Technical Report 2003-1

IDAHO COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT

PASSAGE OF RADIO-TAGGED ADULT SALMON AND STEELHEAD AT JOHN DAY DAM WITH EMPHASIS ON FISHWAY TEMPERATURES: 1997-1998

A report for Project ADS-00-2

by

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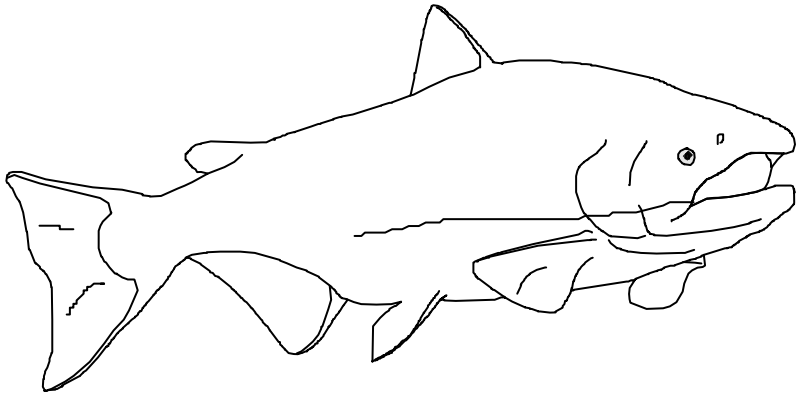

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Preface

Results presented here were collected in association with a basin-wide project to monitor passage and behavior of adult salmon, steelhead, and Pacific Lamprey migrating upstream in the Columbia and Snake rivers. Studies were initiated in 1996 with tagging operations at Bonneville Dam. Studies have emphasized questions pertaining to improving passage and survival through the federal hydropower system of dams and reservoirs. Research results have been summarized in a series of reports which can be downloaded from our website at http://www.cnr.uidaho.edu/adultsalmon/.

Acknowledgements

Many people assisted with the field work associated with the information summarized here. Rudy Ringe and Steve Lee oversaw tagging operations at Bonneville Dam. Ken Tolotti, Travis Dick and Patrick Keniry maintained and downloaded telemetry equipment. Michelle Feeley, Brian Hastings, Michael Jepson, and Jay Nance played important roles in the study. Temperature data from John Day Dam fishways was collected and summarized by Mike Jonas and Robert Stansell from USACE Fisheries Field Unit, Bonneville Dam. Lowell Stuehrenberg and Alicia Matter from the National Marine Fisheries Service assisted with the telemetry database management. This project was funded by the U.S. Army Corps of Engineers, Portland and Walla Walla Districts. Thanks to Mike Langeslay, David Clugston, Marvin Shutters, Jennifer Sturgill and Tammy Mackey, USACE for their assistance.

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Abstract

To better understand the effects of elevated fishway temperatures at John Day Dam on passage of adult salmonids, we examined and compared behavior of radio-tagged adult chinook salmon, sockeye salmon and steelhead at both John Day and The Dalles dams in 1997 and 1998. We calculated passage times through tailraces, fishways, transition pools and ladders and overall dam passage times, as well as the proportions of each run that exited fishways into tailrace areas and fishway exit rates.

Fish from all runs passed the dams more quickly as water temperatures increased each year, but median passage times at John Day Dam were longer than at The Dalles Dam for all groups. In almost all months of all years, fish that exited a fishway into a tailrace had significantly longer passage times than fish that moved straight through and exited from the tops of ladders. Far more fish exited John Day Dam fishways than exited fishways at The Dalles Dam. Proportionately more fish exited John Day Dam fishways into the tailrace as daily ladder temperatures increased. Exit rates at John Day Dam tended to be higher from the OR-shore fishway, which typically had warmer water than the WA-shore fishway. Exit rates from both John Day Dam fishways were strongly correlated with mean and maximum ladder water temperatures. However, exit rates were higher at John Day Dam than at The Dalles Dam during a wide range of temperature conditions, suggesting that factors other than temperature alone contribute to slow adult passage at John Day Dam.

Introduction

Relatively long delays for adult salmonids passing John Day Dam, relative to delay at other lower Columbia River dams, have been documented for many years (e.g. Liscom and Stuehrenberg 1983; University of Idaho, this study). One hypothesis has been that elevated water temperatures in John Day Dam fishways contribute to passage delays at the dam: temperatures recorded in fish ladders, and particularly the south-shore ladder, have occasionally been several degrees warmer than the mainstem Columbia River water. Dalen et al. (1999) reported that warm water from the John Day River often collects at the surface of the John Day Dam forebay, then enters the top of the south-shore ladder. As a result, a steep thermal gradient occurs near the bottom of the ladder where cooler tailrace water is pumped into the fishway through diffusers. Associations between adult migrant behavior and elevated fishway temperatures or the presence of strong thermal gradients between the tailrace, fishways and the forebay have not been well examined. In this report, we compared passage times and behaviors of radio-tagged fish at John Day Dam to their behavior at The Dalles Dam, where elevated fishway temperatures have not been recorded. We also used hourly ladder temperature data collected by the Portland District Corps of Engineers Fisheries Field Unit (FFU) and hourly and daily forebay and tailrace data collected by USACE at John Day Dam to evaluate relationships between temperature and adult behavior.

Methods

We monitored radio-tagged adult passage with receivers in the tailrace and top-of-ladder exits, at north ladder entrances, at north collection channel entrances, at south shore entrances and in transition pools at John Day Dam in 1997 and 1998. Antennas were also in place near the WA-shore count window and the OR-shore diffusers in the upper section of the ladder for all of 1998 and part of 1997. Between-year differences in telemetry coverage were minimal and it is assumed that they did not substantively affect results. Data were collected for spring–summer chinook salmon in both years, for steelhead and sockeye salmon in 1997 and for fall chinook salmon in 1998. A partial telemetry set-up at John Day Dam in 1996 prevented us from using data from that year in this analysis.

Dam passage was split into five components: 1) from first tailrace record to first fishway approach, 2) from first fishway approach to first fishway entry, 3) from first fishway entry to first transition pool entry, 4) from first transition pool entry to exit a pool into a ladder and 5) from transition pool exit to exit from the top of a ladder (ladder ascension). Two additional passage time measures were used to describe overall behavior at the dams: 1) from first tailrace record to exit from the top of a ladder (total dam passage time) and 2) from first fishway entry to exit from the top of a ladder. Only actions with known times were used in calculations—unknown fishway approaches, entries and exits were common because most collection channel entrances (orifice gates) were unmonitored.

Passage times and fishway behaviors at John Day Dam were compared to those at The Dalles Dam, which is the next nearest project on the Columbia River and which had a telemetry configuration (tailrace, major fishway entrances, transition pools, tops of ladders) similar to that at John Day, although actual dam configurations were different.

To address the question of fishway fallout into the tailrace (fishway exit), we calculated 1) the proportion of each run that exited, 2) the number of exits per fish that entered a fishway and per fish that exited a fishway and 3) daily exit rates using the number of exits per fish that entered fishways. To locate potential problem passage areas, we identified the uppermost fishway or ladder site reached before fish first exited a fishway. Turn-around sites reached prior to subsequent fishway exits appeared to be broadly similar to those reached by naïve fish before their first exit, and were not summarized.

Several temperature measures were used for analysis: 1) mean hourly temperature at the USACE forebay water quality monitoring site, 2) mean daily temperatures at the forebay site, 3) maximum hourly temperatures at sites near the count window in the WA-shore ladder and the mid-ladder diffusers in the OR-shore ladder, 4) mean daily temperatures at the ladder sites, and 5) the maximum daily difference between maximum ladder and mean forebay temperatures.

Daily exit rates (see above) were correlated with mean daily ladder temperatures and with maximum daily temperature differences. We also used maximum hourly ladder temperatures to calculate the proportions of fishway entries that resulted in exits to the tailrace. Because some fish exited and re-entered 25 times or more, there may be autocorrelation concerns with these types of analyses, but we believe they provide valuable qualitative results.

Results and Discussion

Between 87 and 96% of radio-tagged adults recorded at John Day Dam passed the dam, and 32 to 62% had telemetry records at all five passage points (Table 1). Unless otherwise reported, sample sizes throughout this report can be approximated from the summary in Table 1.

Passage times

Overall, steelhead and sockeye salmon passed John Day Dam fastest and spring–summer chinook salmon passed most slowly (Table 2). Fish took 4 to 7 h longer (median times) to pass from tailrace to top-of-ladder sites at John Day Dam than at The Dalles Dam in all species-years. Passage times from first fishway entry to top-of-ladder sites, a measure that excludes initial tailrace behavior, were 10 to 22 h at John Day Dam, 2.4 to 4.5 times (6 to 16 h) longer than the same measure at The Dalles Dam.

In all species-years, time from first tailrace to first fishway approach was 1-2 h longer at The Dalles Dam than at John Day Dam. Passage time differences through the

tailraces were a function of distance between telemetry sites (3.2 km at The Dalles, 1.8 km at John Day); passage rates did not differ by more than 0.2 km/h for each species-year (Table 2). Times from first fishway approach to first fishway entry were similar between dams for all species-years. Times from first fishway entry to first transition pool entry were longer at John Day Dam than at The Dalles Dam, but passage through the segment was fast overall. Passage from first to last transition pool records, which included time fish spent exiting and re-entering fishways, were the most variable among all segments. In all species-years, median first to last pool times were substantially longer at John Day than at The Dalles Dam, particularly in 1998. Median ladder ascension times (last transition pool to exit top of ladder) at John Day Dam were longer than at The Dalles Dam by about 1 h in all species-years; differences were likely due in part to longer ladders at John Day Dam.

Table 1. Number of adult radio-tagged fish recorded at John Day Dam that passed the dam, and how many 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.

	Sp/Su CK		Steelhead	Fall CK	Sockeye
	1997	1998	1997	1998	1997
Recorded at dam	654	674	599	554	485
Known to pass dam	629	639	554	483	468
Percent known to pass dam	96%	95%	92%	87%	96%
Recorded first tailrace passage	564	560	535	397	385
Recorded first fishway approach[1]	625	646	506	479	430
Recorded first fishway entrance[1]	484	522	390	335	381
Recorded first transition pool entry	597	642	527	479	420
Recorded transition pool exit	571	602	479	400	416
Recorded ladder exit	611	594	531	410	430
Recorded at all passage points	389	398	304	154	271
Percent with all passage points[2]	62%	62%	55%	32%	58%

[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

All passage time distributions were right-skewed, with some fish taking a day or more to pass through each dam segment. More fish took > 12 h to pass through the tailrace and first enter a fishway at The Dalles Dam, while more took > 12 h to first enter a transition pool at John Day Dam (Figure 1). Between 24 and 48% of each run took > 12 h from first to last transition pool records at John Day Dam, about double the proportions at The Dalles Dam. Less than 4% took > 12 h to ascend ladders at either dam, except 15% of steelhead took that long at John Day Dam. From Table 2 and

Table 2. Median times (h) for radio-tagged fish to approach, enter and pass through fishways and transition pools and to pass John Day and The Dalles dams. Includes all fish with records at each end of the passage segment.

	Sp/Su CK		Steelhead	Fall CK	Sockeye
First tailrace to pass dam	1997	1998	1997	1998	1997
John Day	**35.8**	**31.2**	**16.9**	**22.9**	**13.3**
The Dalles	31.2	23.9	13.3	15.7	7.9
Fishway entry to pass dam					
John Day	**11.1**	**20.5**	**10.5**	**21.5**	**10.3**
The Dalles	4.7	4.6	4.2	6.3	3.0
Tailrace to fishway approach					
John Day	**2.6**	**2.0**	**2.3**	**1.6**	**1.6**
The Dalles	5.3	3.6	4.3	3.3	2.6
Fishway approach to fishway entry					
John Day	**2.4**	**2.6**	**0.3**	**0.5**	**0.0**
The Dalles	3.2	2.7	0.6	1.3	0.0
Fishway entry to transition pool					
John Day	**0.4**	**0.6**	**0.2**	**1.2**	**0.0**
The Dalles	0.0	0.0	0.0	0.0	0.0
First to last transition pool					
John Day	**1.4**	**6.5**	**2.0**	**9.0**	**1.8**
The Dalles	0.8	1.0	0.5	2.3	0.7
Last transition pool to pass dam					
John Day	**2.9**	**2.7**	**2.9**	**2.8**	**2.9**
The Dalles	2.1	2.0	1.9	2.0	1.7

Figure 1, most 'delay' at John Day Dam relative to The Dalles Dam occurred after fish first entered fishways and during the time between first and last transition pool records, which included fishway exit and re-entry behavior for the majority of each run.

Between 69 and 78% of spring–summer chinook salmon, steelhead and fall chinook salmon and 60% of sockeye salmon passed the dam via the OR-shore (south) fishway at John Day Dam. Median dam passage times were 1.8 to 2.3 h (6-11%) longer for spring–summer chinook salmon and steelhead that passed the WA-shore (north) fishway; fall chinook salmon passage times were similar for fish that passed both fishways. Sockeye salmon took 10.8 h to pass the dam via the WA-shore fishway and 15.6 h (44% longer) to pass via the OR-shore fishway. In all cases, fish may have entered and exited one or both fishways prior to dam passage.

Exit behavior and passage time

The best predictors of dam passage time and time from first to last transition pool records were whether or not fish exited fishways and/or transition pools into the tailrace.

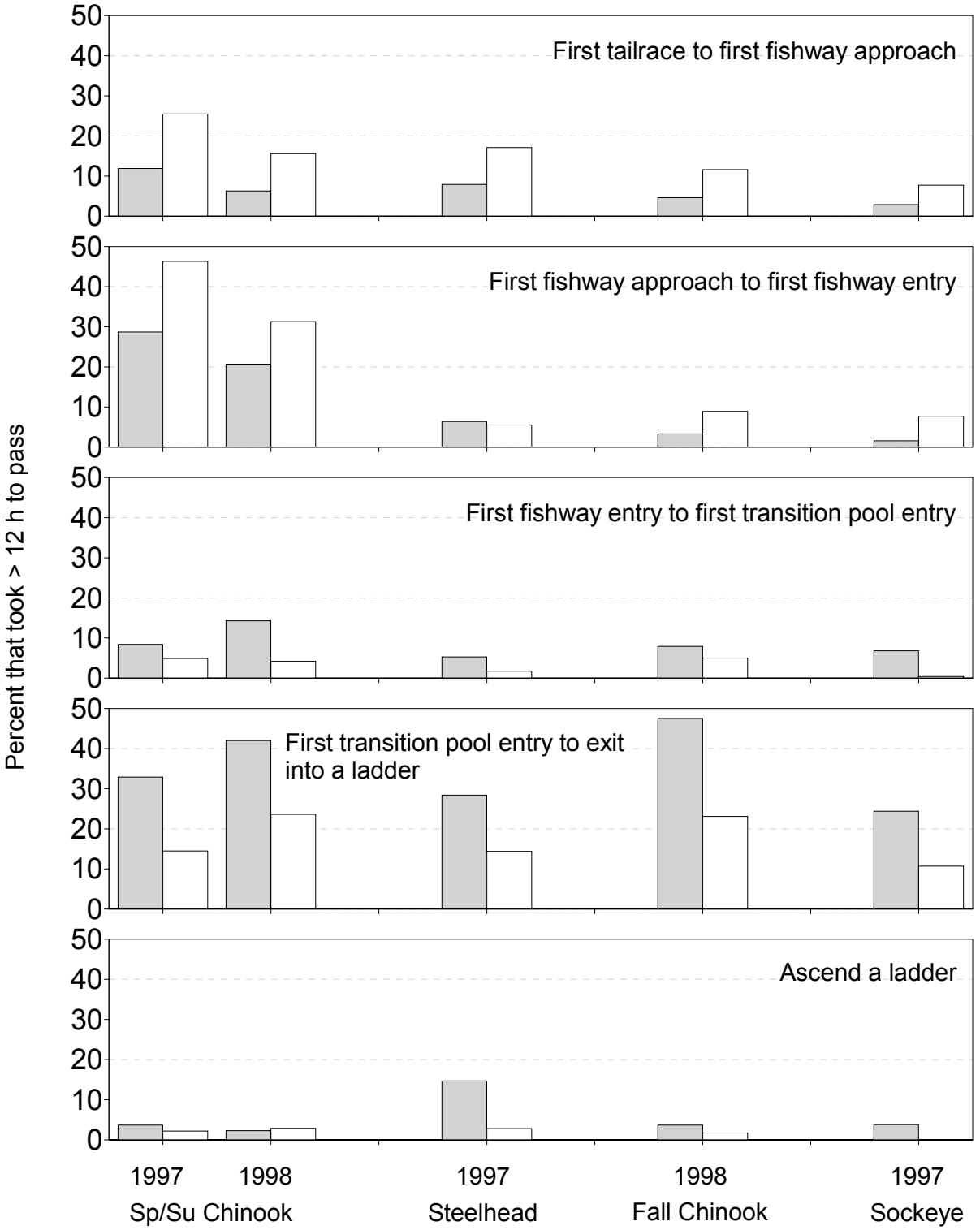

Figure 1. Percent of fish that took > 12 h to pass through each dam passage segment at John Day (grey bars) and The Dalles (white bars) dams.

Fish from all runs were far more likely to exit fishways and transition pools at John Day than at The Dalles Dam (Table 3). Between 56 and 97% of radio-tagged fish were known to exit John Day Dam fishways and 43 to 87% exited transition pools at least once. Fish that exited John Day Dam fishways tended to exit more than once: exits/exit fish and exits/entry fish were several times higher at John Day than at The Dalles Dam (Table 3). Similar proportions of spring–summer chinook salmon (74-83%), steelhead (78-82%) and fall chinook salmon (90-93%) exited both the OR- and WA-shore fishways at least once; 55% of sockeye salmon exited the WA-shore and 76% exited the OR-shore fishway at least once.

In almost all months of all runs, radio-tagged fish that exited a John Day Dam fishway had significantly longer median dam passage times than fish that did not exit (Table 4). There were significant differences in exit proportions and passage times between species and years and with time of migration, suggesting species and possibly even different portions of the same run should not be lumped together. In most months, fish that exited at John Day Dam had longer dam passage times than fish that exited at The Dalles Dam. Spring–summer chinook and sockeye salmon that did not exit at John Day Dam also tended to have longer dam passage times than at The Dalles Dam, but differences were smaller than for fish that exited; no consistent differences were found for steelhead and fall chinook salmon that did not exit at the two dams (Table 4).

John Day Dam passage times for spring–summer chinook salmon in both years were longest in April and decreased each month through July. Times decreased for exit and non-exit spring–summer chinook salmon in each month, but exit fish took 16 to 54 h longer to pass in all months except April 1997, when median times were > 6 d (144 h) for both groups. Except for April, spring–summer chinook salmon delays related to fishway exit were greater in 1997 (high flow) than in 1998 (average flow). In both years, proportions of spring–summer chinook salmon that exited John Day Dam fishways increased each month, a pattern that also occurred at The Dalles Dam. Exit proportions, however, were higher at John Day than at The Dalles Dam in all months.

Steelhead passed John Day Dam fastest in August and September 1997 (Table 4). In all months except November, steelhead that exited took 12 to 14 h longer to pass the dam than fish that did not exit; exit fish took 44 h longer to pass in November. Fall chinook salmon that exited John Day Dam fishways also took 12 to 14 h longer to pass the dam than non-exit fish. Sockeye salmon that exited took 12 h longer to pass in June and 7 h longer in July. Proportions of fall chinook and sockeye salmon that exited were more consistent between months than for either spring–summer chinook salmon or steelhead, but exit proportions tended to be highest in months when mainstem temperatures were highest. Steelhead, sockeye salmon and fall chinook salmon exit proportions were higher at John Day than at The Dalles Dam in all months.

Location of uppermost site reached before first fishway exit

Almost all fish that first entered and exited at the WA-shore fishway turned around in the transition pool and the transition pool (Figure 2). More than 90% of spring–summer

Table 3. Proportion of radio-tagged fish that entered and subsequently exited fishways and transition pools into tailraces at John Day and The Dalles dams, and the average number of fishway exits per fish that entered and per fish that exited.

	Sp/Su CK		Steelhead	Fall CK	Sockeye
Exited fishways (%)	1997	1998	1997	1998	1997
John Day	**56.0**	**77.5**	**67.4**	**96.5**	**70.1**
The Dalles	33.8	46.4	37.0	66.3	29.7
Exited transition pools (%)					
John Day	**42.5**	**62.3**	**55.9**	**86.6**	**45.0**
The Dalles	23.9	38.3	29.6	51.2	22.3
Number of fishway exits/entry fish					
John Day	3.1	4.1	4.0	10.5	2.2
The Dalles	0.8	1.1	1.1	1.8	0.5
Number of fishway exits/exit fish					
John Day	5.5	5.3	5.9	10.8	3.1
The Dalles	2.5	2.4	3.0	2.8	1.8

chinook and steelhead were recorded at transition pool antennas before their first fishway exit, as were more than 95% of fall chinook and sockeye salmon. Very few fish were recorded at the antenna just upstream from the transition pool, or at antennas near the count window or at the top of the ladder before backing down.

The uppermost sites reached by fish that first exited the OR-shore fishway were mostly at the southern end of the collection channel (36-66%), the north end of the collection channel (16-34%) or at one of several sites within the influence of the transition pool (16-41%) (Figure 3). Fish that first turned around within the transition pool influence included those recorded at the collection channel antenna between the southernmost fishway entrance and the first transition pool weir (< 5%), those at the antenna between the first and second weirs in the transition pool (< 20% except steelhead = 33%), those at antennas in the submerged-weir portion of the transition pool (< 5% except chinook salmon in 1997 = 21%), and those recorded at an antenna just upstream from the switch to overflow weirs at the bottom of the ladder (< 10%). Some fish recorded at the latter antenna were likely in the upper transition pool when they turned. Differences between 1997 and 1998, particularly the proportion of turns in the OR-shore transition pool, may have been a function of much higher tailwater elevations in 1997.

Proportionately more spring–summer chinook salmon and steelhead in 1997 first turned around near the antenna near the eighth transition pool weir when tailrace elevations were highest and it was possible that fish swam over the first weirs in that year. We moved the mid-transition pool antenna five weirs higher (to the 13th weir) in

Table 4. Median passage times (tailrace to top of ladder) for radio-tagged fish that either did or did not exit from a fishway into the tailrace before passing John Day and The Dalles dams, with proportions that exited fishways each month.

	John Day Dam					The Dalles Dam				
	Exited		No Exits		%	Exited		No Exits		%
Month	N	Hours	N	Hours	Exited	N	Hours	N	Hours	Exited
Spring–Summer Chinook 1997										
Apr	25	146.3	33	143.2	43%	12	167.0	106	95.2	10%
May	105	76.9	170	**23.3	38%	50	72.3	171	51.5	23%
Jun	43	44.3	27	**12.1	61%	41	29.4	42	**11.1	49%
Jul	103	31.9	21	**9.6	83%	62	17.1	71	**9.5	47%
Spring–Summer Chinook 1998										
Apr	64	69.2	40	**15.9	62%	63	55.8	78	**34.0	45%
May	115	43.0	111	**22.4	51%	90	31.8	132	**13.8	41%
Jun	54	32.4	20	*13.5	73%	46	24.6	52	**12.3	47%
Jul	74	26.1	27	**9.9	73%	40	18.0	29	**8.4	58%
Steelhead 1997										
Jun	2	29.5	5	15.8	29%	1	27.0	7	10.6	13%
Jul	26	24.2	15	*11.3	63%	18	15.7	31	14.1	37%
Aug	16	21.8	7	*7.9	70%	21	20.4	19	**9.8	53%
Sep	140	19.0	66	**7.4	68%	27	25.6	61	**9.5	31%
Oct	109	28.1	67	**15.6	62%	31	22.2	84	**13.8	27%
Nov	12	55.0	7	*10.8	63%	1	28.3	2	13.3	33%
Sockeye 1997										
Jun	71	24.7	29	**12.0	71%	48	18.5	104	**6.3	32%
Jul	159	14.6	77	**7.5	67%	65	15.0	193	**6.0	25%
Aug	6	11.4	1	6.2	86%	2	50.0	5	6.1	29%
Fall Chinook 1998										
Sep	151	22.4	5	*10.3	97%	86	17.7	52	**9.3	62%
Oct	130	25.1	10	*10.9	93%	52	19.8	24	**12.2	68%
Nov	1	40.2			100%	1	10.7	1	25.4	50%

* $P < 0.05$, ** $P < 0.005$ (Kruskal-Wallis χ^2 test of medians); comparing times for fish that did or did not exit

1998. The move upstream, combined with lower tailwaters in 1998 probably explains the lower proportion of first turns recorded in mid-transition pool in 1998. The distribution of OR-shore fishway turn-around locations did not change much through each migration. An exception was the 1997 spring–summer chinook salmon run, which had more fish turn around at the southern end of the collection channel or in the transition pool in April, May and June but far more turns in the north end of the collection channel (or at unmonitored mid-collection channel sites) in July.

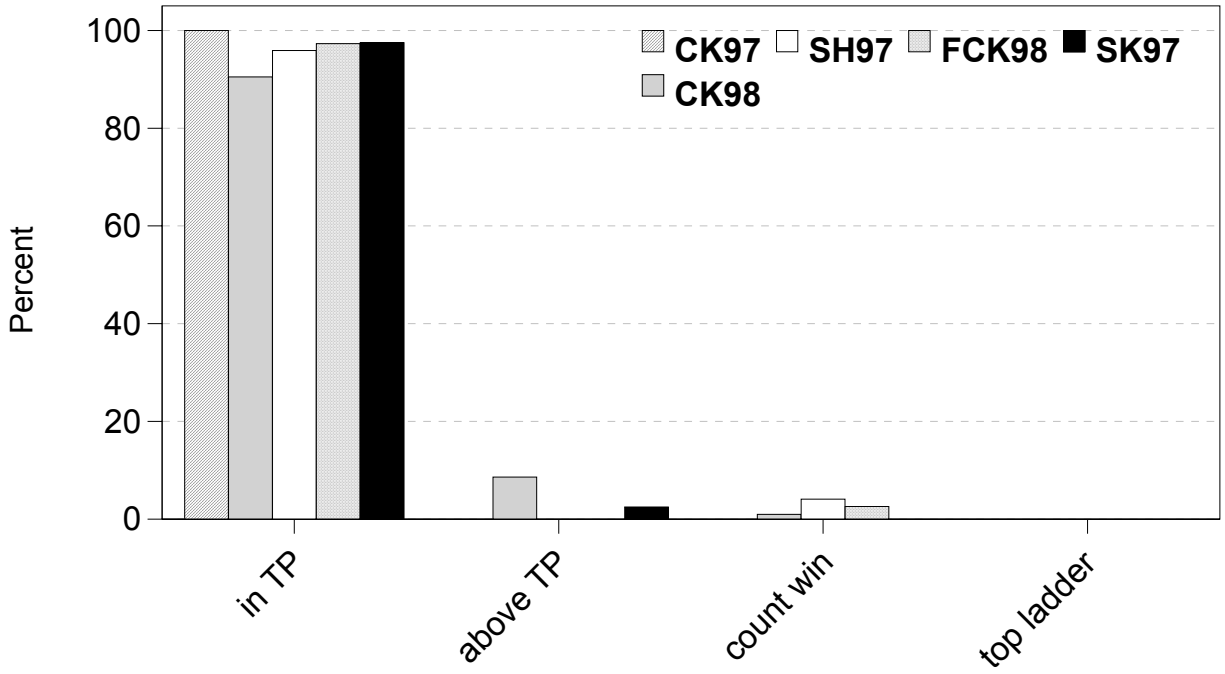

Figure 2. Location of uppermost WA-shore fishway site reached before first fishway exit.

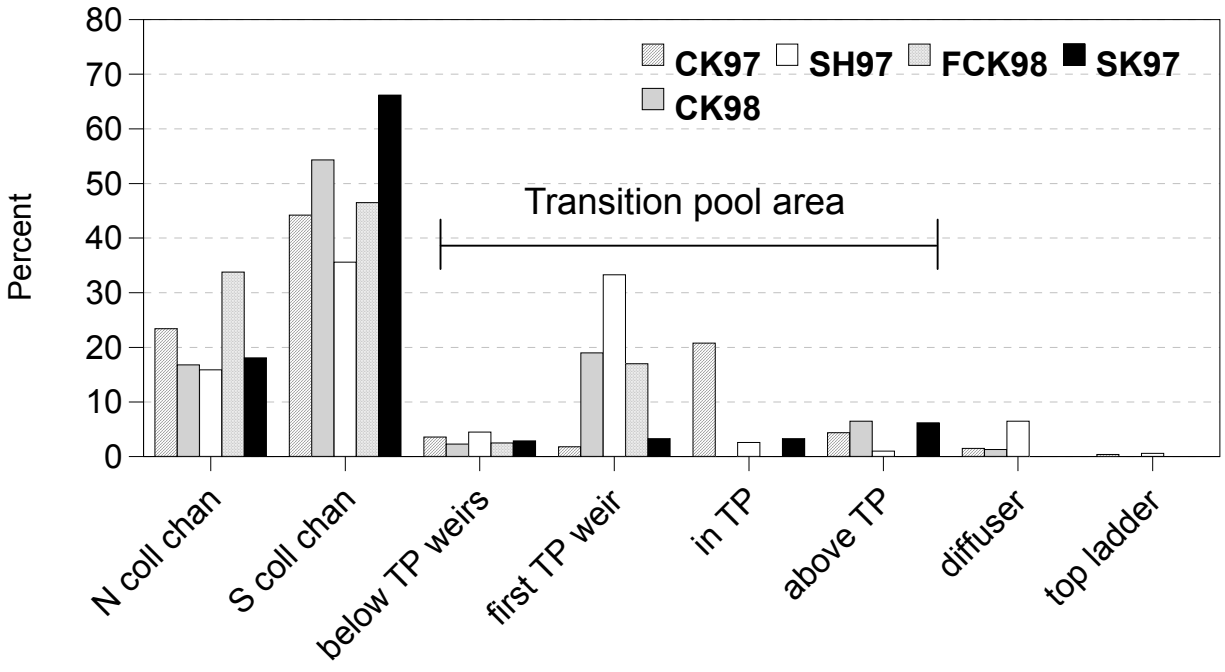

Figure 3. Location of uppermost OR-shore fishway site reached before first fishway exit.

Most fish from all species-years made the majority of their first turn-arounds during daylight hours. We did not identify major changes in the distribution of turn-around locations during different times of day. However, when water temperatures were warmest, the proportions of first turn-arounds between 6 a.m. and noon increased and proportions of first turns between noon and 6 p.m. decreased for both spring–summer chinook salmon and steelhead. This pattern may have been a function of significantly higher proportions of those runs exiting fishways during the warmest months (see above) and the tendency for fish to first enter fishways in the morning.

Exit behavior and temperature

Mean daily water temperatures in the John Day Dam forebay, tailrace, and both ladders were warmer in 1998 than in 1997 on almost all days from April through September (USACE and FFU data). Water in the OR-shore ladder was consistently warmer than in the WA-shore ladder in both years. The greatest differences between ladder and forebay temperatures were in the OR-shore ladder in 1998 (Table 5). Larger temperature differences between forebay and ladder temperatures occurred mostly during afternoon hours (see also Dalen et al.1999).

The likelihood of a fishway entrance resulting in an exit back to the tailrace was similar for fish that entered the WA- and OR-shore fishways at most temperatures, except that sockeye salmon were generally less likely to exit the WA-shore fishway (Figure 4). The proportion of fish that made one or more fishway exits tended to increase with temperature, as indicated by the monthly exit proportions in Table 4. For all species and years, the proportions that exited were highest in the warmest months at John Day Dam. Similarly, the proportion of all fishway entries that resulted in exits increased with maximum hourly temperatures for spring–summer chinook and sockeye salmon, and increased slightly with temperature for steelhead and fall chinook salmon.

Exit rates per fish per day also tended to increase with mean daily ladder temperatures, particularly for the OR-shore fishway (Figure 5). Quadratic equations, weighted by the number of fish on each day, using all days when more than 5 fish entered were significant for both fishways for spring–summer chinook salmon ($P < 0.0001$), and for the OR-shore fishway for sockeye salmon ($P = 0.01$), fall chinook salmon ($P = 0.007$), and steelhead ($P = 0.06$). Exit rates were consistently higher from the OR-shore fishway than from the WA-shore fishway for sockeye salmon, steelhead, and fall chinook salmon. Because individual fish entered and exited both fishways, we modeled exits/fish/day for the two fishways combined and used OR-shore fishway temperatures, as they were likely the warmest fish encountered on any day. Exits/fish/day increased with temperature for all species-years: 1997 spring–summer chinook salmon ($P < 0.0001$, $r^2 = 0.87$), 1998 spring–summer chinook salmon ($P < 0.0001$, $r^2 = 0.79$), 1997 sockeye salmon ($P = 0.002$, $r^2 = 0.36$), 1997 steelhead ($P = 0.018$, $r^2 = 0.11$), 1998 fall chinook salmon ($P = 0.003$, $r^2 = 0.20$).

Table 5. Summary of daily maximum temperature differences between ladder monitoring sites and the forebay at John Day Dam in 1997 and 1998, April through mid-September. (Forebay data unavailable after ~17 September in both years.)

	1997		1998	
Measure	OR-shore	WA-shore	OR-shore	WA-shore
Average	0.84	0.12	1.26	0.38
Median	0.70	0.10	1.10	0.20
STD	0.55	0.20	0.81	0.43
Max.	2.70	0.90	3.90	2.40
Min.	-0.01	-0.30	0.20	0.00

Compared to mean daily ladder temperatures, maximum daily differences between forebay and fishway temperatures were a poor predictor of exit rates/fish/day for both fishways, and for the two fishways combined. (*Note*: the analysis using maximum differences was limited for 1997 steelhead and 1998 fall chinook salmon because forebay temperatures were unavailable after mid-September.) Based on half-degree increments, there was little evidence that the magnitude of temperature differences was a strong contributor to fishway exit rates during individual months (Figure 6). Instead, rates tended to be highest in the warmest months for all species-years, regardless of daily forebay-fishway temperature difference. Results were similar when fishways were examined separately, except that OR-shore fishway exit rates tended to be higher for all categories.

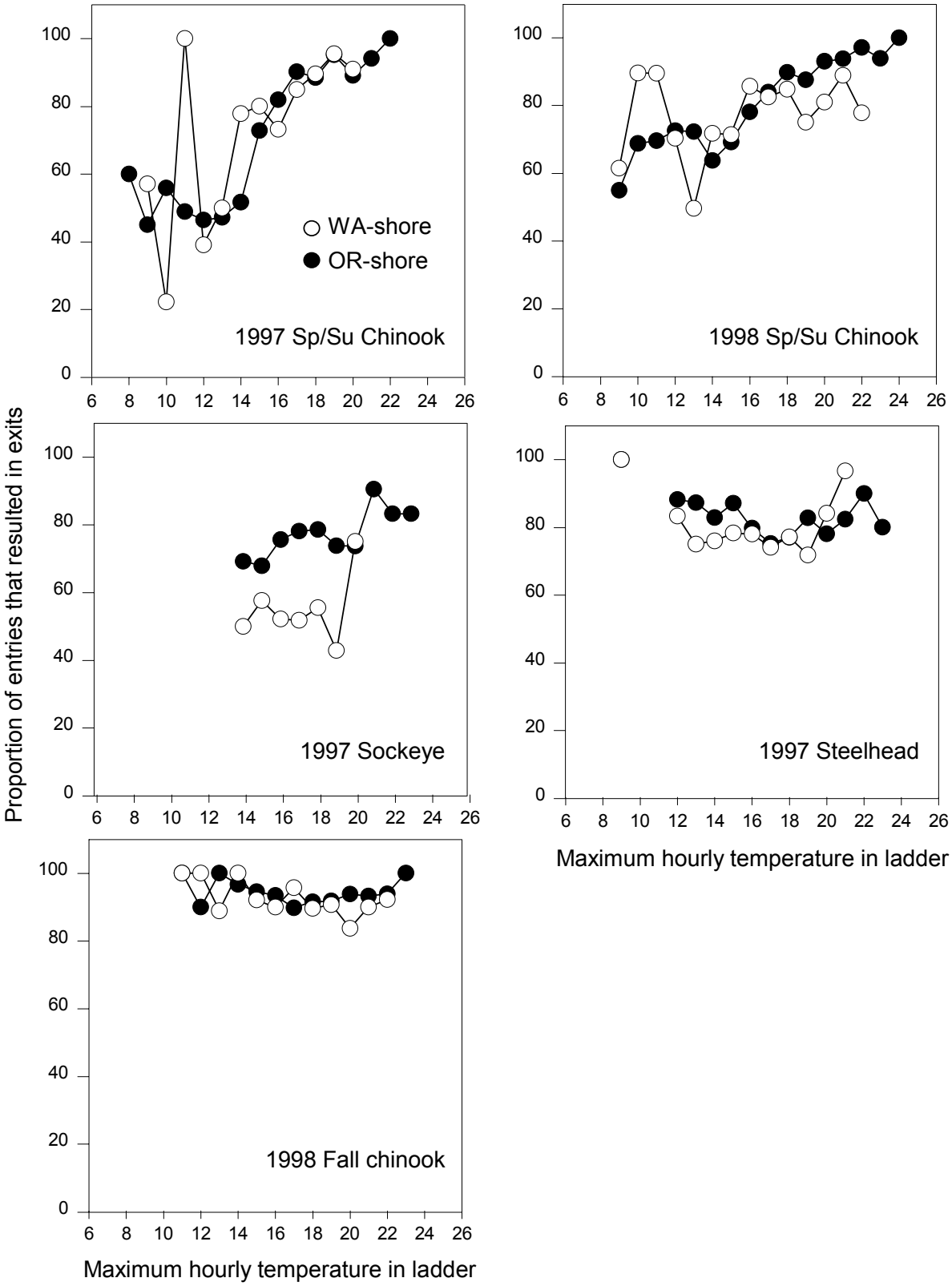

Figure 4. Proportion of fishway entries that resulted in fishway exits based on maximum hourly fishway temperature at the time of fishway entry.

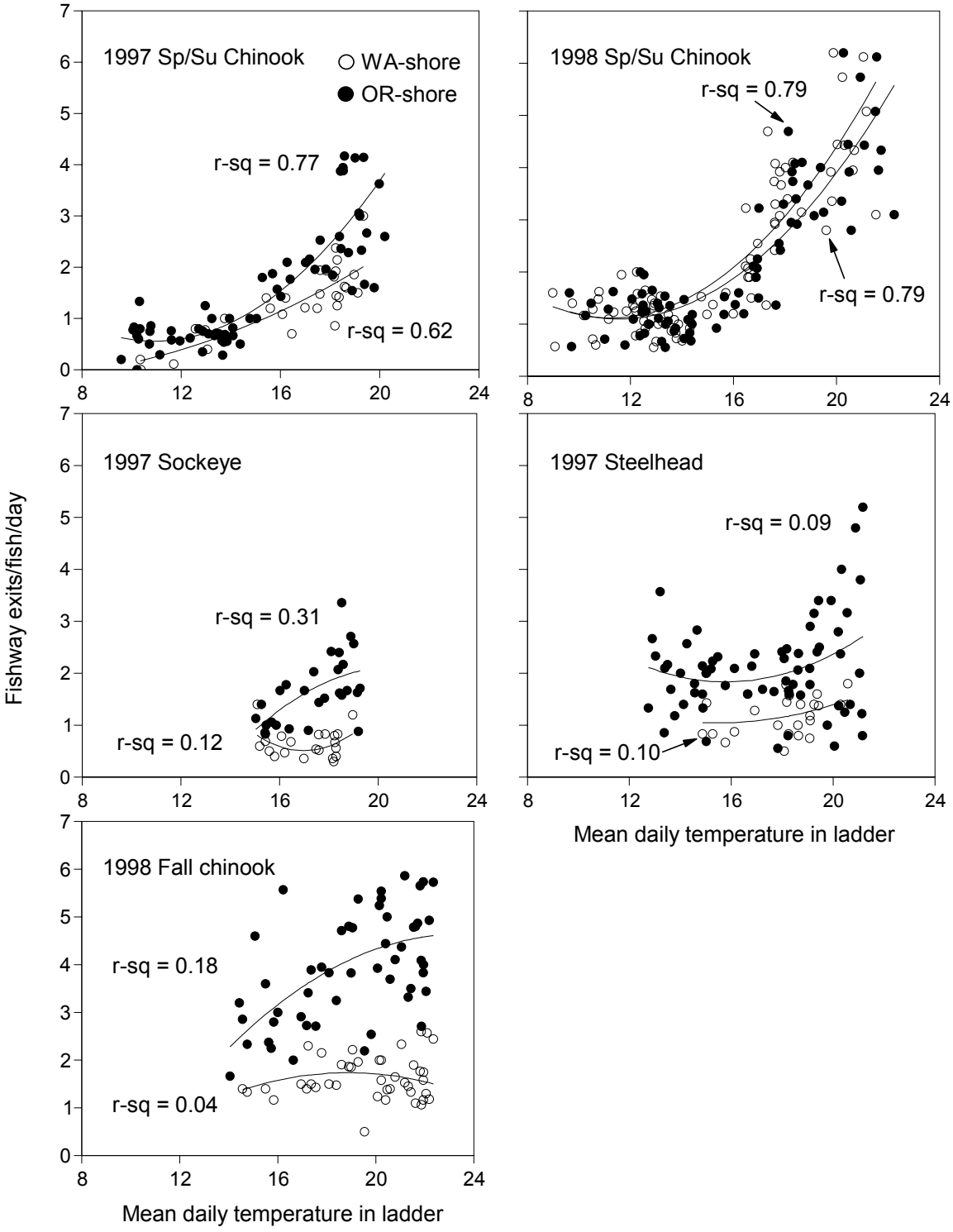

Figure 5. Fishway exits per fish per day, based on number of fish that entered each fishway each day (days with < 5 fish excluded) and mean daily ladder temperature.

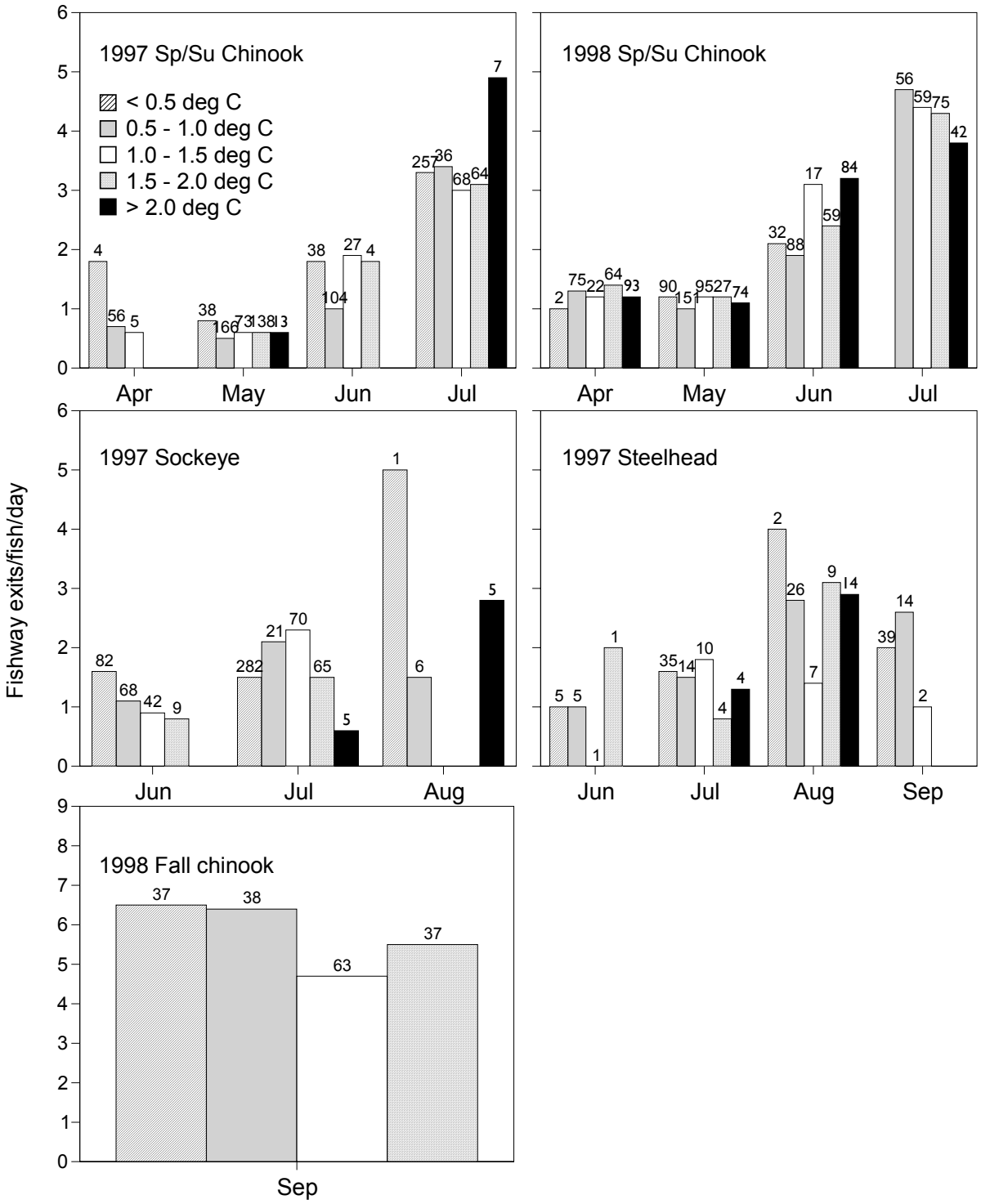

Figure 6. Fishway exits per fish per day (both fishways combined) based on month and maximum daily difference between forebay and OR-shore fishway temperatures.

Summary

It is difficult to establish cause and effect with this type of non-experimental, retrospective analysis, but we did observe some behaviors that were similar between species and between years. Radio-tagged salmonids from all species-years took longer to pass John Day than The Dalles dams. Fish from all species-years also tended to pass the dams more quickly as water temperatures increased.

'Delay' at John Day Dam appeared to accrue mainly after fish first entered a fishway, and fish that exited a fishway had significantly longer passage times than fish that did not exit in almost all months of all years. Similar patterns were observed at The Dalles Dam. However, far more fish exited John Day Dam fishways and transition pools into the tailrace than at The Dalles Dam, and this is likely the primary explanation of why dam passage times were longer at John Day Dam.

Similar proportions of each run exited from the WA- and OR-shore fishways at John Day Dam, but exit rates were typically higher for the OR-shore fishway. The proportions of spring–summer chinook and sockeye salmon that exited increased as maximum hourly ladder temperatures increased. Exits/fish/day increased significantly with daily ladder temperatures for both fishways (spring–summer chinook salmon) and the OR-shore fishway (sockeye salmon, steelhead, fall chinook salmon). Exits/fish/day tended to be higher for the OR-shore fishway at all temperatures, especially for sockeye salmon, steelhead and fall chinook salmon.

Mainstem Columbia River water temperatures were similar at The Dalles and John Day dams in the two years (DART database), but fishway temperatures tended to be higher at John Day Dam than at The Dalles Dam, especially in the John Day Dam south-shore ladder (Dalen et al. 1999).

Mean and maximum ladder temperatures at John Day Dam were much more strongly correlated with exit rates than were differences between forebay and ladder temperatures. There was little compelling evidence that steep gradients between forebay and fishway temperatures were an important independent cause of fishway exits or delay: the temperature gradient between the cooler lower-ladder water (downstream from diffusers) and water in the upper ladder may exacerbate exit behavior by adult fish because it occurs in the transition pool area, a location where we have identified adult delays at many dams. High rates of fishway and transition pool exit behavior under a wide range of temperature conditions, however, suggest that factors other than temperature alone were responsible for relatively slow passage at John Day Dam. Configuration of fishway entrances, collection channels and/or transition pools, and conditions in the fishways (e.g. quality and quantity of attractive flow, ease of finding orifice openings, etc.) should be further evaluated. Specifically, additional research is recommended for the OR-shore fishway, where John Day Dam exit rates are highest and where most fish pass the dam.

Elevated water temperatures in the south-shore ladder appear to be related to the location of the John Day River just upstream from the ladder exit (Dalen et al. 1999). Supplying cooler water to the upper ladder could potentially reduce temperature-averse behavior by adult migrants in the lower ladder. However, cool water additions in the upper ladder could also result in fish encountering steep temperature gradients when they reach the top of the ladder. How fish would respond to elevated temperatures at the ladder exit is unknown.

References

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