001$) except in 1998 ($P = 0.09$ for both tests) (Table 33). Fish that delayed had longer median times than those that moved straight through in 2001 ($P = 0.03$). In contrast, the 7 fish that moved straight through took longer than the 36 that delayed in 2000 (5.3 h, $P = 0.04$). Patterns in July were similar to those in June: fish that exited to the tailrace had longer dam passage times that those that moved straight through or delayed in pools ($P < 0.05$) in all years, except in 1998 when a small number (8) of fish moved straight through. Differences between fish that moved straight through or delayed were non-significant in July.

Similar patterns emerged when we considered each transition pool separately. Fish that exited either the OR- or WA-shore transition pool into the tailrace tended to have longer passage times than fish that moved straight through a pool or delayed in the pool or collection channel each year (Table 34). For fish that first entered the OR-shore transition pool, median passage times for all behavior groups were longest in 1997 and shortest in 2001 or 1998. Between-year patterns were less consistent for fish that first entered the WA-shore pool, but fish that exited to the tailrace in 1998 had the longest median passage times of all groups, followed by those that delayed and exited in 1997.

Table 34. 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 The Dalles Dam.

	First entered OR-shore fishway				First entered WA-shore fishway			
	1997	1998	2000	2001	1997	1998	2000	2001
Moved straight through pool	65	48	80	140	11	17	15	1
1st Quartile (h)	13.14	12.64	8.88	9.04	4.37	6.11	6.88	4.60
Median (h)	**24.28**	**20.12**	**19.54**	**17.29**	**13.65**	**11.19**	**20.80**	**4.60**
3rd Quartile (h)	70.94	45.34	39.67	23.17	101.5	47.13	41.95	4.60
Moved downstream, didn't exit	58	63	137	161	141	140	131	56
1st Quartile (h)	19.74	9.92	12.82	7.77	12.16	5.93	8.14	7.32
Median (h)	**33.57**	**17.42**	**19.75**	**15.61**	**38.94**	**17.10**	**20.56**	**14.73**
3rd Quartile (h)	97.87	33.23	45.79	22.17	130.9	45.61	44.12	21.93
Exited pool to collection chan	11	12	12	29				
1st Quartile (h)	13.17	11.24	25.13	18.16				
Median (h)	**27.43**	**20.69**	**37.55**	**25.39**				
3rd Quartile (h)	191.1	30.65	80.00	42.61				
Exited pool to tailrace	39	65	93	239	48	105	28	59
1st Quartile (h)	21.92	16.47	18.45	18.16	14.54	24.29	13.71	17.80
Median (h)	**40.45**	**28.01**	**26.35**	**25.39**	**33.16**	**46.59**	**24.17**	**25.24**
3rd Quartile (h)	110.7	46.01	40.43	42.61	88.48	68.58	31.21	43.26

Between 55 and 69% of Chinook salmon that exited the OR-shore transition pool into the tailrace took > 24 h to pass the dam each year (Figure 16). Percentages that took > 24 h to pass the dam were lower for fish that moved straight through, delayed or exited the pool into the collection channel than for those that exited into the tailrace except in 2000 when 75% of those

that moved back to the OR-shore collection channel took > 24 h to pass (Figure 16). Between 43 and 77% of fish that exited the WA-shore pool took > 24 h to pass the dam; proportions for fish that exited were higher than proportions for other categories in 1998 and 2001, but were only marginally different in 1997 and 2000 (Figure 16).

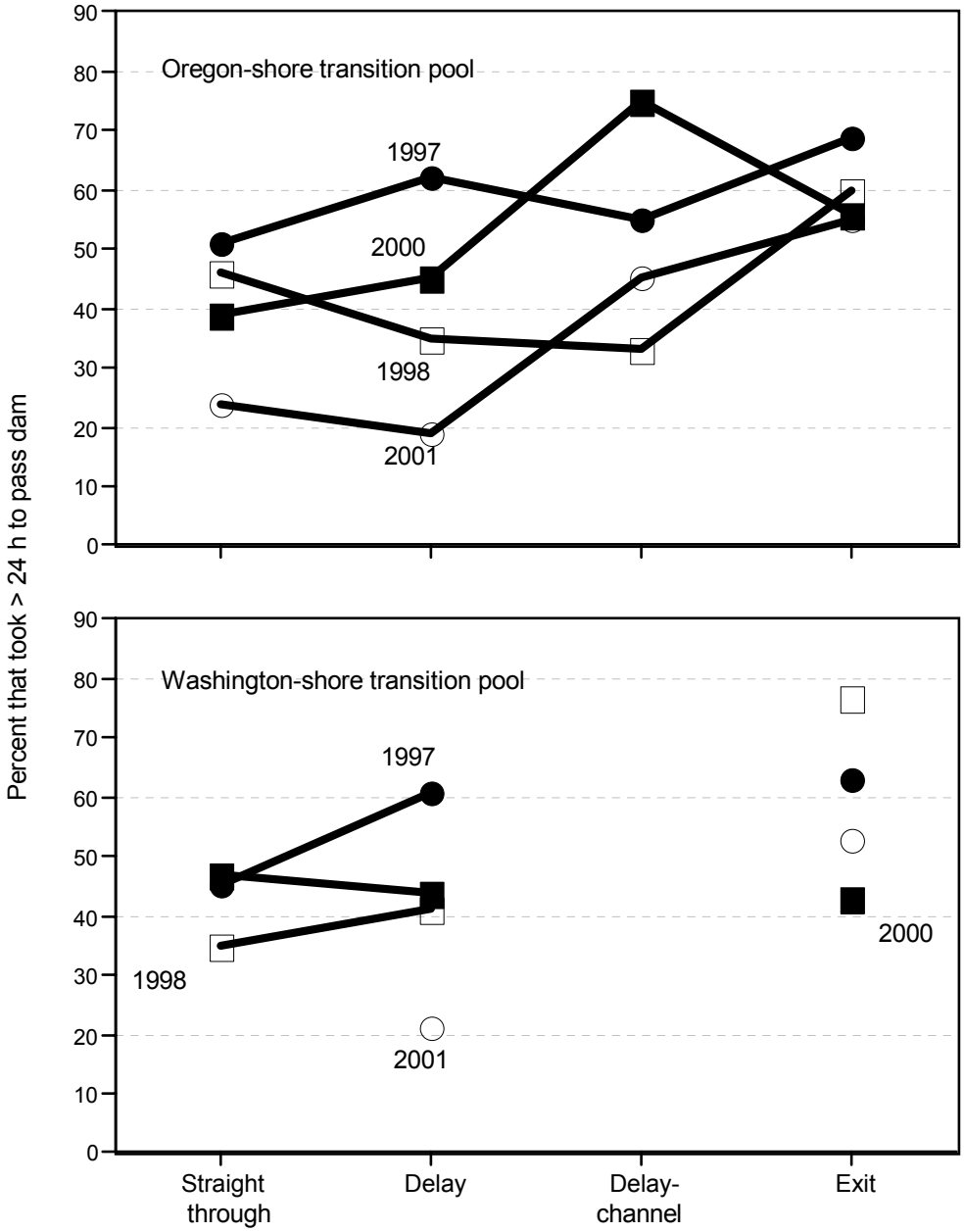

Figure 16. Percent of spring–summer Chinook salmon that took > 24 h to pass The Dalles Dam based on behavior in the OR- and WA-shore transition pools.

As with both transition pools combined (Table 33), fish that exited the OR-shore transition pool had the longest dam passage times in almost every month of each year (Table 35; Figure 17). Compared to fish that moved straight through a transition pool in April, fish that exited took 4 to 45 h (~ 18 h on average) longer in April. Median times were 5 to 16 h (~ 10 h on average)

longer for fish that exited in May, 9 to 23 h (~ 15 h on average) longer in June and 2 to 13 h (~ 9 h on average) longer in July (Table 35).

Table 35. Number of adult radio-tagged Chinook salmon, and median times (h) to pass from first tailrace record to pass The Dalles 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	13	**98.4**	13	**32.1**	23	**36.4**	74	**21.7**
May	26	**35.7**	19	**24.3**	30	**21.7**	27	**13.9**
June	15	**16.2**	9	**18.0**	15	**7.0**	23	**11.4**
July	11	**9.3**	7	**12.8**	11	**9.3**	16	**7.8**
All months	65	**24.3**	48	**20.1**	79	**19.9**	140	**17.3**
Moved downstream, no tailrace[1]								
April	18	**232.2**	14	**28.4**	45	**33.9**	89	**23.1**
May	59	**56.1**	35	**18.4**	77	**22.9**	45	**13.2**
June	16	**15.4**	10	**21.2**	19	**13.0**	28	**7.7**
July	11	**9.6**	16	**11.0**	8	**11.5**	28	**8.7**
All months	104	**33.5**	75	**18.4**	149	**21.4**	190	**16.3**
Exited pool to tailrace								
April	5	**143.4**	11	**42.7**	15	**40.5**	69	**35.8**
May	16	**51.8**	28	**30.3**	30	**26.3**	57	**28.6**
June	8	**39.0**	13	**25.8**	27	**26.4**	59	**20.2**
July	10	**20.4**	13	**15.0**	20	**18.6**	51	**21.2**
All months	39	**40.5**	65	**28.0**	92	**26.4**	236	**25.4**

[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 some months (Table 36). We compared median dam passage times for those combinations with > 10 fish that exited and delayed in individual months of each year. Those that exited in April took about 30 h longer to pass the dam than those that delayed in April in 1997 and 2001. Those that exited took 14 to 35 h longer than those that delayed in May of 1997, 1998 and 2001. Delays were 5 to 28 h for those that exited in June of 1997, 1998 and 2000 and about 7 h for those that exited in July 1998 (Table 36).

***Steelhead*:**

Transition pool selection and behavior in pools -- We analyzed behavior of 181 to 697 steelhead with complete passage histories as they moved into fishways, through transition pools and up ladders at The Dalles Dam in three years; another 34 to 94 fish had complete tailrace, transition pool and top-of-ladder histories but were not recorded on their first fishway

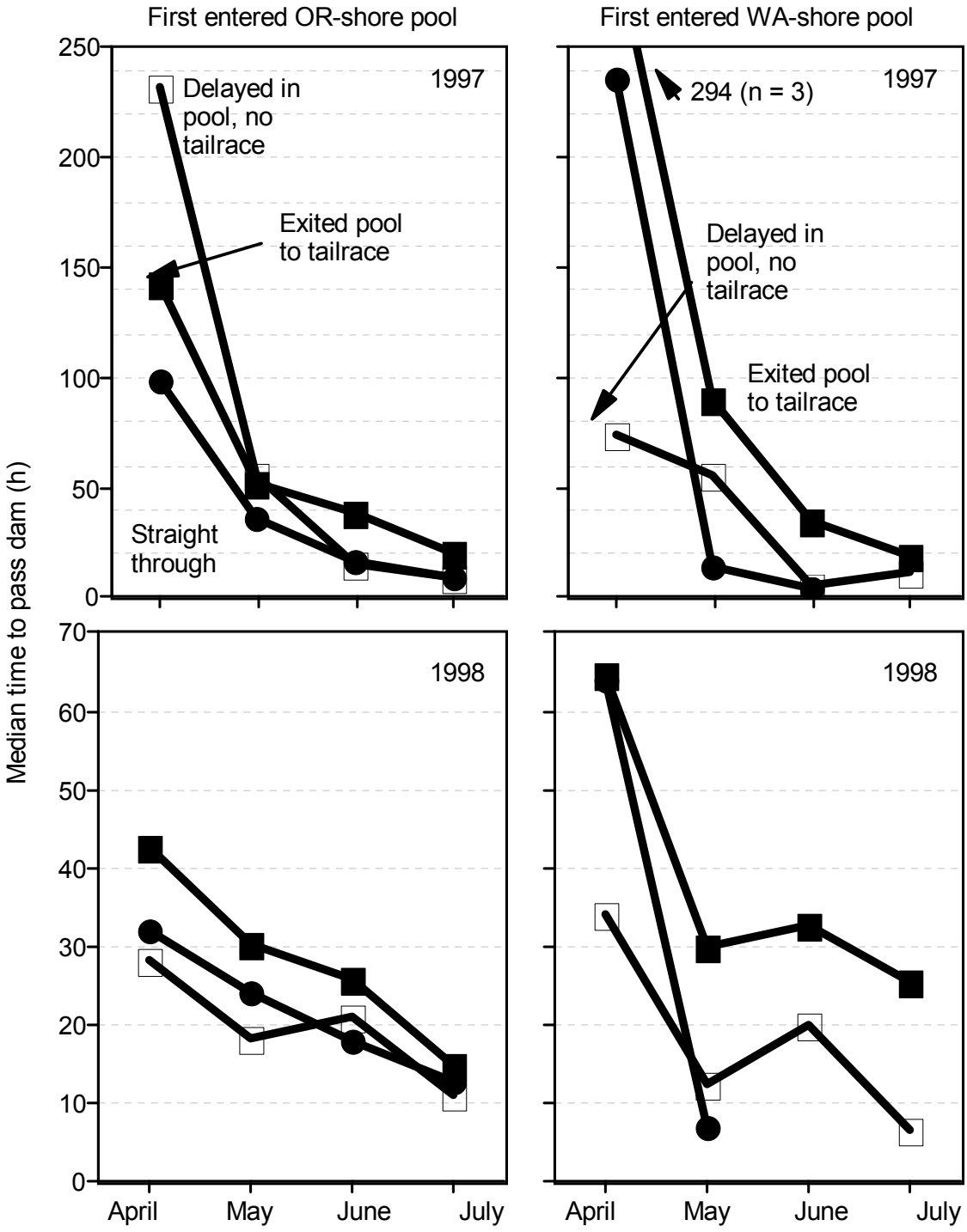

Figure 17. Median time for spring–summer Chinook salmon to pass from the first tailrace record over The Dalles Dam, based on transition pool behavior and month fish first entered the tailrace. Sample sizes in Tables 35 and 36.

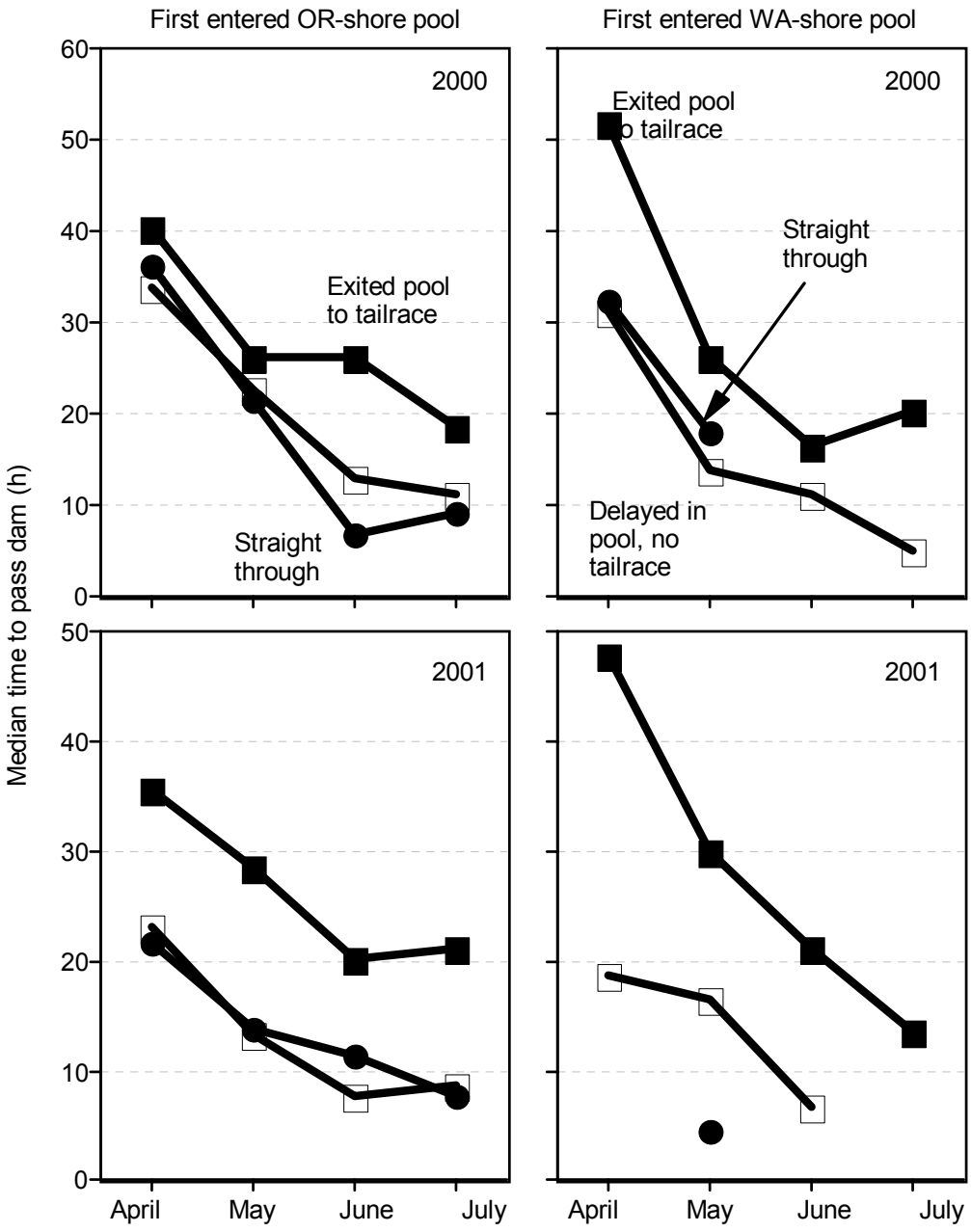

Figure 17. (continued)

entry (Table 37). 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.

Most fish (86 to 90%) passed the dam via the same transition pool they first entered, while remainders (10 to 14%) exited the first transition pool they entered, crossed the tailrace and passed the dam via the other fishway (Figure 18). Between 78 and 86% first entered the transition pool at the bottom of the OR-shore ladder and passed the dam via the OR-shore ladder each year. Four to 8% first entered the pool at the bottom of the WA-shore ladder and passed via the WA-shore ladder. One to 5% first entered the transition pool in the OR-shore

Table 36. Number of adult radio-tagged Chinook salmon, and median times (h) to pass from first tailrace record to pass The Dalles 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	4	**236.0**	5	**64.0**	9	**32.6**	-	**-**
May	5	**13.7**	8	**7.0**	6	**18.0**	1	**4.6**
June	2	**3.7**	2	**35.3**	-	**-**	-	**-**
July	-	**-**	1	**9.3**	-	**-**	-	**-**
All months	11	**13.7**	16	**11.2**	15	**20.8**	-	**4.6**
Moved downstream, no tailrace[1]								
April	53	**74.1**	42	**34.0**	61	**31.2**	19	**18.8**
May	59	**55.2**	68	**12.6**	49	**13.8**	26	**16.6**
June	10	**6.1**	23	**20.2**	17	**11.4**	8	**6.8**
July	19	**11.2**	7	**6.7**	3	**5.1**	2	**18.3**
All months	141	**38.9**	140	**17.1**	130	**20.5**	55	**15.9**
Exited pool to tailrace								
April	3	**293.9**	44	**64.5**	5	**51.8**	12	**47.9**
May	13	**90.0**	41	**29.9**	4	**26.3**	17	**30.1**
June	13	**34.5**	8	**32.8**	14	**16.5**	16	**21.2**
July	19	**19.0**	12	**25.4**	5	**20.5**	13	**13.5**
All months	48	**33.2**	105	**46.6**	28	**21.5**	58	**25.2**

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

Table 37. Transition pool behavior by adult radio-tagged steelhead and sockeye salmon at The Dalles 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	181		600		697		234	
Moved straight through pool	89	**49.2**	152	**25.3**	150	**21.5**	68	**29.1**
Moved downstream, but didn't exit	37	**20.4**	171	**28.5**	220	**31.6**	105	**44.9**
Exited pool to collection channel	8	**4.4**	9	**1.5**	23	**7.6**	4	**1.7**
Exited pool to tailrace	47	**26.0**	268	**44.7**	304	**43.6**	57	**24.4**
All records except fishway entry								
N	94		28		34		89	
Moved straight through pool	46	**48.9**	6	**21.4**	11	**32.4**	40	**44.9**
Moved downstream, but didn't exit	17	**18.1**	6	**21.4**	4	**11.8**	28	**31.5**
Exited pool to collection channel	5	**5.3**	1	**3.6**	3	**8.8**	4	**4.5**
Exited pool to tailrace	26	**27.7**	15	**53.6**	16	**47.1**	17	**19.1**

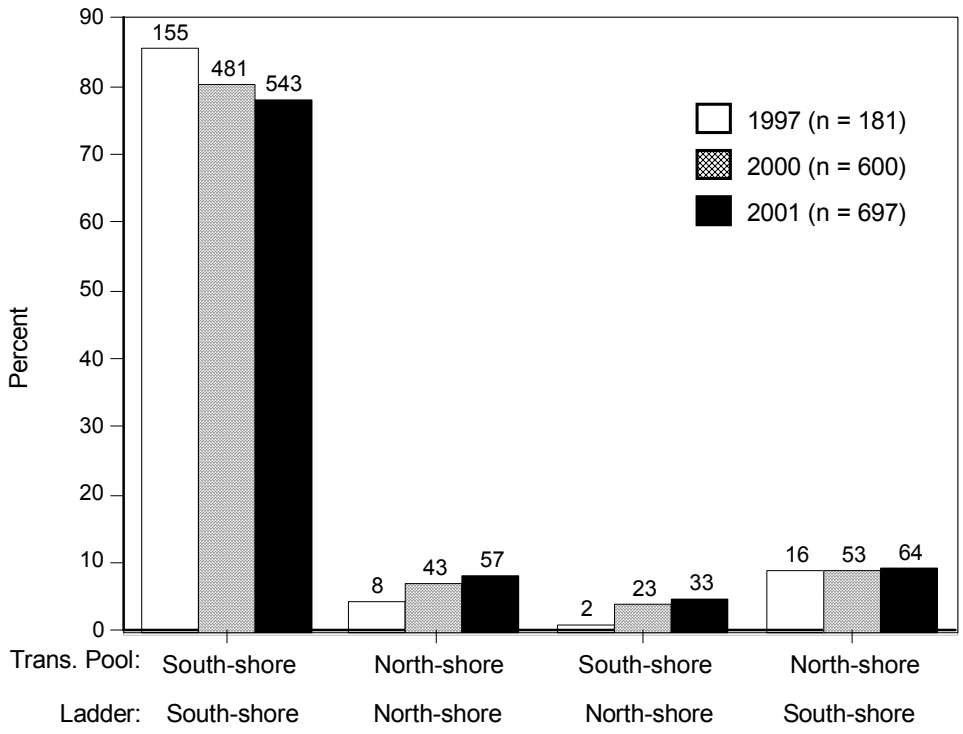

Figure 18. Number of steelhead with telemetry records at all passage points that passed The Dalles Dam, the transition pool first entered, and the ladder used to pass the dam.

fishway, exited the pool into the tailrace and passed the dam via the WA-shore ladder. About 9% first entered the WA-shore transition pool, but passed the dam via the OR-shore ladder (Figure 18).

Twenty-two to 49% of fish with complete passage histories moved straight through a transition pool and entered a ladder with no downstream movement (Table 37). Twenty to 32% 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. Two to 8% 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: 26% in 1997, 45% in 2000 and 44% in 2001 (Table 37).

Far more steelhead (> 80%) first entered the OR- than WA-shore transition pool in all years. Nineteen to 42% of fish that first entered the OR-shore pool and 58 to 71% that first entered the WA-shore pool exited into the tailrace (Table 38). Higher percentages (29 to 54%) moved straight through the OR-shore transition pool than through the WA-shore pool (2 to 17%) in all years, but antenna configurations in the WA-shore pool may have led to underestimates of straight-through behavior. Between 22 and 30% delayed in the OR-shore pool, but were not recorded in the collection channel or in the tailrace; 13 to 41% delayed in the WA-shore pool (Table 38).

Proportions that exited the OR-shore transition pool into the tailrace tended to decrease as the migration progressed in 2000 and 2001 and stayed at relatively low levels in 1997 (Figure 19). 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 and no clear pattern emerged for the three years.

Table 38. Transition pool behavior by adult radio-tagged steelhead and sockeye salmon at The Dalles 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	157		504		576		94	
Moved straight through pool	85	**54.1**	148	**29.4**	148	**25.7**	54	**57.4**
Moved downstream, but didn't exit	34	**21.7**	138	**27.4**	171	**29.7**	20	**21.3**
Exited pool to collection channel	8	**5.1**	9	**1.8**	23	**4.0**	4	**4.3**
Exited pool to tailrace	30	**19.1**	209	**41.5**	234	**40.6**	16	**17.0**
First entered WA-shore pool								
N	24		96		121		140	
Moved straight through pool	4	**16.7**	4	**4.2**	2	**1.7**	14	**10.0**
Moved downstream, but didn't exit	3	**12.5**	33	**34.4**	49	**40.5**	85	**60.7**
Exited pool to collection channel	-	**-**	-	**-**	-	**-**	-	**-**
Exited pool to tailrace	17	**70.8**	59	**61.5**	70	**57.9**	41	**29.3**

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. Median times to first enter the OR-shore transition pool for all fishway entrances combined were < 3 min (0.04 h) (Table 39). Median times from first entry at the SSE to first pool entry ranged from 1.8 to 2.3 h in all years, from 0.5 to 1.0 h from first entry at the WPE, and were < 0.02 h (1.2 min) from first entry at the ELE. Almost no steelhead took > 24 h from first fishway entry to first transition pool entry at either fishway (Table 39).

Steelhead behavior in transition pools (pass straight through, delay, exit) was not a good predictor of differences in time to first enter a pool. Tests of median times from first fishway entry to first pool entry between behavior groups produced some significant ($P < 0.05$) results, but differences were generally < 5 min and 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 0.5 to 1.3 h for both ladders combined; medians were 0.4 to 1.1 h for the OR-shore pool and 2.6 to 3.5 h for the WA-shore pool (Table 40). Fish that moved straight through a transition pool on their first attempt, with no recorded downstream movements, had median passage times < 0.25 h (15 min) (Table 41). 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 0.4 to 0.7 h through both transition pools in all years. Median times were 2.0 to 3.8 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

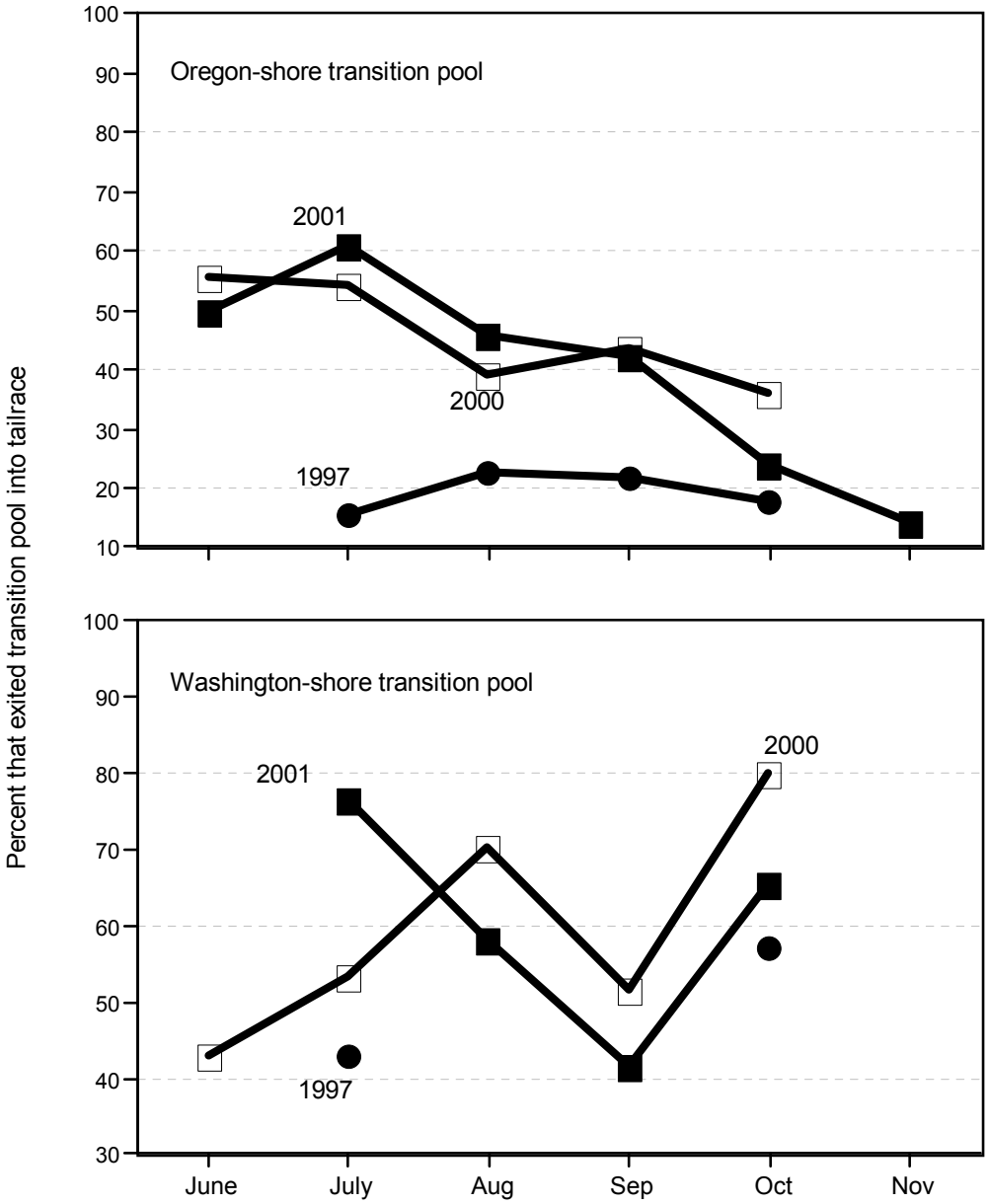

Figure 19. Percent of steelhead that exited transition pools into the tailrace at The Dalles Dam by month each fish first entered a transition pool. Only includes fish with complete dam passage histories.

pool into the tailrace had median times from 13.4 to 25.5 h from first pool entry to exit into the ladder; medians for those that exited the WA-shore pool into the tailrace were 5.9 to 10.9 h (Table 41). Between 18 and 53% 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 40). In 1997, 17% of the fish that exited the OR-shore pool into the tailrace took more than 2 d to pass into the ladder.

Table 39. 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 The Dalles Dam.

	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	157	504	576	94	24	96	121	140
1st Quartile (h)	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01
Median (h)	**0.04**	**0.00**	**0.01**	**0.04**	**0.01**	**0.01**	**0.01**	**0.01**
3rd Quartile (h)	1.08	0.52	1.18	0.67	0.02	0.02	0.01	0.01
Percent that took > 24 h	0.0%	0.2%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%

	Both fishways combined			
	Steelhead			SK
First fishway entry to first pool	1997	2000	2001	1997
N	181	600	697	234
1st Quartile (h)	0.01	0.00	0.00	0.01
Median (h)	**0.03**	**0.00**	**0.01**	**0.01**
3rd Quartile (h)	0.98	0.34	0.97	0.04
Percent that took > 24 h	0.0%	0.2%	0.4%	0.0%

Table 40. 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 The Dalles Dam.

	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	157	504	576	94	24	96	121	140
1st Quartile (h)	0.20	0.23	0.29	0.09	0.98	0.67	0.44	0.48
Median (h)	**0.39**	**0.85**	**1.13**	**0.23**	**2.69**	**3.45**	**2.59**	**1.14**
3rd Quartile (h)	1.69	7.68	7.83	1.96	6.95	15.22	15.41	2.63
Percent that took > 24 h	10%	11%	13%	7.4%	13%	15%	12%	2.1%

	Both fishways combined			
	Steelhead			SK
First pool to last pool	1997	2000	2001	1997
N	181	600	697	234
1st Quartile (h)	0.21	0.25	0.31	0.19
Median (h)	**0.45**	**1.13**	**1.26**	**0.80**
3rd Quartile (h)	2.66	9.06	9.28	2.39
Percent that took > 24 h	11%	11%	13%	4.7%

Table 41. 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 The Dalles Dam based on fish behavior in each pool.

	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	85	148	148	54	4	4	2	14
1st Quartile (h)	0.15	0.16	0.19	0.07	0.13	0.13	0.12	0.09
Median (h)	**0.21**	**0.19**	**0.25**	**0.11**	**0.14**	**0.20**	**0.12**	**0.12**
3rd Quartile (h)	0.29	0.25	0.32	0.19	0.19	0.26	0.13	0.16
Moved downstream, didn't exit	34	138	171	20	3	33	49	85
1st Quartile (h)	0.42	0.27	0.29	0.34	0.32	0.37	0.28	0.48
Median (h)	**0.74**	**0.42**	**0.44**	**0.94**	**0.33**	**0.53**	**0.43**	**0.83**
3rd Quartile (h)	1.43	0.85	0.78	1.56	0.80	0.88	0.70	1.51
Exited pool to collection chan	8	9	23	4	N/A			
1st Quartile (h)	1.05	2.68	1.64	2.30				
Median (h)	**1.95**	**3.77**	**2.23**	**2.39**				
3rd Quartile (h)	3.94	4.46	3.20	3.34				
Exited pool to tailrace	30	209	234	16	17	59	70	41
1st Quartile (h)	6.54	3.67	5.06	7.64	2.52	4.04	3.57	2.73
Median (h)	**25.50**	**13.44**	**14.04**	**18.66**	**5.91**	**10.86**	**10.74**	**7.11**
3rd Quartile (h)	38.19	24.06	27.31	30.25	11.24	22.83	21.38	15.20
Percent that took > 24 h	53%	26%	31%	44%	18%	24%	21%	10%

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 ($P < 0.001$, K-W χ^2 tests); too few steelhead passed straight through the WA-shore pool for meaningful tests.

Passage time to ascend a ladder – After exiting transition pools into ladders, steelhead ascended ladders relatively quickly at The Dalles Dam in all years. Median times to ascend both the OR- and WA-shore ladders were 1.7 to 2.4 h (Table 42). More than 75% of the fish ascended ladders in < 3 h and < 1% took more than 24 h to ascend. Steelhead behavior in the OR-shore transition pool (pass straight through, delay, exit) did not significantly affect ladder ascension times ($P > 0.05$) except for three comparisons where fish that exited in 2000 and 2001 passed up the ladder from 8 to 11 minutes faster than fish that delayed or moved straight through the pool ($P < 0.04$, K-W χ^2 tests); differences were probably not biologically significant. Similarly, behavior in the WA-shore pool did not appear to substantively affect ladder ascension times in any year.

Table 42. Number 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 The Dalles Dam based on the transition pool first entered.

	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	157	504	576	94	24	96	121	140
1st Quartile (h)	1.57	1.37	1.68	1.58	1.91	1.43	1.72	1.29
Median (h)	**1.85**	**1.66**	**2.01**	**1.83**	**2.42**	**1.68**	**2.06**	**1.47**
3rd Quartile (h)	2.34	2.09	2.66	2.23	3.28	2.24	2.98	1.82
Percent that took > 24 h	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.8%	0.0%

	Both fishways combined[1]			
	Steelhead			SK
Last pool record to pass dam	1997	2000	2001	1997
N	181	600	697	234
1st Quartile (h)	1.58	1.38	1.69	1.36
Median (h)	**1.89**	**1.66**	**2.02**	**1.62**
3rd Quartile (h)	2.54	2.13	2.67	1.98
Percent that took > 24 h	0.0%	0.0%	0.4%	0.0%

[1] includes fish that passed via either ladder

Passage time from first tailrace record to pass the dam – Steelhead behavior in transition pools was a good predictor of overall time to pass The Dalles 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 in all years ($P < 0.0001$, 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 15.8 h (Table 43). Median times for fish that exited to the tailrace were 11.2 to 16.7 h longer than fish for that delayed. Differences in median times between fish that moved straight through and those that delayed were < 1 h in all years.

Unlike for spring–summer Chinook salmon, no clear patterns emerged between dam passage time and month of passage by steelhead (Figure 20). 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 the fish in other categories in each month. Fish that exited to the tailrace in summer months 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 (Figure 20). To facilitate statistical comparisons, fish that exited a pool into the collection channel were combined with those that delayed in a pool for Table 43 and Figure 15.

In June, fish that exited to the tailrace had longer median dam passage times than those that moved straight through or delayed in 2001 ($P < 0.01$). No other differences between behavior groups were significant for June ($P > 0.20$) in any year, in part because sample sizes were small. Fish that exited in July had longer passage times than the other groups in 2001 ($P < 0.001$) and than those that delayed in 2000 ($P = 0.02$). Fish that exited in August had longer

Table 43. Number of adult radio-tagged steelhead and sockeye salmon, and median times (h) to pass from first tailrace record to pass The Dalles 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.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
All fish	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
All months	181	**14.1**	600	**15.9**	697	**16.6**	234	**6.6**
Moved straight through pool								
June	-	**-**	3	**8.5**	8	**17.1**	24	**8.7**
July	9	**16.9**	12	**16.0**	13	**16.2**	42	**8.4**
August	9	**9.8**	25	**15.8**	16	**12.7**	2	**10.3**
September	24	**10.9**	72	**10.9**	55	**12.3**	-	**-**
October	46	**13.9**	40	**9.0**	56	**12.5**	-	**-**
November	1	**17.4**	-	**-**	2	**61.2**	-	**-**
All months	89	**12.4**	152	**11.5**	150	**12.9**	68	**8.4**
Moved downstream, no tailrace[1]								
June	2	**19.2**	5	**7.5**	15	**15.0**	45	**4.6**
July	8	**17.6**	10	**10.4**	29	**13.6**	63	**4.3**
August	6	**9.5**	23	**11.4**	35	**12.4**	1	**12.8**
September	15	**10.4**	85	**11.9**	87	**11.4**	-	**-**
October	13	**22.6**	52	**12.9**	71	**13.7**	-	**-**
November	1	**9.1**	5	**23.3**	6	**11.5**	-	**-**
All months	45	**11.5**	180	**12.1**	243	**12.6**	109	**4.5**
Exited pool to tailrace								
June	-	**-**	8	**15.9**	28	**24.1**	27	**17.7**
July	5	**16.0**	26	**26.6**	67	**31.6**	30	**10.8**
August	9	**31.7**	46	**22.3**	55	**26.8**	-	**-**
September	17	**32.7**	125	**23.4**	99	**23.2**	-	**-**
October	15	**21.7**	63	**23.9**	54	**24.1**	-	**-**
November	1	**28.3**	-	**-**	1	**11.2**	-	**-**
All months	47	**28.2**	268	**23.3**	304	**24.7**	57	**13.5**

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

passage times than the other groups in all years ($P < 0.005$ in 2000 and 2001; $P < 0.02$ in 1997). Fish that exited in September or October had longer passage times than the other groups in all years ($P < 0.001$). The difference in median times between fish that moved straight through or delayed was only significant in October 2000, when fish that moved straight through had a median 3.9 h shorter than those that delayed ($P = 0.02$).

Similar patterns emerged when we considered transition pools separately (Table 44). Compared to other behavior groups, steelhead that exited from the OR-shore transition pool into the tailrace were delayed 21 to 22 h in 1997 and 12 to 13 h in 2000 and 2001. Fish that exited the WA-shore pool were delayed 9 to 14 h compared to those that hesitated in the transition pool; small sample sizes limited comparisons for fish that moved straight through the WA-shore pool.

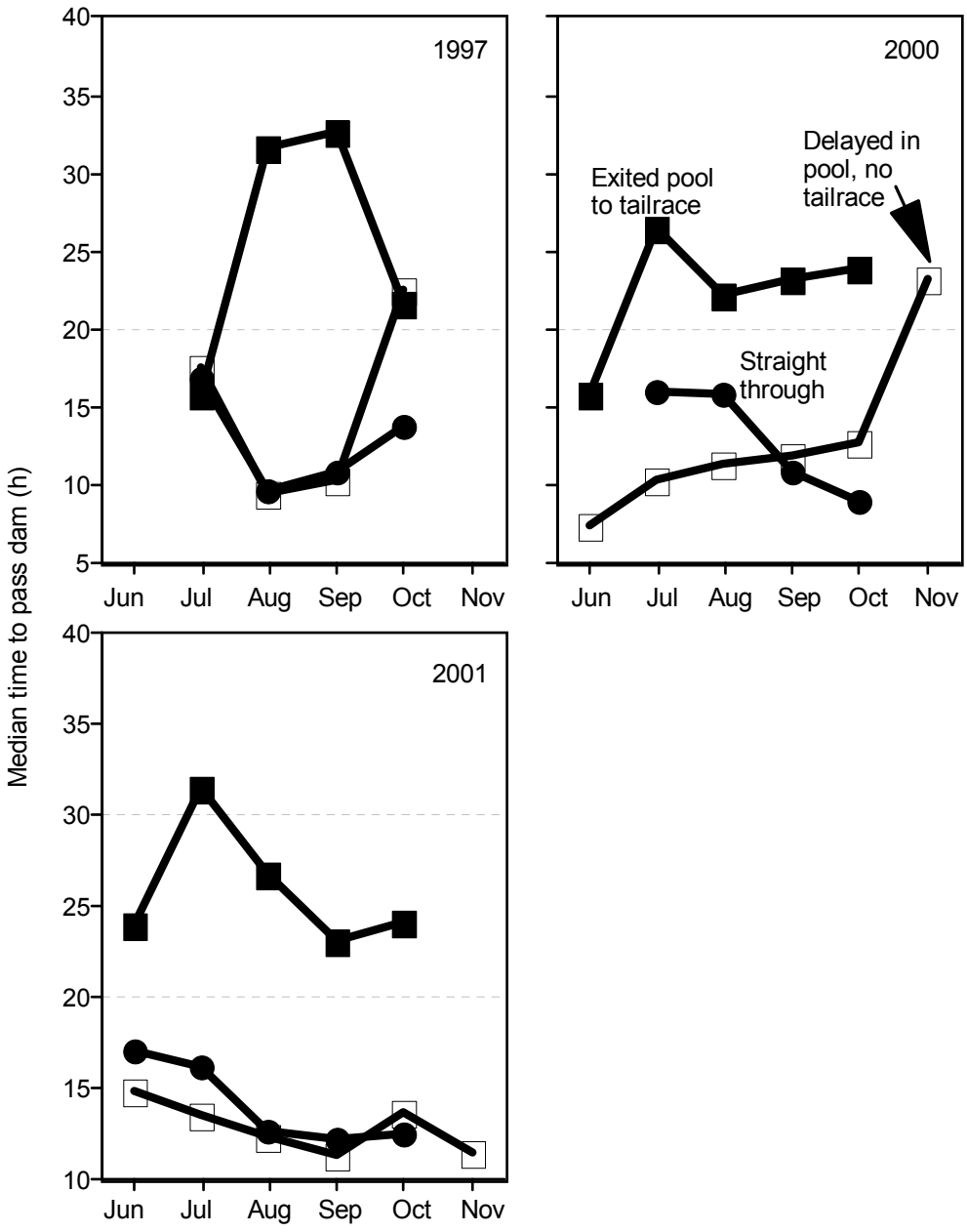

Figure 20. Median time for steelhead to pass from the first tailrace record over The Dalles Dam, based on transition pool behavior and month. Sample sizes in Table 43.

Between 51 and 70% of steelhead that exited the OR-shore transition pool into the tailrace took > 24 h to pass the dam in each year (Figure 21), versus < 22% of fish that moved straight through, delayed, or exited the pool into the collection channel. Between 29 and 41% of fish that exited the WA-shore pool took > 24 h to pass the dam, compared to < 10% for fish that had other behaviors (Figure 21).

As with both transition pools combined (Table 43), fish that exited the OR-shore transition pool had the longest dam passage times in almost every month of each year (Table 45). Compared to fish that moved straight through a transition pool, fish that exited took 11 to 25 h

Table 44. 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 The Dalles Dam.

	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	85	148	148	54	4	4	2	14
1st Quartile (h)	8.45	7.34	8.18	6.48	17.95	6.33	16.12	2.79
Median (h)	**12.32**	**11.68**	**12.77**	**10.38**	**26.99**	**8.79**	**16.44**	**3.05**
3rd Quartile (h)	16.76	17.97	18.73	15.23	130.9	13.20	16.77	4.07
Moved downstream, didn't exit	34	138	171	20	3	33	49	85
1st Quartile (h)	8.76	8.66	9.30	6.23	10.30	6.46	5.39	3.26
Median (h)	**11.88**	**12.15**	**13.67**	**7.70**	**14.07**	**8.48**	**7.83**	**4.10**
3rd Quartile (h)	21.80	18.02	19.17	9.96	21.44	12.43	12.59	5.19
Exited pool to collection chan	8	9	23	4	N/A			
1st Quartile (h)	9.37	14.37	8.97	11.97				
Median (h)	**10.79**	**16.92**	**13.85**	**13.70**				
3rd Quartile (h)	13.70	19.79	16.82	15.63				
Exited pool to tailrace	30	209	234	16	17	59	70	41
1st Quartile (h)	17.60	14.90	18.11	13.32	10.03	12.36	14.46	5.59
Median (h)	**33.00**	**24.19**	**26.02**	**24.36**	**15.98**	**17.35**	**21.83**	**11.90**
3rd Quartile (h)	49.63	40.52	47.05	35.38	28.20	29.31	37.18	21.66

(*medians*) longer to pass the dam in all months of all years (comparisons for months with > 5 fish in each category only). Median delays of > 20 h were observed for August of 1997 and 2001 and September of 1997 (Table 45). Median times were 9 to 25 h longer for fish that exited than for those that delayed in a pool in all months of all years (Table 45).

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 except September 2001 (Table 46). For combinations with > 10 fish that exited and delayed in individual months of each year, exit fish took 7.8 and 11.1 h longer than those that delayed in September of 2000 and 2001, respectively ($P < 0.001$, K-W χ^2 tests). Those that exited in August 2001 took 16.7 h longer than those that delayed that month ($P < 0.0001$).

Sockeye salmon:

Transition pool selection and behavior in pools – We analyzed behavior of 234 sockeye salmon with complete passage histories as they moved into fishways, through transition pools and up ladders at The Dalles Dam in 1997; another 89 fish had complete tailrace, transition pool and top-of-ladder histories but were not recorded on their first fishway entry (Table 37). Fish that missed antennas behaved like those with complete records.

Most sockeye salmon (89%) passed the dam via the same transition pool they first entered; 11% exited the first pool they entered, crossed the tailrace and passed the dam via the other fishway. Thirty-eight percent first entered the transition pool at the bottom of the OR-shore ladder and passed the dam via the OR-shore ladder, 51% first entered the pool at the bottom

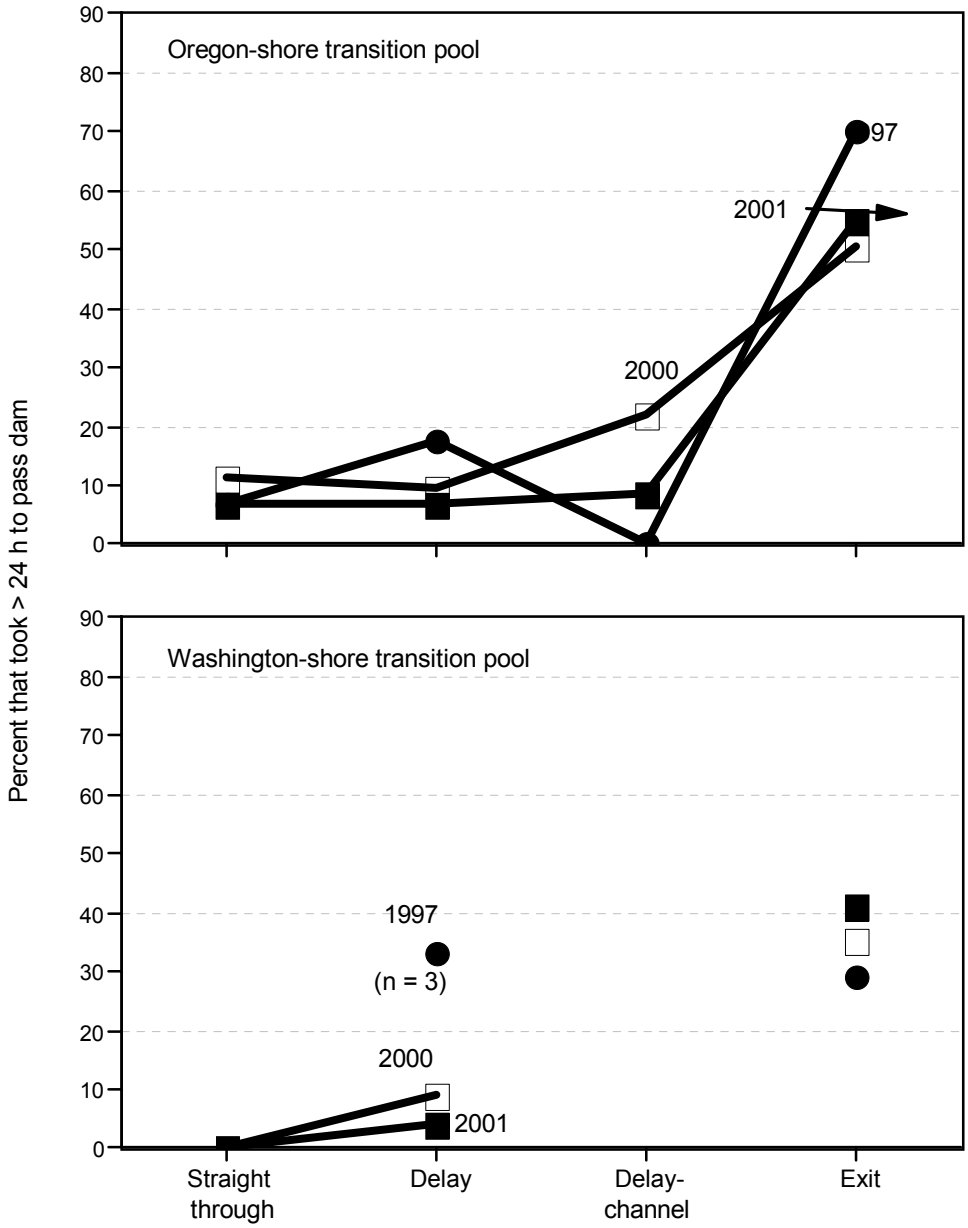

Figure 21. Percent of steelhead that took > 24 h to pass The Dalles Dam based on behavior in the OR- and WA-shore transition pools.

of the WA-shore ladder and passed via the WA-shore ladder. Two percent first entered the OR-shore pool, but passed the dam via the WA-shore ladder, and 9% first entered the WA-shore pool, but passed via the OR-shore ladder.

Twenty-nine percent of the fish with complete passage histories moved straight through a transition pool and entered a ladder with no downstream movement, and 45% delayed in a transition pool without exiting to the collection channel or tailrace (Table 37). Two percent exited the OR-shore transition pool into the collection channel but did not exit into the tailrace. The remaining 24% exited a pool into the tailrace before passing the dam (Table 37).

Table 45. Number of adult radio-tagged steelhead and sockeye salmon, and median times (h) to pass from first tailrace record to pass The Dalles 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.

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Moved straight through pool	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
June	-	**-**	3	**8.5**	8	**17.1**	23	**9.6**
July	7	**14.2**	11	**15.9**	12	**15.0**	30	**10.4**
August	9	**9.8**	24	**16.4**	16	**12.7**	1	**16.6**
September	24	**10.9**	71	**11.0**	54	**12.3**	-	**-**
October	44	**13.9**	39	**9.4**	56	**12.5**	-	**-**
November	-	**-**	-	**-**	2	**61.2**	-	**-**
All months	85	**12.3**	148	**11.7**	148	**12.8**	54	**10.4**
Moved downstream, no tailrace[1]								
June	2	**19.2**	1	**13.7**	15	**15.0**	13	**8.0**
July	6	**15.2**	4	**12.0**	25	**14.5**	10	**8.7**
August	6	**9.5**	16	**11.4**	21	**13.6**	1	**12.8**
September	15	**10.4**	71	**12.1**	66	**13.6**	-	**-**
October	12	**22.9**	50	**13.2**	63	**13.7**	-	**-**
November	-	**-**	5	**23.3**	4	**12.1**	-	**-**
All months	42	**11.3**	147	**12.3**	194	**13.8**	24	**8.2**
Exited pool to tailrace								
June	-	**-**	5	**17.1**	24	**24.4**	9	**32.5**
July	2	**20.6**	18	**27.0**	54	**33.1**	7	**22.3**
August	5	**31.7**	27	**32.5**	34	**37.6**	-	**-**
September	12	**35.7**	109	**23.8**	84	**23.3**	-	**-**
October	11	**33.3**	50	**25.7**	37	**24.8**	-	**-**
November	-	**-**	-	**-**	1	**11.2**	-	**-**
All months	30	**33.0**	209	**24.2**	234	**26.0**	16	**24.4**

[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 (60%) first entered the WA- than OR-shore transition pool. Seventeen percent of fish that first entered the OR-shore pool and 29% that first entered the WA-shore pool exited into the tailrace (Table 38). A higher percentage (57%) moved straight through the OR-shore transition pool than through the WA-shore pool (10%) in 1997, although the antenna configuration in the WA-shore pool may have led to underestimates of straight-through behavior. Twenty-one percent delayed in the OR-shore pool; 61% delayed in the WA-shore pool (Table 38).

Percentages that exited OR- and WA-shore transition pools into the tailrace were higher in June than in July: 20% exited the OR-shore pool in June, 15% exited in July; 35% exited the WA-shore pool in June, versus 26% in July.

Table 46. Number of adult radio-tagged steelhead and sockeye salmon, and median times (h) to pass from first tailrace record to pass The Dalles Dam based on month fish were first detected in the tailrace and transition pool behavior in the **WA-shore pool.**

	Steelhead						Sockeye	
	1997		2000		2001		1997	
Moved straight through pool	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**
June	-	**-**	-	**-**	-	**-**	1	**2.8**
July	2	**27.0**	1	**21.0**	1	**17.1**	12	**3.1**
August	-	**-**	1	**4.4**	-	**-**	1	**4.0**
September	1	**16.6**	1	**10.6**	1	**15.8**	-	**-**
October	2	**216.8**	1	**7.0**	-	**-**	-	**-**
November	-	**-**	-	**-**	-	**-**	-	**-**
All months	4	**27.0**	4	**8.8**	2	**16.4**	14	**3.1**
Moved downstream, no tailrace[1]								
June	-	**-**	4	**6.8**	-	**-**	32	**4.2**
July	2	**21.4**	6	**10.4**	4	**8.0**	53	**4.0**
August	-	**-**	7	**10.8**	14	**7.9**	-	**-**
September	-	**-**	14	**8.9**	21	**6.4**	-	**-**
October	1	**6.5**	2	**6.7**	8	**13.0**	-	**-**
November	-	**-**	-	**-**	2	**9.7**	-	**-**
All months	3	**14.1**	33	**8.5**	49	**7.8**	85	**4.1**
Exited pool to tailrace								
June	-	**-**	3	**6.7**	4	**23.0**	18	**16.2**
July	3	**16.0**	8	**19.8**	13	**21.3**	23	**9.5**
August	4	**28.4**	19	**16.2**	21	**24.6**	-	**-**
September	-	**-**	16	**16.7**	15	**17.5**	-	**-**
October	4	**10.5**	13	**22.2**	17	**20.0**	-	**-**
November	1	**28.3**	-	**-**	-	**-**	-	**-**
All months	17	**16.0**	59	**17.4**	70	**21.8**	41	**11.9**

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

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 were < 3 min (0.04 h) (Table 39). Median times to first pool entry were 2.7 h from first fishway entry at the SSE, 1.2 h from first entry at the WPE, and < 0.02 h (1.2 min) from first entry at the ELE. No sockeye salmon took > 24 h from first fishway entry to first transition pool entry at either fishway (Table 39).

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 0.80 h for both ladders combined, 0.23 h for the OR-shore pool,

and 1.14 h for the WA-shore pool (Table 40). Fish that moved straight through a transition pool on their first attempt, with no recorded downstream movements, had median times < 0.12 h (7 min) (Table 41). Fish that delayed in a transition pool by moving downstream had median passage times from 0.8 to 0.9 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 2.4 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 18.7 h from first pool entry to exit into the ladder; the median for those that exited the WA-shore pool into the tailrace was 7.1 h (Table 41). Seven of 16 (44%) sockeye salmon that exited the OR-shore pool into the tailrace and 4 of 41 (10%) that exited the WA-shore pool took more than 24 h to pass through a pool into a ladder, compared to 0% for fish that did not exit to the tailrace (Table 40).

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. Differences between groups with > 5 fish were all significant ($P < 0.001$, K-W χ^2 tests). Patterns were similar for the WA-shore transition pool (Table 40).

Passage time to ascend a ladder – After exiting transition pools into ladders, sockeye salmon ascended ladders quickly at The Dalles Dam. Median times were 1.8 h up the OR-shore ladder and 1.5 h up the WA-shore ladder (Table 42). More than 75% of the fish ascended a ladder in < 3 h and no fish took more than 1 d 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 The Dalles 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 5 h longer than those that moved straight through a transition pool, and 9 h longer than those that delayed in a pool (Table 43). 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.

Similar patterns emerged for each transition pool separately. Fish that exited either the OR- or WA-shore transition pool into the tailrace tended to have longer passage times than fish that moved straight through a pool or delayed in the pool or collection channel each year (Table 44). 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 8 to 9 h compared to those that did not exit; fish that exited the OR-shore pool took 11 to 17 h longer to pass (Table 44).

Fifty percent (8/16) of fish that exited the OR-shore pool to the tailrace took > 24 h to pass the dam, versus 4% (3/78) of fish that moved straight through, delayed, or exited the pool into the collection channel. Twenty-four percent (10/41) of fish that exited the WA-shore pool into the tailrace took > 24 h to pass the dam, versus 0% of 99 that did not exit.

Monthly comparisons were similar. As with both transition pools combined (Table 43), fish that exited the OR-shore transition pool had the longest dam passage times in both June and July (Table 45). Fish that exited took 12 to 23 h (*medians*) longer to pass the dam than fish that moved straight through a transition pool and 14 to 25 h longer than those that delayed in both months ($P < 0.001$, K-W χ^2 tests).

Transition Pool Exits by Salmon: Effects of River Environment

The largest dam passage delays for spring–summer Chinook and sockeye salmon occurred when fish exited transition pools into the tailrace. We evaluated several variables that may have affected pool exit behavior including date, transition pool entry time, tailwater elevation, water temperature and turbidity. Flow and spill levels at the dam should not have affected fish behavior when they were inside fishways and were not included in models.

Tailwater elevation at The Dalles 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 or high turbidity could also create passage deterrents in the pools.

We evaluated exit behavior using univariate and multiple logistic regressions. Logistic models were selected because exit behavior is binary: fish either exited or did not exit a transition pool. The likelihood of Chinook salmon exiting either the OR- or WA-shore transition pools into the tailrace increased significantly ($P < 0.005$) as water temperature increased and with date of migration in 1997, 2000 and 2001, but not in 1998 (Table 47). Exit probabilities for fish entering both transition pools increased 3- to 16-fold over the range of temperatures encountered each year; minimum estimated rates were between 4 and 22% at the lowest temperatures and were 40 to 70% at peak temperatures. Exit probabilities increased significantly with tailwater elevation in 2000 from the OR-shore pool, but decreased significantly from the WA-shore pool in 1998 and 2000. Exits tended to increase with increased turbidity, particularly from the WA-shore pool (Table 47). No univariate models were significant ($P > 0.05$) for sockeye salmon.

Table 47. Results of univariate logistic regression models for Chinook and sockeye salmon that either did or did not exit transition pools into the tailrace, based on date, time, water temperature, tailwater elevation and turbidity at the time fish entered a pool. Arrows indicate direction of regression lines.

	Date	Time	Temperature	Tailwater	Turbidity
			First entered Oregon-shore transition pool		
Chinook 1997	** ▲		** ▲		* ▲
Chinook 1998					
Chinook 2000	** ▲		** ▲	** ▲	
Chinook 2001	** ▲		** ▲		**▼
Sockeye 1997					
			First entered Washington-shore transition pool		
Chinook 1997	** ▲	*▼	** ▲		* ▲
Chinook 1998				**▼	** ▲
Chinook 2000	** ▲		** ▲	**▼	** ▲
Chinook 2001	** ▲		** ▲		
Sockeye 1997					

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

In stepwise multiple logistic regression models, water temperature or date was selected first in all models in 1997, 2000 and 2001. Temperature and date were highly correlated each year, and turbidity was weakly correlated with temperature; we believe temperature was the best explanatory variable. Tailwater elevation was selected second in some models, and first in the 1998 model for the WA-shore transition pool. Relationships between water temperature and

tailwater elevation tended to be parabolic, with the highest elevations occurring at intermediate temperatures (during mid-migration runoff peaks). Given the tendency for Chinook salmon to first turn around in transition pools prior to fishway exit (see Table 11) and the apparent relationship between tailwater elevation and turn-around location in the pools, it seems likely that tailwater elevation contributed to transition pool exit behavior, but that elevation was secondary to temperature. Interactions between the explanatory variables were also possible, though these were not tested.

Circumstances of the Most and Least Efficient Passages

Chinook salmon:

The 10% of radio-tagged spring–summer Chinook salmon that took the longest to pass The Dalles Dam mostly entered the tailrace in mid-April to early May in each year, significantly earlier in the migration than the 10% that passed the dam the most rapidly each year (Figure 22). 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. The 10% that passed the dam the fastest in each year were distributed over a greater proportion of the migration than the slower fish; median arrival dates at the dam for the fastest fish ranged from 18 May in 1998 to 1 July in 1997 (Figure 22).

The 10% of Chinook salmon that passed the dam fastest in 1997 and 2000 encountered median flow levels that were significantly lower ($P < 0.001$, K-W χ^2 tests) than those encountered by the slowest 10% (Table 48). However, flow was higher for fish that passed fastest in 1998, when peak flows occurred several weeks later than in 1997 and 2000. Differences in flow encountered by the fastest and slowest groups were non-significant in low-flow 2001. Differences in spill encountered by Chinook salmon followed patterns similar to those for flow. In all years, median water temperatures were significantly higher (2.8 to 6.3° C) for fish that passed the dam fastest ($P < 0.001$), with the largest differences in 1997 and 2001. Median Secchi disk visibility was higher for fish that passed fastest in 1997 and 2000, but was lower in 1998 and 2001; all differences were significant ($P < 0.01$) (Table 48). Comparisons of the fastest and slowest 25% produced similar results for all environmental variables.

Fishway use – The fastest 10% of Chinook salmon first approached the WA-shore fishway (NLE) at significantly higher rates than the slowest 10% in 1997, 1998, and 2000 ($P < 0.003$, Z tests) (Figure 23). Between 63 and 74% of the fastest fish first approached NLE compared to 18 to 28% of the slowest fish in the three years. More of the fastest fish first approached the NLE in 2001, but the difference was not significant ($P = 0.37$). Significance levels and overall patterns were similar in comparisons of the fastest and slowest 25% (Figure 23). The slowest 10% first approached the SSE at rates 1.8 to 4 times higher than the fastest 10%. Two to 8% of the fastest 10% first approached the WPE in all years, compared to 18 to 36% of the slowest 10%. More of the slowest fish first approached the ELE, but differences were smaller than at the other OR-shore fishway entrances.

The fastest 10% first entered the NLE at higher rates than the slowest 10% in all years (Figure 24). Differences were significant in 2000 ($P = 0.002$, Z test) and 2001 ($P = 0.02$), nearly so in 1998 ($P = 0.06$), but not in 2001 ($P = 0.11$). Comparisons of the fastest and slowest 25% showed no significant ($P > 0.10$) differences in the percentage first entering the NLE in all but 2000 ($P = 0.04$) (Figure 24). More of the slowest 10% first entered the SSE, WPE and ELE in all years, with the largest differences at the SSE.

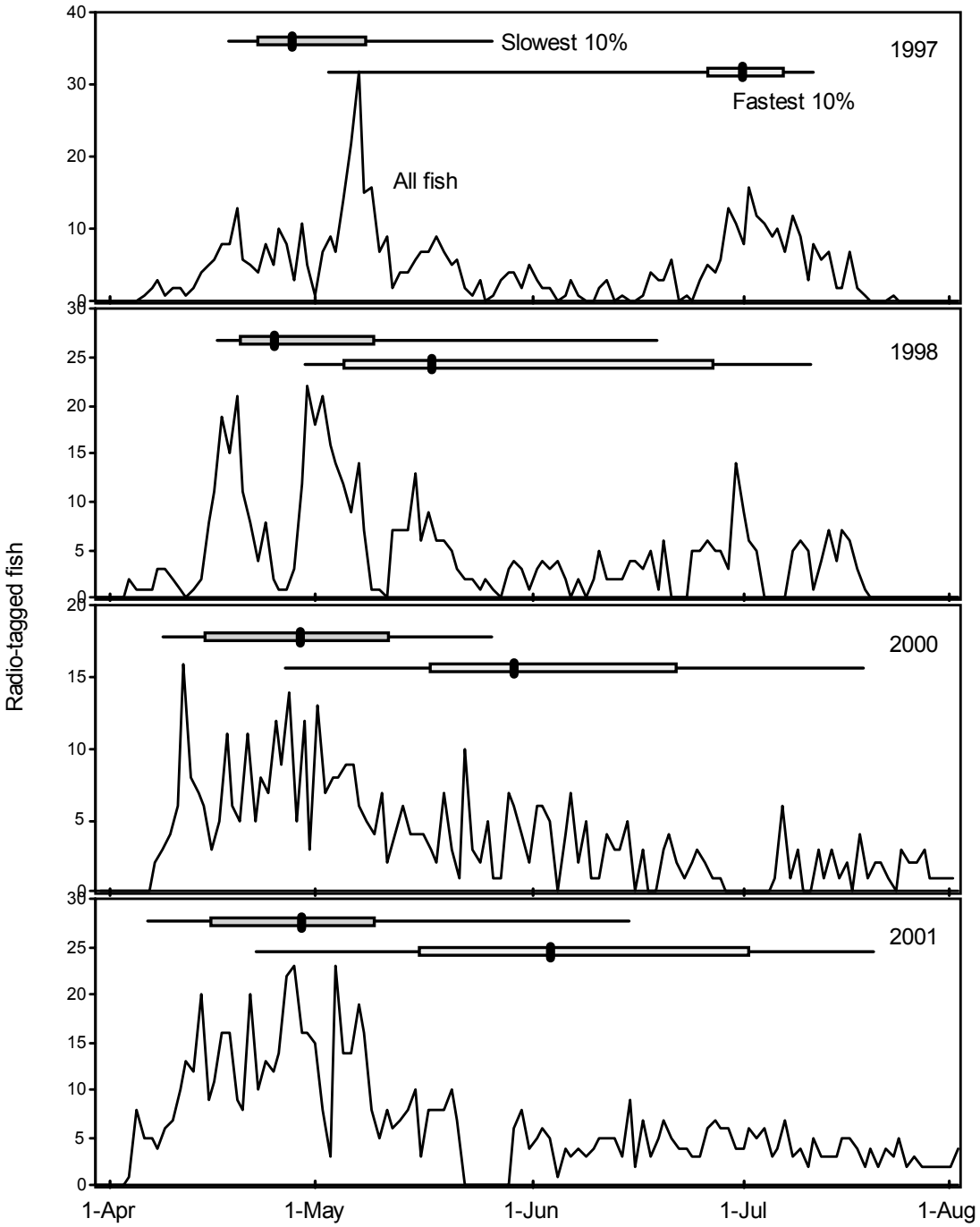

Figure 22. Passage of radio-tagged spring–summer Chinook salmon (lines), with median, quartile, 5th and 95th percentile dates for the 10% (boxplots) that passed the fastest and slowest in each year.

Table 48. Environmental conditions in the tailrace when radio-tagged fish first arrived at The Dalles Dam, for the 10 and 25% that passed the dam fastest and slowest.

		Fastest 10%	Slowest 10%		Fastest 25%	Slowest 25%	
Median flow:	Chinook –1997	306	**427**	***	295	**419**	***
	Chinook – 1998	**286**	206	***	**259**	229	***
	Chinook – 2000	229	**281**	***	230	**276**	***
	Chinook – 2001	**123**	119		118	**119**	
	Steelhead – 1997	**183**	175		173	**182**	
	Steelhead – 2000	108	**113**		108	**116**	**
	Steelhead – 2001	83	**84**		83	83	*
	Sockeye – 1997	288	**315**	***	182	**303**	***
Median spill:	Chinook –1997	192	**284**	***	183	**280**	***
	Chinook – 1998	**128**	78	***	**120**	89	***
	Chinook – 2000	89	**104**		91	**105**	**
	Chinook – 2001	0	0	***	0	0	***
	Steelhead – 1997	0	0		0	0	
	Steelhead – 2000	0	0		0	0	
	Steelhead – 2001	0	0		0	0	*
	Sockeye – 1997	181	**195**	***	183	**189**	**
Med. Temp.:	Chinook – 1997	**16.4**	10.1	***	**16.4**	10.1	***
	Chinook – 1998	**13.7**	10.9	***	**13.7**	12.2	***
	Chinook – 2000	**15.0**	11.1	***	**14.9**	11.0	***
	Chinook – 2001	**16.5**	10.9	***	**16.1**	11.1	***
	Steelhead – 1997	20.1	**20.6**	N/A	20.0	**20.2**	N/A
	Steelhead – 2000	19.4	**19.8**	N/A	19.4	**19.8**	N/A
	Steelhead – 2001	20.3	20.3	N/A	20.2	20.0	N/A
	Sockeye – 1997	17.2	16.4		16.8	16.5	*
Med. Secchi:	Chinook – 1997	**2.0**	1.3	***	**2.0**	1.3	***
	Chinook – 1998	2.5	**2.9**	***	**2.5**	2.7	***
	Chinook – 2000	**4.0**	3.5	**	**3.8**	3.5	**
	Chinook – 2001	4.1	**4.5**	***	4.5	**5.0**	***
	Steelhead – 1997	3.5	3.5		3.4	**3.5**	
	Steelhead – 2000	4.0	4.0		4.0	4.0	
	Steelhead – 2001	**5.0**	4.0	*	5.0	5.0	
	Sockeye – 1997	2.0	2.0		**2.0**	1.6	**

* P < 0.05, ** P < 0.01, *** P < 0.001; K-W χ^2 tests

Significantly lower proportions of the fastest 10% exited a fishway into the tailrace than of the slowest 10% in 1998 and 2001 ($P < 0.001$) and in 2000 ($P = 0.004$), but not in 1997 ($P = 0.21$) (Figure 25). Lower proportions of the fastest 25% exited fishways than of the slowest 25% in all years ($P < 0.005$). The fastest fish also exited from a transition pool into the tailrace at lower rates than the slowest fish in all years (Figure 26). Between 4 and 11% of the fastest fish exited a transition pool into the tailrace, compared to 18 to 76% of the slowest fish; differences were significant in 1998 and 2001 ($P < 0.001$), 1997 ($P = 0.01$) and nearly so in

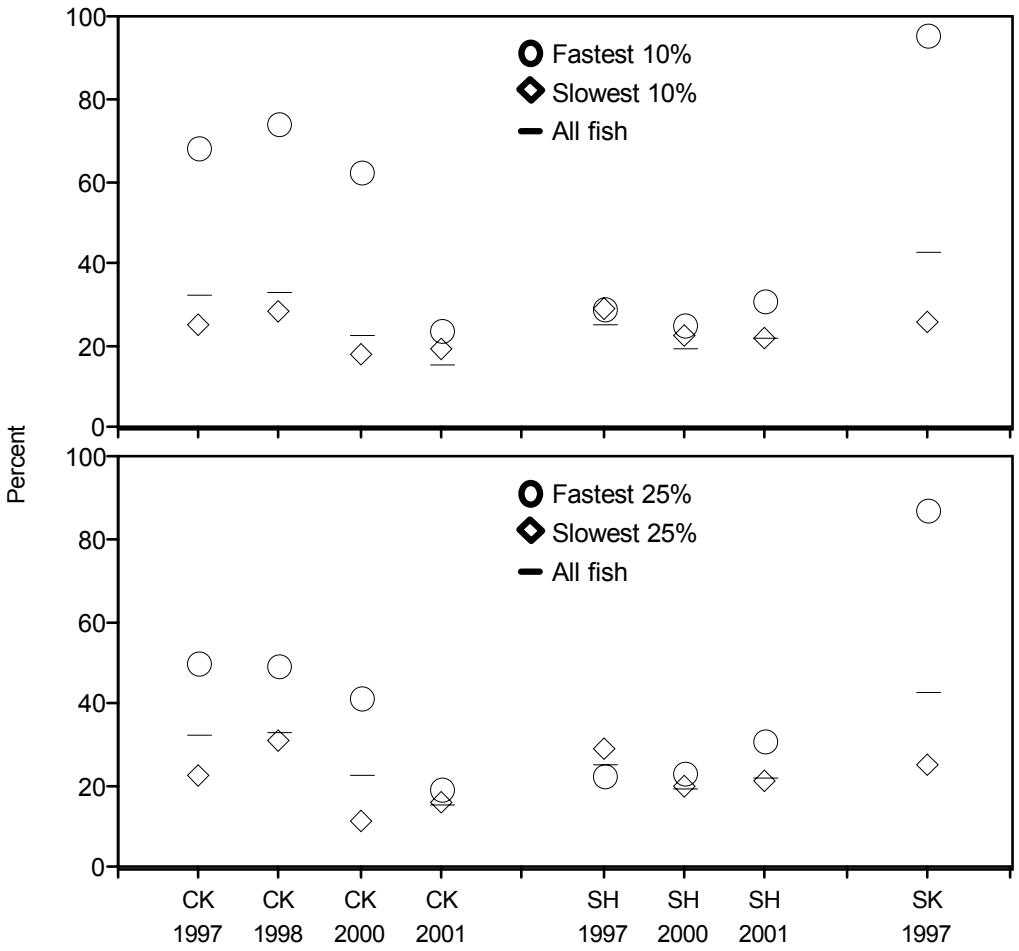

Figure 23. Percent of fastest and slowest 10 and 25% of radio-tagged fish that first approached at the WA-shore fishway, compared to all fish that approached. Only includes fish with known passage times.

2000 (P = 0.052). Lower proportions of the fastest 25% exited transition pools than of the slowest 25% in all years with significant differences in 1998 and 2001 (P < 0.001) but not in 1997 or 2000 (P ~ 0.15) (Figure 26).

Steelhead:

Most of the 10% of radio-tagged steelhead that passed The Dalles Dam the fastest in 2001 first arrived in the tailrace in September and October, with a median arrival date more than a month later than the slowest 10% (Figure 27). Arrival distributions for the fastest and slowest 10% overlapped in 1997 and 2000, with most fish arriving in September or early October; some fish from each category arrived at the dam during each month that radio-tagged fish were passing the dam.

Unlike spring–summer Chinook salmon, environmental conditions encountered by the fastest and slowest passing steelhead did not differ significantly (Table 48). Median flows were within 10 kcfs for both groups in each year, median spill was zero for all groups in all years, and Secchi depth visibilities were the same in 1997 and 2000. Turbidity was less in 2001 for the fastest-migrating fish (P < 0.05) (Table 48). Because water temperature was not

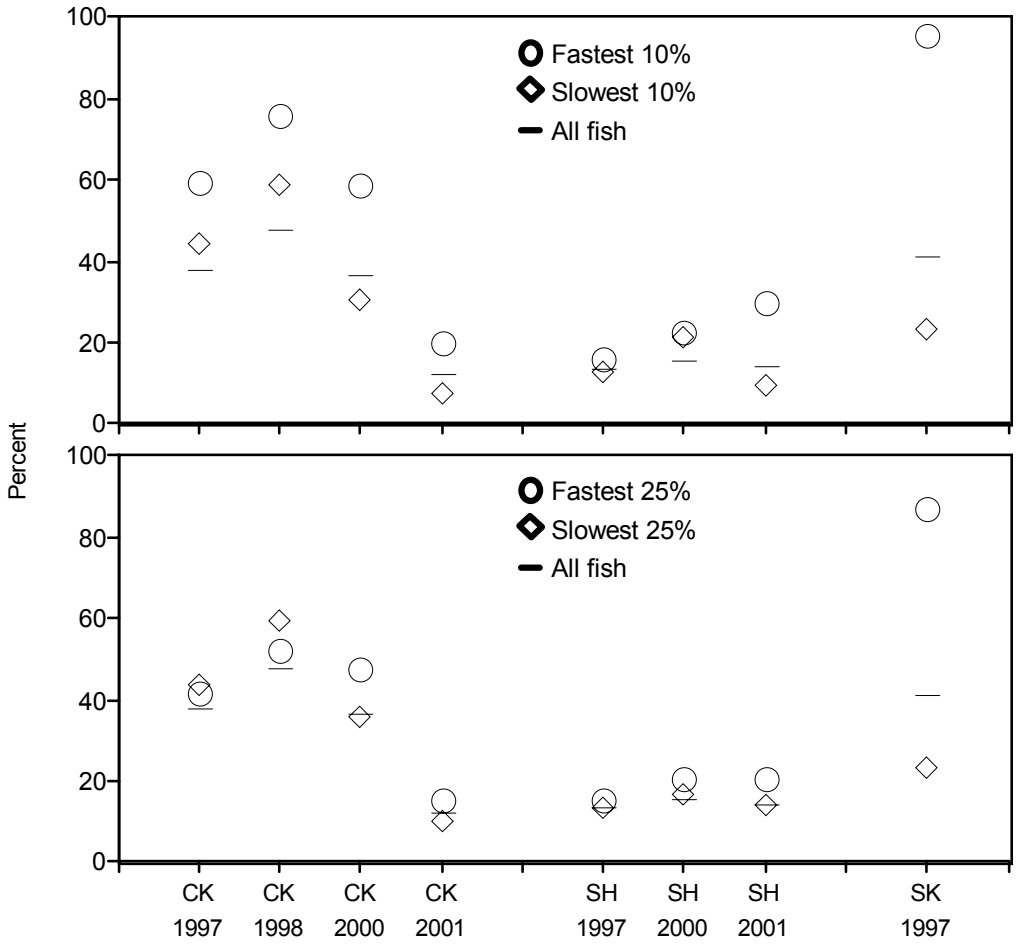

Figure 24. Percent of fastest and slowest 10 and 25% of radio-tagged fish that first entered at the WA-shore fishway, compared to all fish that entered. Only includes fish with known passage times.

collected through portions of the fall in each year, statistical comparisons were not made. However, for those steelhead that passed on days with known water temperature, the slowest 10% tended to encounter higher water temperatures than the fastest 10% by about 0.5° C. Comparisons of the fastest and slowest 25% produced similar results (Table 48).

Fishway use – The fastest 10% of steelhead first approached the WA-shore fishway (NLE) at rates similar to the slowest 10% (Figure 23) in all years. The proportion of the fastest 25% that first approached the WA-shore fishway was also similar to the proportion of the slowest 25%, except in 2001 when more of the faster fish first approached there ($P = 0.02$). Four to 23% of the fastest-passing steelhead first approached the WPE at the OR-shore fishway compared to 18 to 35% of the slowest fish; significantly lower percentages of the fastest fish approached the WPE in 2000 ($P = 0.05$) and 2001 ($P = 0.003$). Higher, but non-significant ($P > 0.05$), proportions of the fastest 10% first approached the ELE in all years.

The fastest 10% tended to first enter fishway entrances in proportions similar to those for the slowest 10% in each year. Exceptions included 30% of the fastest fish first entered the NLE compared to 10% of the slowest fish in 2001 ($P = 0.001$), and 17% of the fastest 10% first entered the SSE in 2001 versus 32% of the slowest 10% ($P = 0.03$). Three percent of the

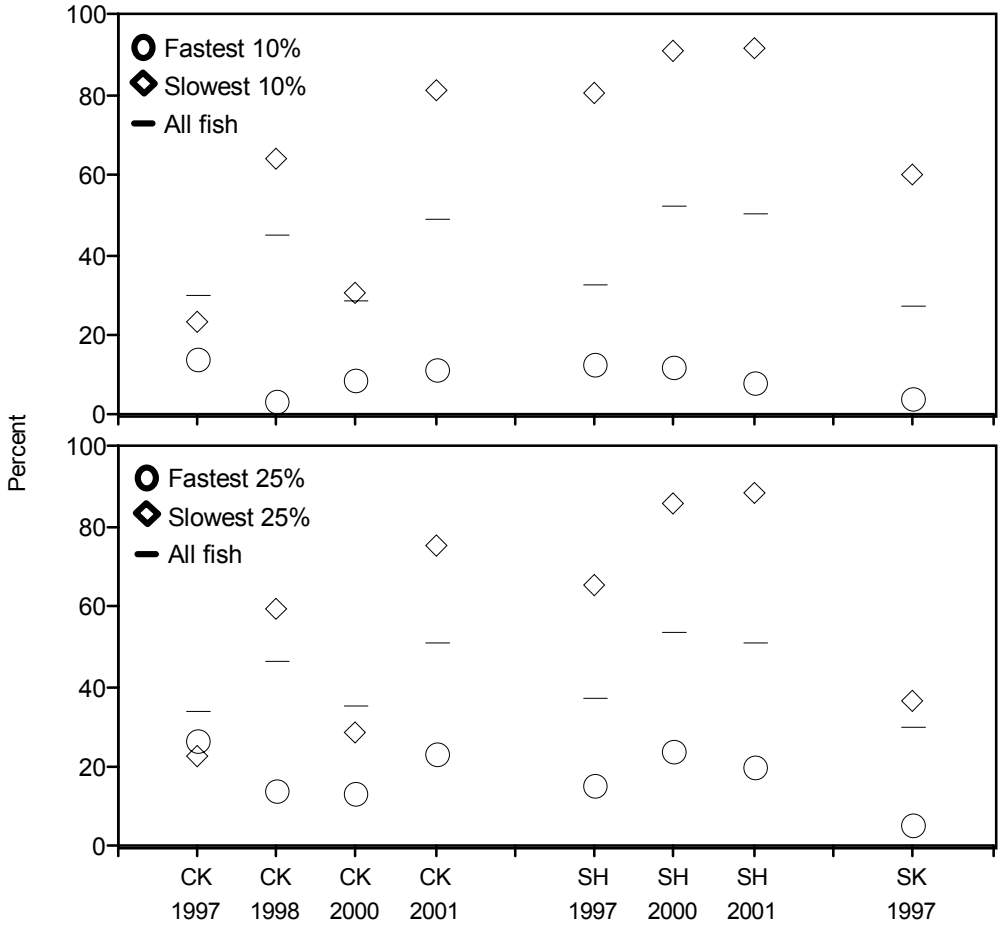

Figure 25. Percent of fastest and slowest 10 and 25% of radio-tagged fish that exited a fishway at The Dalles Dam, compared to all fish that exited. Only includes fish with known passage times.

fastest 10% first entered the WPE in 2000, compared to 12% of the slowest 10% ($P = 0.05$), and 45% of the fastest fish first entered the ELE in 1997 compared to 23% of the slowest fish ($P = 0.06$). No other comparisons of first entrance use were significant.

The slowest 10% of steelhead were far more likely to exit a fishway into the tailrace than the fastest 10% (81–91% versus 11–13%, $P < 0.001$) (Figure 25). Exit percentages were 65 to 86% for the slowest 25% compared to 15 to 24% for the fastest 25% ($P < 0.001$) (Figure 25). The fastest 10% of steelhead also exited from transition pools into the tailrace at far lower rates than the slowest 10% in all years ($P < 0.001$) (Figure 26).

Sockeye salmon:

The 10% of sockeye salmon that passed The Dalles Dam fastest in 1997 arrived in the tailrace mostly during peak passage in the first week of July. The 10% that passed the slowest tended to arrive at the dam slightly earlier, but overlap between the two groups was extensive (Figure 28).

Median flow and spill levels encountered by the fastest 10% were significantly lower than the medians for the slowest 10% ($P < 0.001$) (Table 48). The median water temperature was

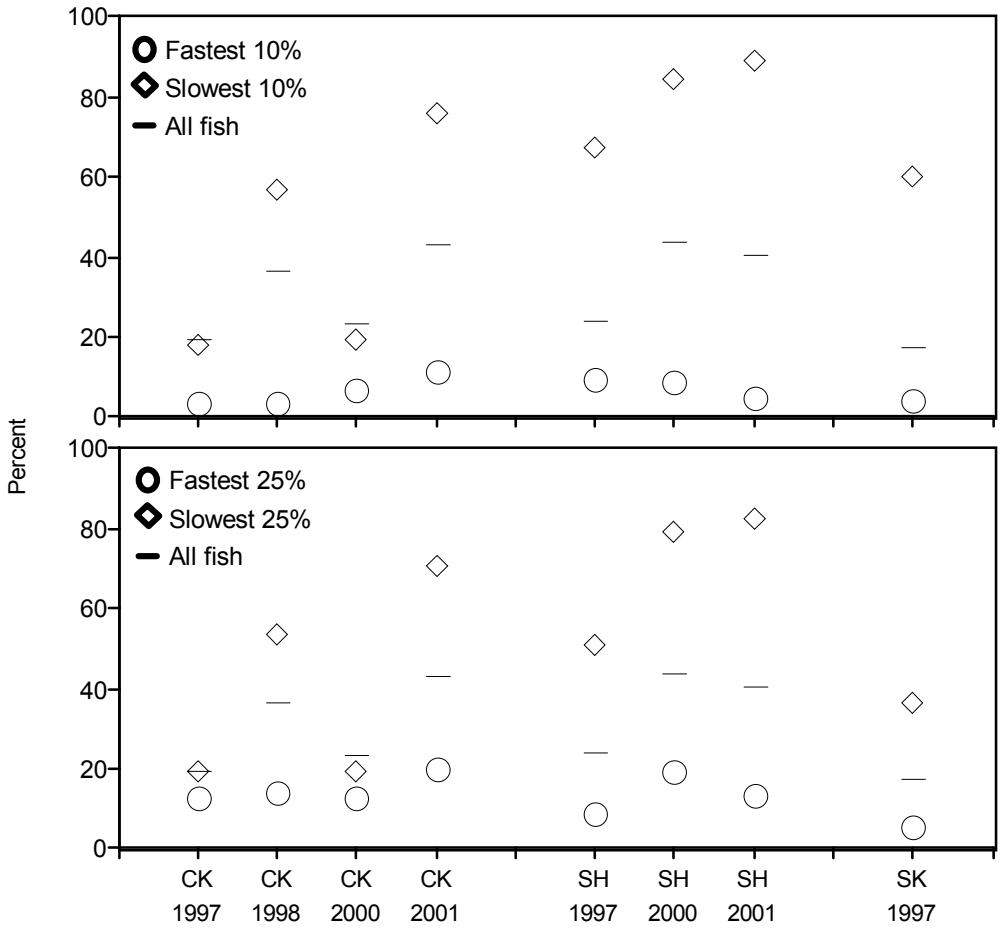

Figure 26. Percent of fastest and slowest 10 and 25% of radio-tagged fish that exited a transition pool into the tailrace at The Dalles Dam, compared to all fish that exited to the tailrace that had known passage times.

0.8° C higher for the fastest 10%, a non-significant difference. Secchi depth visibility was the same for both groups (Table 48). Patterns were similar for the fastest and slowest 25% of sockeye salmon.

Fishway use – Almost all of the fastest 10% of sockeye salmon first approached and first entered the WA-shore fishway entrance (NLE) (Figures 23 and 24). Ninety-six percent of the fastest fish first approached and first entered at the NLE, compared to 26% and 23% of the slowest fish, respectively ($P < 0.001$). No fish from either group first approached or first entered at the SSE. None of the fastest 10% first approached or entered at the WPE, compared to about 15% of the slowest fish. Less than 3% of the fastest fish first approached or entered at the ELE, compared to 33% of first approaches and 23% of first entries by the slowest 10%. All differences were significant ($P < 0.05$).

Far more of the slowest sockeye salmon exited fishways or transition pools into the tailrace than the fastest fish (Figures 25 and 26). Four percent of the fastest 10% exited a fishway, compared to 86% of the slowest 10%; four percent of the fastest fish exited a transition pool into the tailrace, compared to 61% of the slowest fish. Patterns were similar for the fastest and slowest 25%, and all comparisons were significant ($P < 0.001$).

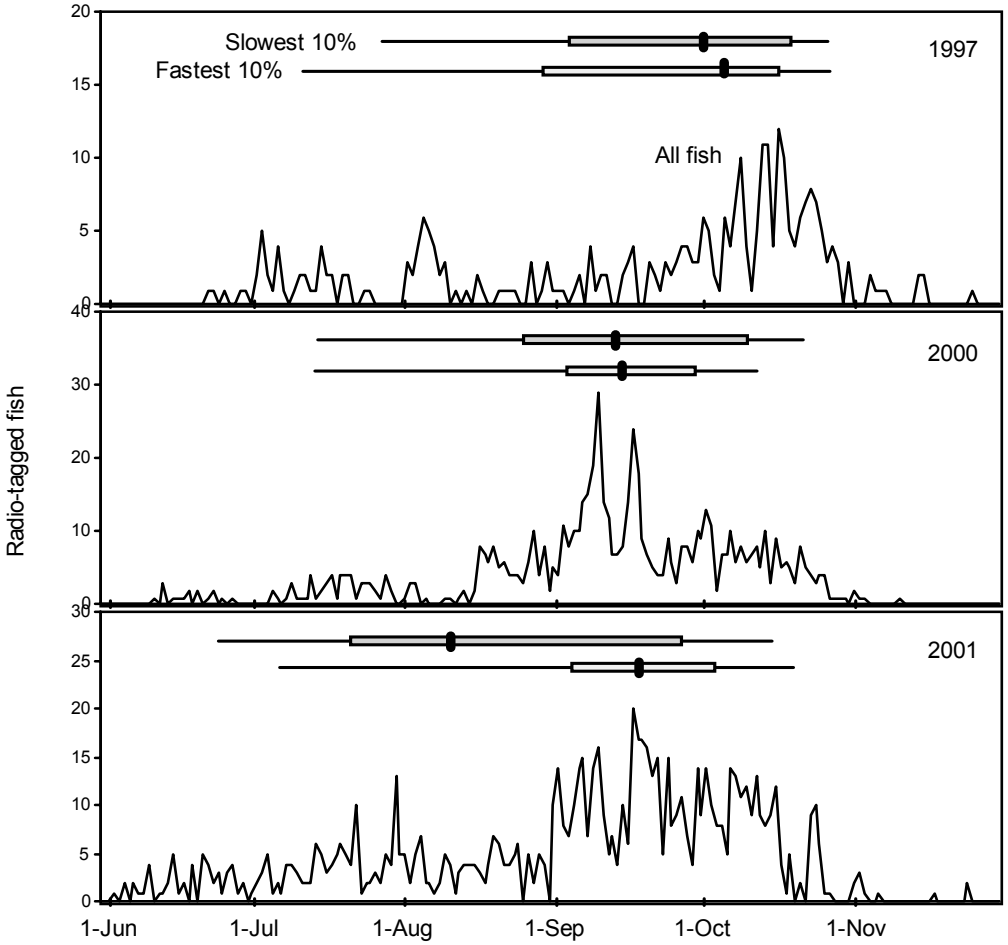

Figure 27. Passage of radio-tagged steelhead (lines), with median, quartile, 5th and 95th percentile dates for the 10% (boxplots) that passed the fastest and slowest in each year.

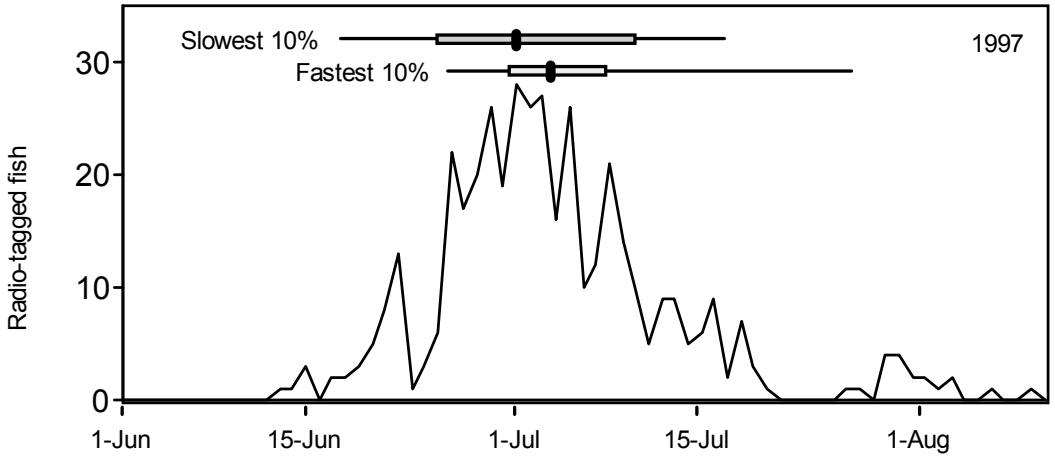

Figure 28. Passage of radio-tagged sockeye salmon (line), with median, quartile, 5th and 95th percentile dates for the 10% (boxplots) that passed the fastest and slowest in 1997.

Effects of Closing Orifice Gates

Chinook salmon:

We did not experimentally test for differences in fish passage times or behaviors with orifice gates closed and open in individual years, but we were able to make retrospective comparisons between years. The primary problem with this type of analysis was separating the wide range of environmental conditions between years from actual differences in fish behavior that were due to orifice gate status. A secondary problem was that orifice gates were open but unmonitored in 1997 and 1998, making it difficult to compare many passage time measures.

We compared total dam passage times for individual years with gates open or closed. For all Chinook salmon, median dam passage times in 1997 (gates open) were significantly longer ($P < 0.0001$, K-W χ^2 tests) than in 2000 and 2001 (gates closed) (Figure 29). The median time for all fish in 1998 (gates open) was significantly longer than in 2001 ($P = 0.0006$), but not 2000 ($P = 0.68$). In individual months, median times were significantly longer in April and May 1997 than in those months in 2000 and 2001 ($P < 0.0001$); the median in June 1997 was also longer than in June 2000 and 2001 ($P \sim 0.04$), while the median in July 1997 was not different than medians in 2000 or 2001. The median time in April 1998 was significantly longer than medians in 2000 ($P = 0.01$) and 2001 ($P < 0.0001$), and the median in June 1998 was longer than in 2000 and 2001 ($P \sim 0.02$) (Figure 29). Median times in May and July 1998 were not significantly different than in those months in 2000 or 2001 ($P > 0.25$).

Although the proportion of unknown first fishway entries was considerably higher in 1997 and 1998 when orifice gates were open but unmonitored than in 2000 and 2001, we compared median times from first tailrace record to first fishway entry under the two conditions. Results were generally similar to those for dam passage times described above. For all Chinook salmon, median times to first entry were significantly higher in 1997 than in 2000 or 2001 ($P < 0.01$) (Figure 29). Median times to first entry were higher in 1998 then in 2001 ($P < 0.001$), but were lower in 1998 than 2000 ($P = 0.001$). In comparisons between individual months, median times were significantly longer to first entry in April and May 1997 than in those months in 2000 and 2001 ($P < 0.0001$). The median time in April 1998 was shorter than in April 2000 ($P = 0.06$), and the median in May 1998 was shorter than May 2000 ($P = 0.001$). Median times in April and May 1998 were longer than those in April ($P < 0.001$) and May ($P = 0.09$) 2001 (Figure 29). Median times in June and July were more similar between years: times were significantly longer in June 1997 and June 1998 than in June 2001 ($P = < 0.01$), while the median in July 1997 was shorter than in July 2000 (Figure 29).

Higher percentages of the spring–summer Chinook salmon that entered the OR-shore fishway had recorded fishway exits in 2000 (29%) and 2001 (42%) when orifice gates were closed, than in 1997 (19%) or 1998 (23%) (Figure 11). Percentages were significantly lower in 1997 than in 2000 ($P = (0.01)$ and 2001 ($P < 0.0001$, Z tests), and in 1998 than in 2001 ($P < 0.0001$). The percentages that exited in June and July of 1997 were lower than in those months in 2000 ($P < 0.06$) and 2001 ($P < 0.01$). The percentage that exited in May 1998 was lower than in May 2000 ($P = 0.03$) and the percentage that exited in July 1998 was lower than in July 2001 ($P = 0.03$). No other between-year comparisons were significant. It was unclear if the higher exit percentages in years with orifice gates closed were related to those closures or to other factors, such as water temperatures in the fishway or tailrace elevations.

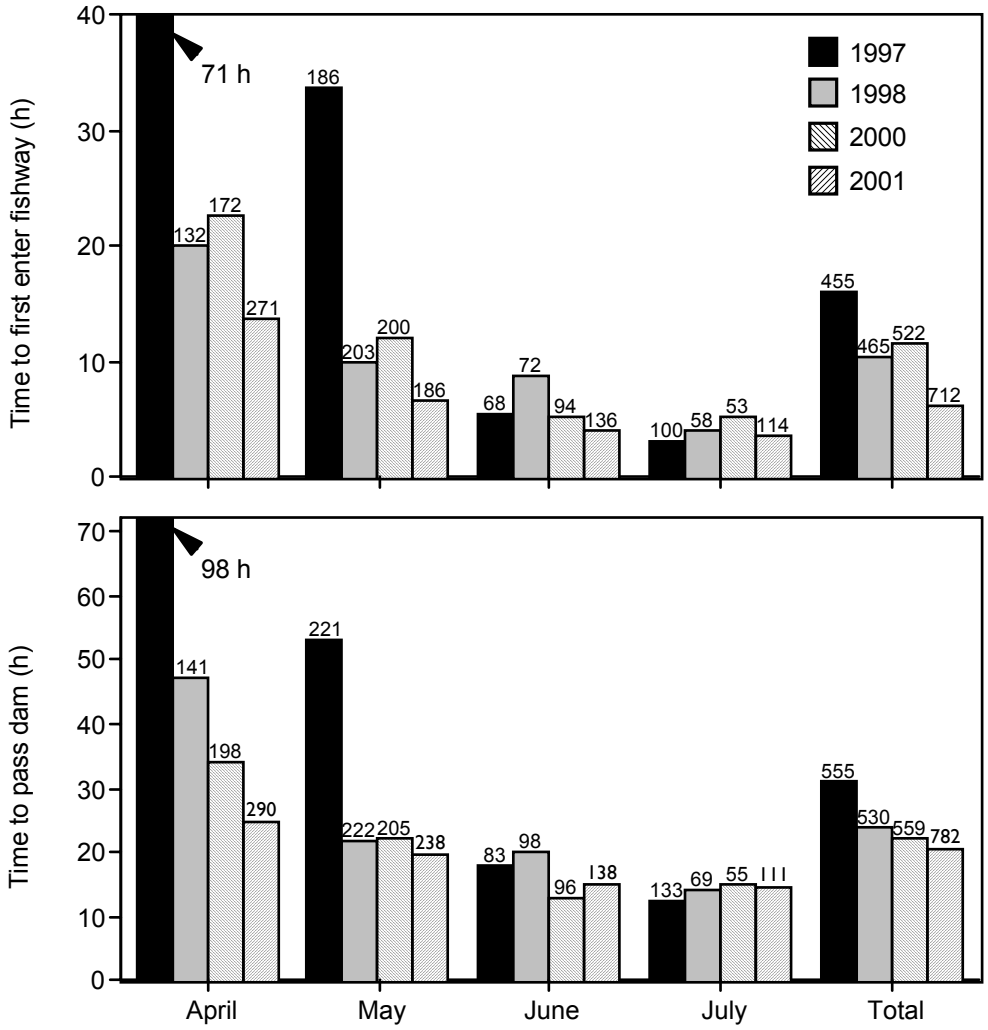

Figure 29. Median passage times from first tailrace record to first fishway entry and to pass the dam of radio-tagged spring–summer Chinook salmon. Orifice gates open in 1997 and 1998, closed in 2000 and 2001. See Tables 2 and 3 for data.

Steelhead:

Unlike spring–summer Chinook salmon, median dam passage times for steelhead in 1997 (gates open) were significantly shorter than in 2000 ($P = 0.01$) and 2001 ($P = 0.0002$, K-W χ^2 tests) (Figure 30). Median times in 1997 were shorter in most months than medians in 2000 and 2001, but these differences were not significant in June, August or October ($P > 0.10$). Medians were significantly shorter in September 1997 than in September 2000 and 2001 ($P \sim 0.005$); the median in July 1997 was significantly shorter than in July 2001 ($P = 0.0009$).

Median times from first tailrace record to first fishway entry in 1997 did not differ for all steelhead combined or for steelhead in July, September or October separately, when compared to 2000 and 2001 (Figure 30). The median in August 1997 was significantly shorter than in August 2000 ($P = 0.003$) and August 2001 ($P = 0.007$).

As with Chinook salmon, higher percentages of steelhead that entered the OR-shore fishway had recorded fishway exits in 2000 (42%) and 2001 (40%) than in 1997 (20%) (see

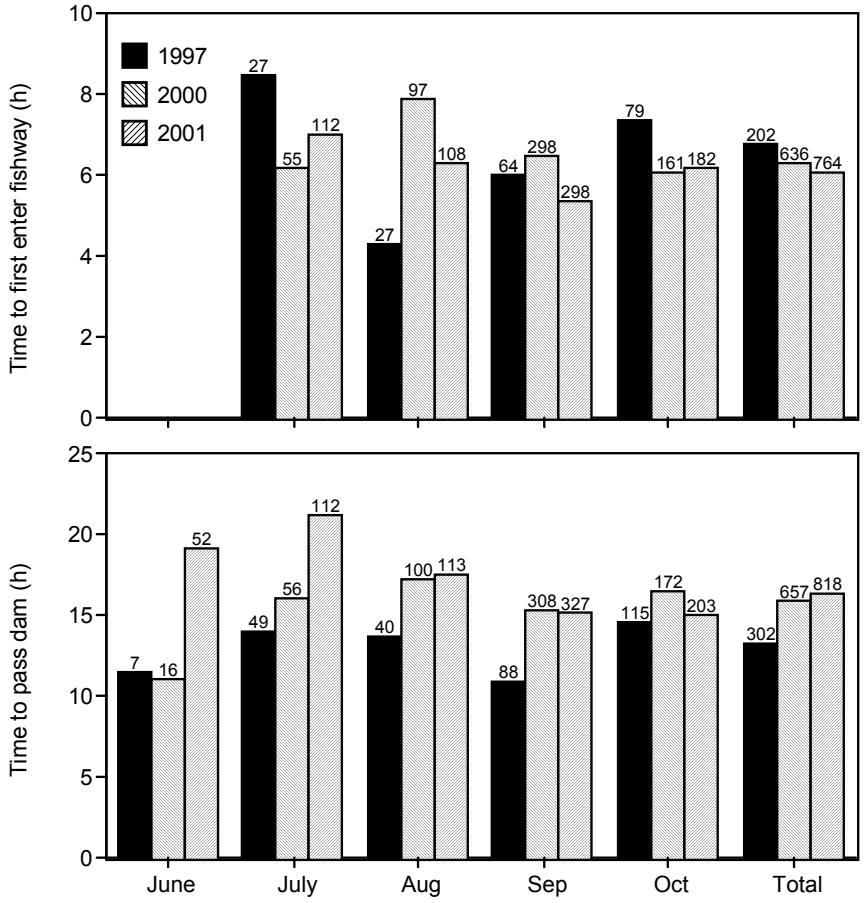

Figure 30. Median passage times from first tailrace record to first fishway entry and to pass the dam for radio-tagged steelhead. Orifice gates open in 1997, closed in 2000 and 2001. See Tables 2 and 4 for data.

Figure 14). Percentages were significantly lower in 1997 than in either 2000 or 2001 (P < 0.001, Z tests). Percentages that exited in July and September 1997 were lower than percentages in those months in both 2000 and 2001 (P < 0.02). The percentage that exited in October 1997 was lower than in October 2000 (P = 0.007) but not 2001 (P = 0.32). Exit rates from the OR-shore pool by steelhead were less likely to be affected by tailrace elevations or fishway temperatures, particularly in September and October, than the rates for Chinook salmon.

Behavior and Fate of Fish that Did Not Pass the Dam

Chinook salmon:

Between 3.6 (2001) and 8.9% (1997) of the spring–summer Chinook salmon recorded in the tailrace or at The Dalles Dam did not pass the dam (Table 49). Of those that did not pass, 23 to 54% were only recorded in the tailrace, 14 to 50% were recorded approaching fishway entrances, 2 to 5% were recorded inside fishways (but not in transition pools), and 21 to 32% were recorded inside transition pools. Of those that entered fishways, most (65 to 94%) were last detected in the OR-shore fishway (Table 49).

Table 49. Final fate, most upstream point reached at dam and last fishway detection for radio-tagged fish that did not pass The Dalles Dam.

	Chinook salmon				Steelhead			Sockeye
	1997	1998	2000	2001	1997	2000	2001	1997
Recorded at dam	784	816	907	1,027	707	910	989	506
Did not pass dam	70	53	63	37	24	39	25	14
Percent that did not pass dam	8.9%	6.5%	6.9%	3.6%	3.4%	4.3%	2.5%	2.8%
Fate of fish that did not pass:								
Unaccounted for	**39%**	28%	32%	32%	**42%**	23%	24%	14%
Recaptured in fisheries	34%	26%	22%	**51%**	**42%**	**59%**	**64%**	**79%**
Entered downstream tributary	16%	**32%**	**35%**	16%	13%	15%	8%	7%
Known or presumed spit tags[1]	11%	13%	11%	--	4%	3%	4%	--
Most upstream point at dam:								
Tailrace	23%	30%	**48%**	**54%**	**42%**	**44%**	36%	50%
Approached fishway only	**50%**	**32%**	30%	14%	33%	8%	20%	--
Inside fishway, no trans. pool	4%	2%	2%	5%	--	5%	--	--
Inside transition pool	23%	**32%**	21%	27%	25%	**44%**	**44%**	50%
Near top of ladder	--	4%	--	--	--	--	--	--
Last fishway detection[2]:								
OR-shore fishway	**70%**	**76%**	**94%**	**65%**	**94%**	**86%**	**88%**	**71%**
WA-shore fishway	30%	24%	6%	35%	6%	14%	12%	29%

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

For the four years combined, similar percentages of the fish that did not pass the dam were unaccounted for downstream (33%), recaptured in fisheries near the dam or in the Bonneville pool (32%), or were last recorded in downstream tributaries (25%) (Table 49). Based on the circumstances of the transmitters, about 12% of the fish that did not pass in the first three years may have regurgitated tags or the fish died and the transmitter was not recovered. In 1997, the highest percentage of the fish that did not pass (39%) was unaccounted for. In 1998 and 2000, the highest percentages were last recorded in tributaries (32 and 35%), and in 2001 the highest percentage was recaptured in fisheries (51%) (Table 49).

Steelhead:

Between 2.5 (2001) and 3.4% (1997) of the steelhead recorded in the tailrace of The Dalles Dam or at the dam did not pass (Table 49). Of these, 36 to 44% were only recorded in the tailrace, 8 to 33% were recorded approaching fishway entrances, < 6% were recorded inside fishways (but not in transition pools), and 25 to 44% were recorded inside transition pools. Of those that entered fishways, most (86 to 94%) were last detected in the OR-shore fishway (Table 49).

For the four years combined, 28% of the fish that did not pass the dam were unaccounted for downstream, 56% were recaptured in fisheries near the dam or in the Bonneville pool, and 13% were last recorded in downstream tributaries (Table 49). An estimated 3% that did not pass may have regurgitated tags or the fish died and the transmitter was not recovered. In all three years, the highest percentages of steelhead that did not pass (42 to 64%) were recaptured in fisheries (Table 49). In 1997, 42% were unaccounted for, and about 24% were unaccounted for in 2000 and 2001.

Sockeye salmon:

Fourteen sockeye salmon (2.8%) did not pass The Dalles Dam in 1997 (Table 49). Half were recorded only in the tailrace and the other half were recorded in transition pools. Five of the seven fish (71%) that entered fishways were last recorded in the OR-shore fishway.

Eleven of the 14 fish (79%) that did not pass were recaptured in fisheries downstream from the dam, 2 (14%) were unaccounted for and 1 (7%) was last recorded in the Klickitat Rivers. Because no sockeye salmon are produced in the Klickitat, the fish last recorded there should be considered unaccounted for (Table 49).

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 The Dalles Dam. Median full-dam passage times during the study years (1997, 1998, 2000, 2001) were longest for radio-tagged spring–summer Chinook salmon (20 to 31 h), intermediate for steelhead (13 to 16 h) and shortest for sockeye salmon (8 h). Mean times were longer than medians for all species/years, because some fish delayed 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). It is probable that some adult migrants historically delayed near the location of The Dalles Dam, which inundated Celilo Falls and several rapids. The area downstream from the dam remains a complex hydraulic environment and some slow passage at the dam may be attributable to variable conditions in and near the tailrace.

To best determine where fish slowed at The Dalles Dam, we partitioned passage by radio-tagged fish at The Dalles 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.

The segment with the largest numbers of spring–summer Chinook salmon with passage times of > 24 h was from first fishway approach to first fishway entry in the first three years and from first transition pool entry to exit a pool into a ladder in 2001 (Figure 31). More than 35% of the Chinook salmon took > 24 h between first fishway approach and entry in 1997, the year with the highest flow and spill, about 4% took > 24 h in 2001 when flow was near record low, and about 20% did in the near-normal flow years 1998 and 2000. The longest passage times from first approach to first entry for Chinook salmon were in April and May in all years (see Table 3), months when flow and spill were generally high and water temperatures were low. In the first three years, another 7 to 16% of Chinook salmon delayed for > 24 h between the first and last transition pool records. Finally, 13% took > 24 h to pass from first tailrace entry to first fishway

approach in 1997. Very few fish of any species took > 24 h to enter a transition pool after entering a fishway or to ascend a ladder.

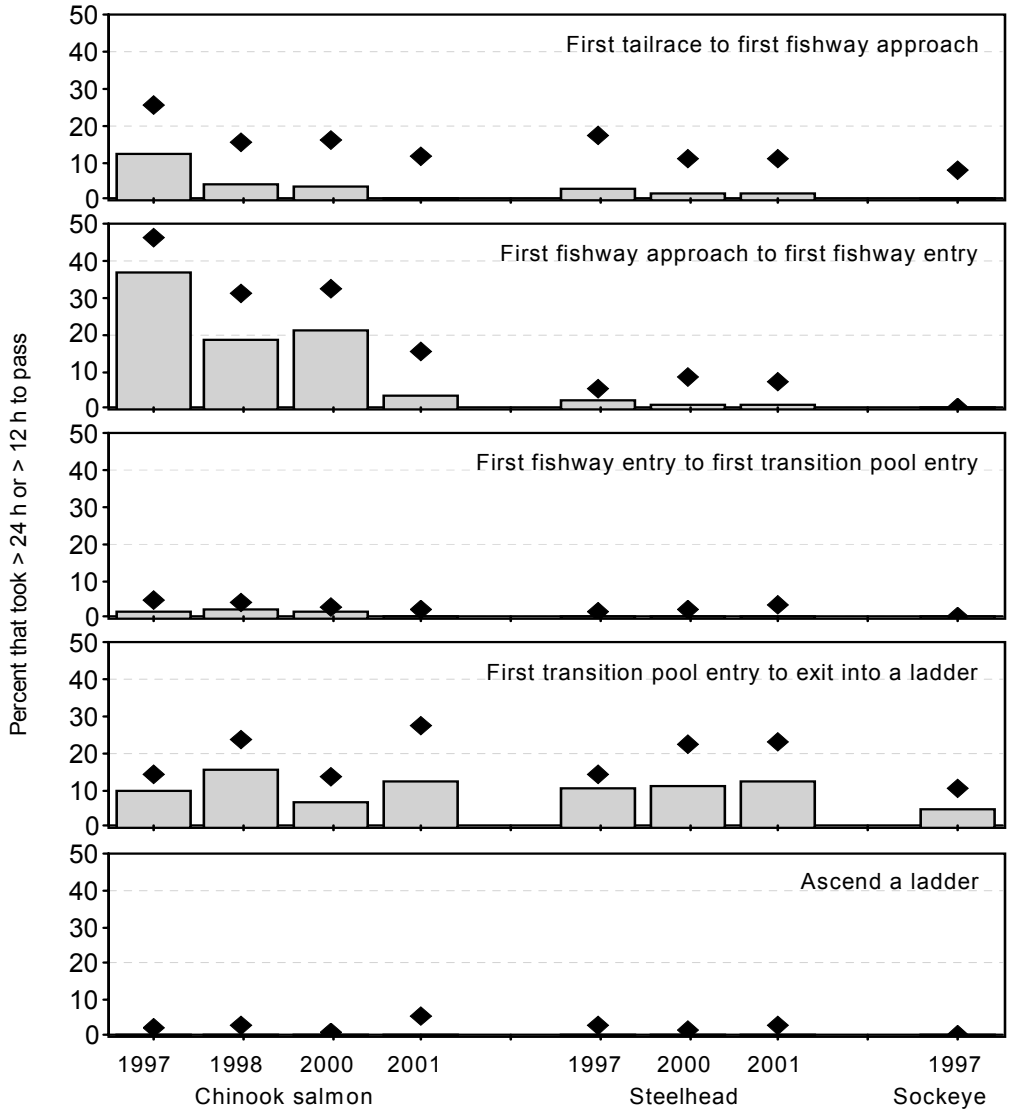

Figure 31. Percent of fish that took > 24 h (gray bars) and > 12 h (black diamonds) to pass through each dam passage segment.

Spring–summer Chinook passage times at The Dalles 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. 2004). 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.

Between 11 and 13% of steelhead and 5% of sockeye salmon took > 24 h to pass through a transition pool (includes time fish spent downstream from a pool), and few fish of either species

were slowed that long through the other four segments (Figure 31). When the 'delay' criteria was lowered to 12 h, 8 to 17% of steelhead delayed between the first tailrace record and the first approach at a fishway and 14 to 23% delayed between first and last transition pool records (Figure 31). Almost all fish of all species that took > 24 h to pass through a transition pool had exited fishways into the tailrace before re-entering the pool and passing into a ladder.

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 9 to > 20 h for spring–summer Chinook, 8 to 14 h for steelhead and 9 to 12 h for sockeye salmon in 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 the best predictors of overall dam passage times for all species. 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 transition pool behaviors we observed. 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). Additional evidence that fishway temperatures can affect exit rates was found at John Day Dam, where fishway exit rates were strongly positively correlated with mean and maximum ladder temperatures (Keefer et al. 2003b). Manipulation of tailwater elevation, which affects water velocities in the lower fishways and transition pools at The Dalles Dam, may also be an effective way to reduce fishway fallout.

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 late in the day tend to pass the following day, resulting in longer passage times.

Our results suggest that the best opportunities for improving adult passage efficiency at The Dalles Dam include reducing fallout from fishways and transition pools and decreasing the time fish take to enter fishways. 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 The Dalles Dam.

Closure of orifice gates at The Dalles Dam may also lower fishway exit rates. However, it was difficult to draw any conclusions regarding orifice gate closures in this study because those entries were not monitored. Comparisons of years with orifice gates open (1997, 1998) and closed (2000, 2001) were further confounded by the large differences in river environment between those years. Earlier studies of orifice gate closures at and Priest Rapids and Wanapum dams (Bjornn et al. 1997; Peery et al. 1998) were equivocal in terms of adult passage; analysis of the effects of orifice gate closure tests at Bonneville Dam are currently

underway. At The Dalles Dam, more explicit experimental testing of orifice gate closures is recommended before this strategy is employed to reduce fishway fallout.

Fishway Use: Telemetry coverage at The Dalles 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.

Chinook salmon approached fishways more often than steelhead or sockeye salmon, and multiple approaches likely contributed to the relatively longer passage times between first fishway approach and first fishway entry for Chinook salmon compared to other species. Chinook salmon may have had difficulty locating or entering fishways—the longest passage times through this segment occurred during high flow and spill conditions, particularly in the high-flow year 1997. Fish from all species were more likely to approach at the North Ladder Entrance (NLE) when spill was occurring, probably because spill provided attractive flow to that fishway. Use of the NLE increased with increasing spill volumes. Not surprisingly, fish were most likely to approach at the NLE in 1997, the study year with the highest Columbia River discharge. In other years, fish favored approaching entries to the Oregon-shore fishway, especially the East Ladder Entrance (ELE) and West Powerhouse Entrance (WPE).

Most fish entered fishways once, though averages were 1.5 to 4 times because some fish entered and exited multiple times. The East Ladder Entrance (ELE) was favored by Chinook salmon and steelhead, while sockeye salmon preferred to enter at the NLE. 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). Radio-tagged fish most frequently selected the ELE at The Dalles Dam when spill levels were low and favored the NLE when spill was high.

Between 30 and 54% of fish from all runs exited a fishway into the tailrace at least once. Exit percentages increased as migrations progressed each year for Chinook salmon, and may have been related to increasing temperatures. The highest numbers of exits were from the South Spillway Entrance (SSE) for Chinook salmon and steelhead, and from the NLE and West Powerhouse Entrance (WPE) for sockeye salmon. Many fish from all runs migrated upstream in the fishways to the transition pool areas before turning around and exiting fishways. Smaller percentages 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.

Fishway and transition pool exit rates, as well the numbers of fishway exits per fish at The Dalles Dam were lower than those recorded at John Day Dam in 1997 and 1998 (Keefer et al. 2003b). Between 22 and 49% of spring–summer Chinook salmon exited transition pools at The Dalles Dam each year, rates that were similar to or higher than those reported for the 1997 Chinook run at McNary and Ice Harbor dams (27-35% exited), but lower than at Bonneville and Lower Granite dams in 1997 (53-55% exited) (Keefer et al. 2003a). Preliminary analyses of fall Chinook salmon fishway use at The Dalles Dam in 1998, 2000, and 2001 indicate that more than 50% of radio-tagged fish from those runs turned around in transition pools (B. Burke, unpublished data). Fish from all runs were more likely to exit the Washington-shore transition pool at The Dalles Dam than the Oregon-shore transition pool (except spring–summer Chinook salmon in 2000). Configuration of the Washington-shore fishway, which has fish enter the

transition pool almost immediately following fishway entry, may explain the higher exit rate there.

Under most operational conditions, radio-tagged fish were more likely to pass The Dalles Dam via the Oregon-shore fishway. This was especially true for steelhead, 85% or more of which passed the dam via this route. The Oregon-shore route preference was most likely related to flow patterns in the tailrace, the location of the Powerhouse near the OR-shore, and the somewhat unique configuration of the dam and main river channels near the dam. 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 Washington-shore fishway. Increasing spill volumes attracted increasing proportions of fish to the Washington-shore fishway. Manipulation of this behavior may be a useful management tool at the dam, especially given the tendency for Chinook and sockeye salmon to pass the dam more quickly via the Washington-shore fishway.

***Dam Conversion*:** In all years, some fish that approached or entered fishways at The Dalles Dam did not pass the dam. Percentages that did not pass ranged from 4 to 9% for Chinook salmon and averaged about 3% for steelhead and sockeye salmon. 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, majorities of steelhead and sockeye salmon and about one-third of Chinook salmon that did not pass The Dalles Dam were harvested in fisheries. Another 25% of Chinook salmon and 13% of steelhead were last recorded in tributaries downstream from the dam, and small percentages appear to have regurgitated transmitters. The remainders could not be accounted for, including about one third of non-passing Chinook salmon, and about a quarter of non-passing steelhead and sockeye salmon. Put another way, 1.2 to 3.4% of Chinook salmon, 0.6 to 1.4% of steelhead, and 0.6% of sockeye salmon that were recorded at The Dalles Dam did not pass the dam and could not be accounted for. These fish were presumed to be mortalities (unreported harvest or undetected tributary entry were also possibilities), but causes for losses could not be identified.

***Fallback*:** The behaviors and passage times described here were for first passages of radio-tagged fish at The Dalles Dam only. Fallback rates at the dam were more than 15% 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 Washington-shore fishway entrances), or to familiarity with passage routes. Most fallback at The Dalles Dam also occurs via the spillway, which would tend to favor second passages via the Washington-shore fishway given its proximity to the spillway. Additional details on fallback at The Dalles dam are provided in Bjornn et al. 2000b.

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