Technical Report 2011-2-Draft

IDAHO COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT

BEHAVIOR OF RADIO-TAGGED ADULT SPRING-SUMMER CHINOOK SALMON AT THE DALLES DAM IN RELATION TO SPILL VOLUME AND THE PRESENCE OF THE BAY 8/9 SPILL WALL AND AT JOHN DAY DAM IN RELATION TO NORTH SHORE LADDER MODIFICATIONS, 2010

by

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2725 Montlake Blvd. East, Seattle, Washington 98112

for

U.S. Army Corps of Engineers
Portland District

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Abstract

The construction of a ~145 meter spill wall at The Dalles Dam was completed in April 2010 and was designed to improve the survival of spillway-passed juvenile salmonids by directing them toward deep water with fewer predators. We evaluated how the new spill wall, spill volume, and a spill pattern, which directs most water though the northern-most spillbays, may have affected behaviors and passage times of radio-tagged adult spring–summer Chinook salmon in 2010.

Tagged salmon had little apparent difficulty locating and using the north fishway at low (0-50 kcfs) and medium (>50-100 kcfs) spill volumes. At high spill volumes (>100-150 kcfs), tagged salmon used the north fishway less frequently. Entrance efficiency decreased from 95% at low and medium spill volumes to 67% at high spill volumes. Approach routes taken by tagged salmon initially recorded on spillway receivers during low and medium spill volumes were generally consistent with the hypothesis that salmon were swimming upstream along the north shore and subsequently approached the north fishway. During periods of high spill, telemetry records suggested that the majority of adults swimming up the north shore encountered the spillway discharge and subsequently crossed the river to the south prior to approaching a powerhouse fishway opening. This was consistent with the high percentage of salmon that first approached powerhouse fishways, the low entrance efficiency at the north fishway, and the low daily Chinook salmon counts at the north ladder during periods of high spill.

The new spill wall and the spill pattern employed in 2010 did not appear to impede the ability of tagged salmon to seek and find alternate passage routes when spill volumes were high or when approaches at the north fishway did not result in a fishway entry. Dam passage times for radio-tagged Chinook salmon in 2010 were the fastest among all comparison years (median = 12.1 h, n = 285), perhaps because approximately two-thirds of the tagged salmon passed the dam by 1 June 2010, a period when mean daily spill volumes were less than 100 kcfs. Our findings did suggest, however, there may be some justification for concerns that smaller fish may be unable to successfully use the north fishway when most or all spill volume is directed through spillbays 1-8.

The counting window at the north fishway at John Day Dam underwent structural modifications in spring 2010. Radio-tagged Chinook salmon consistently used less time to pass the counting window in 2010 compared to monthly median passage times recorded in 1998, the lone comparison year. The available data suggest the modifications had little or no adverse affects on adult salmon passage.

Acknowledgements

Many people assisted with the field work and data compilation for this report and its successful completion was made possible through their efforts. They include: Dennis Quaempts, Dan Joosten, Eric Johnson, Steve Lee, and George Naughton for performing the radiotagging of adult salmon, Matt Knoff and Mark Morasch for downloading receivers, and Kinsey Frick for administering the database in Seattle. This study was funded by the U.S. Army, Corps of Engineers (USACE), Portland District, with assistance provided by Sean Tackley.

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Introduction

The construction of a ~145 meter spill wall at the western base of The Dalles Dam was completed in April 2010 and was designed to improve the survival of spillway-passed juvenile salmonids by directing them toward deep water with fewer predators (Figure 1). In addition to the installation of the spill wall, spillway discharge was to be directed through the northern-most spill bays. The spill pattern raised concerns that adult salmonid migration might be slowed through an inability to find or use the north-shore fishway. This report evaluates how the new spill wall, spill volume, and the spill pattern may have affected behaviors and passage times of radio-tagged adult spring–summer Chinook salmon in 2010. Specific objectives at The Dalles included:

1) Estimation of entrance efficiency at the north-shore entrance (i.e., number of entries / number of approaches) and spillway residency time of tagged salmon in relation to spill volume.
2) Evaluation of any effects of fish size on route selection and dam passage times.
3) Evaluation of any effects of water temperature, date, flow, and spill volume on tailrace to first fishway entry times.

Figure 1. Photograph of spill walls at bays 6/7 (left) and 8/9 (right) at The Dalles Dam in 2010.

The upper section of the north shore fish ladder at John Day Dam was reconstructed during winter 2009-2010. Specific modifications included: 1) removal of existing concrete weirs in the fish ladder along with the existing sill gates and actuators; 2) construction of new concrete weirs; 3) modification of existing concrete baffles in the transition section located in the non-overflow portion of the dam; 4) modifications to the floor, diffuser, and the fish counting building within the fish ladder; 5) replacement of the existing bulkhead, picket leads, crowder, and light box and the addition of a window washer for the fish counting building (USACE solicitation found at http://www.dgmarket.com/tenders/np-notice.do~4109482).

We evaluated passage of radio-tagged adult Chinook salmon through the new ladder section at John Day Dam in 2010 and compared monthly window passage times from 2010 to those from 1998, the lone year when we had similar telemetry coverage.

Methods

Radio-tagging

From 10 April through 30 June 2010, we collected and intragastrically radio-tagged 600 spring–summer Chinook salmon at the Adult Fish Facility of Bonneville Dam and released them approximately nine kilometers downstream from the dam (Figure 2). A description of the collection and tagging methods is presented in Keefer et al. (2004) and passage behavior of the tagged sample at Bonneville Dam in 2010 is the subject of a separate report (Jepson et al. *in review*). A total of 313,142 adult spring Chinook salmon and 72,322 adult summer Chinook salmon were counted passing the dam during the tagging period. Radio-tagged salmon represented ~0.2% of the salmon counted at the dam during the tagging period.

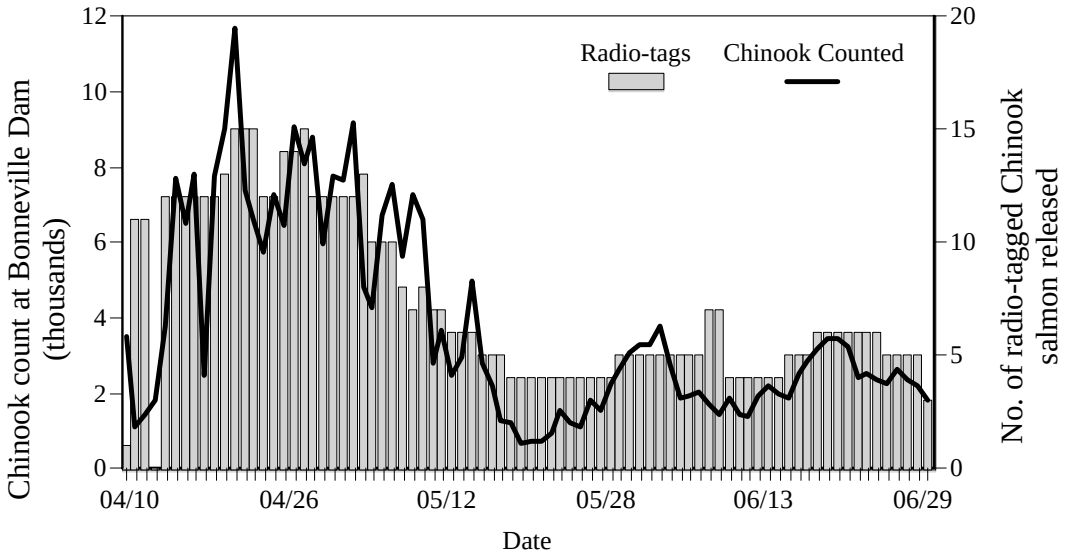


Figure 2. The number of Chinook salmon radio-tagged and released downstream from Bonneville Dam and the count of adult Chinook salmon passing the dam from 10 April through 30 June 2010.

Receiver Deployments

During 2010, The Dalles Dam was outfitted with underwater antennas outside of all main fishway openings, within major fishways, and at both ladder tops (Figure 3). We additionally installed three SRX receivers with six-element yagi antennas on the Washington shore approximately 150, 180, and 210 m downstream from the north fishway opening. These receivers were deployed to monitor the movements and residency times of tagged Chinook salmon immediately downstream from spillbays 1-8. We also deployed an SRX receiver with an aerial yagi antenna at the top of spillbay 20 to monitor the tailrace area south of the new spill wall.

John Day Dam was outfitted with two SRX receivers with six-element yagi antennas in the tailrace, one on each side of the river (Figure 4). Ladder tops were monitored with underwater antennas and the count window stations had an underwater antenna deployed both upstream and downstream from it (i.e., the antennas used to calculate window passage times).

Receiver Outages

The sensitivity of the underwater antenna deployed at the north-shore ladder exit was determined to be low on 27 May 2010. A total of 45 passage events via the north ladder were undetected between 16 April and 27 May 1010 (inferred from records within the north-shore fishway and subsequent detections upstream from The Dalles Dam) while 72 known passage events were detected in this interval. Estimates of dam passage times for radio-tagged that passed the north-shore fishway undetected could not be made with confidence and were therefore excluded from any passage time summaries or analyses.

Spillway Residency Times

For evaluations of behaviors of tagged salmon detected downstream from the spillway (Figure 3), we defined spillway residency time as the interval between the initial detection on a north-shore spillway receiver to the last detection on a north-shore spillway receiver before its first fishway approach.

Evaluations of Fish Size, Route Selection, and Passage Times

We used the salmon fork length distribution to assign the sample fish into three size classes with approximately equal numbers of fish in each class: small (< 73 cm), medium (73-79cm), and large (> 79 cm) (Figure 5). We compared the frequencies of different size classes that made their first fishway approach at, or passed the dam via, the north-shore fishway using Chi-square tests. We evaluated the effects of fork length on $\log^e$-transformed tailrace to first fishway entry times using linear regression and we used logistic regression to evaluate fish size as a potential correlate with dam passage route (North or East) as the dependent variable.

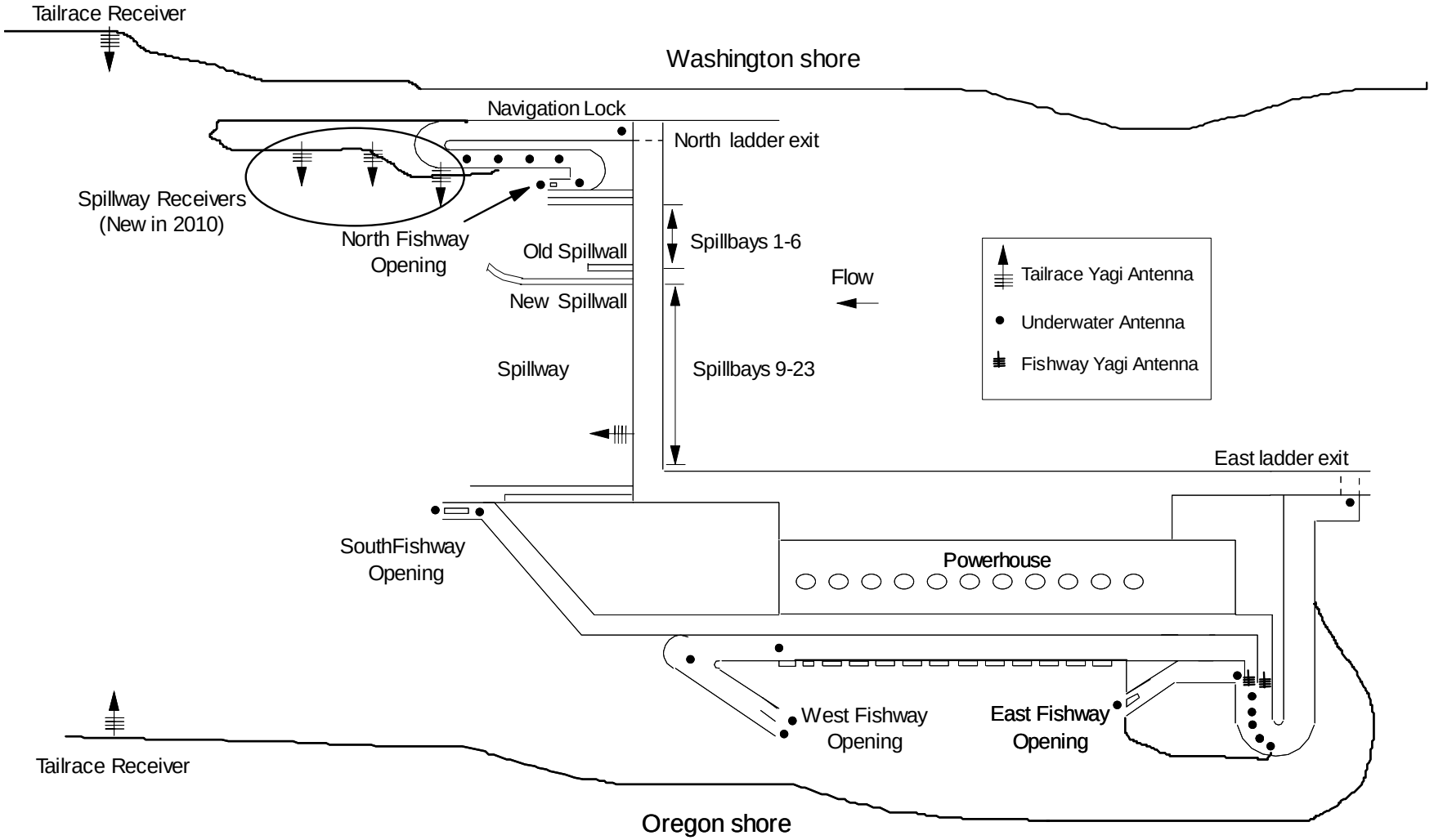


Figure 3. Aerial view of radio antennas deployed at The Dalles Dam in 2010 (drawing not to scale).

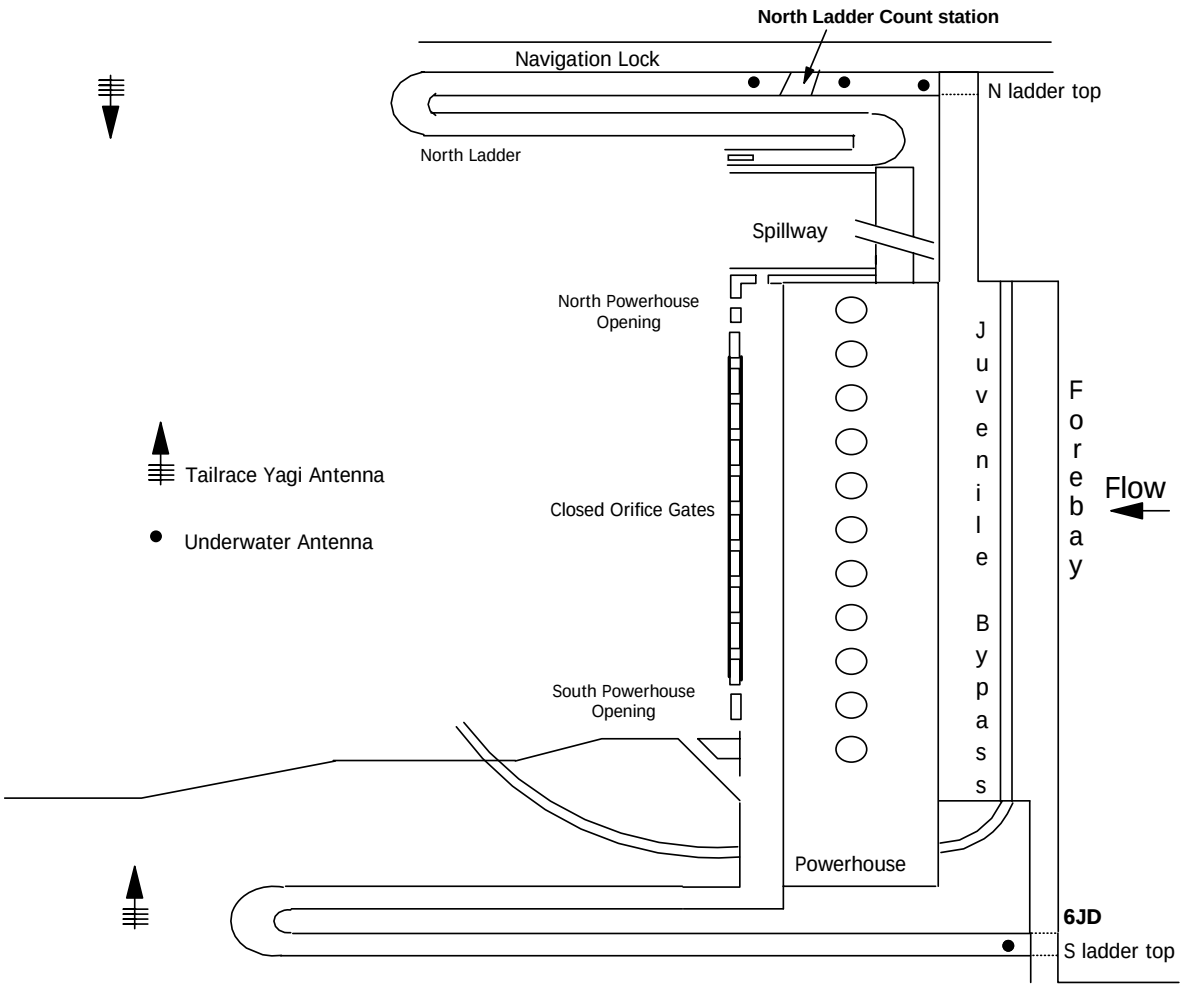


Figure 4. Aerial view of radio antennas deployed at John Day Dam in 2010.

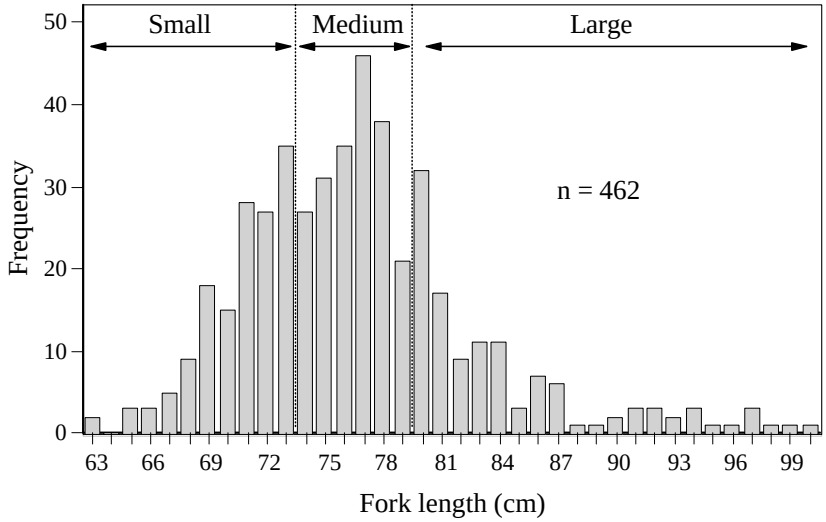


Figure 5. Distribution of fork lengths of radio-tagged spring–summer Chinook salmon detected at The Dalles Dam in 2010.

Results

Of the 600 tagged salmon released downstream from Bonneville Dam in 2010, 464 were recorded at The Dalles Dam (Figure 6 and Table 1). Initial detection dates of tagged salmon at The Dalles Dam ranged from 16 April through 6 July. The number of tagged salmon first arriving at the dam averaged 5.6 fish per day (*range* = 0-19) over the course of the study. A total of 246,636 adult Chinook salmon were counted passing the dam during the study period and tagged salmon represented ~0.2% of those counted. With few (i.e., 5 days) exceptions, the daily count of adult Chinook salmon passing the dam via the East ladder exceeded the count of Chinook salmon passing via the North ladder and the ratio of salmon counted in the north ladder to the count in the east ladder decreased through the study (while flows increased) (Figure 7).

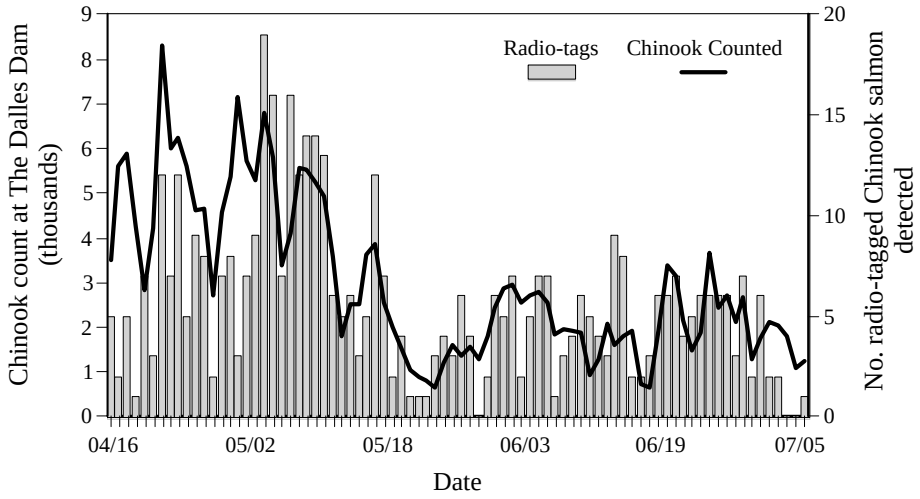


Figure 6. The number of unique, radio-tagged Chinook salmon detected at The Dalles Dam and the count of adult Chinook salmon passing the dam from 16 April through 06 July 2010.

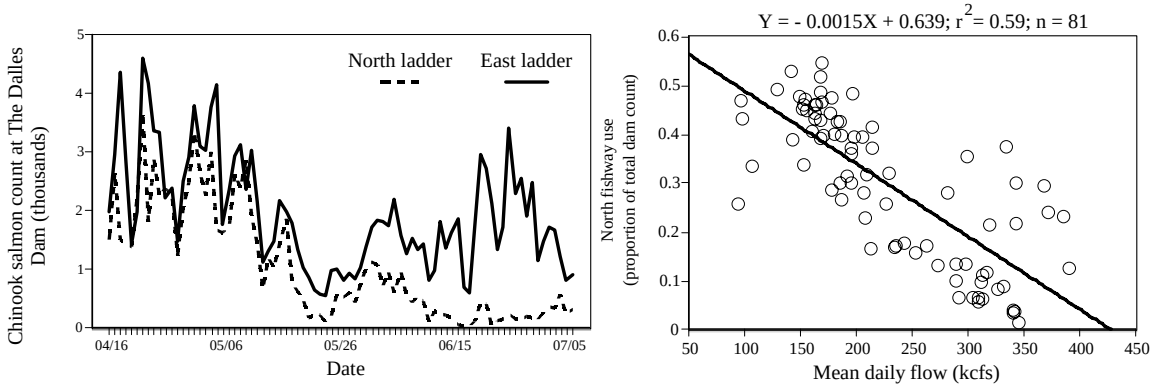


Figure 7. The daily number of adult Chinook salmon counted passing the North and East ladders of The Dalles Dam from 16 April through 06 July 2010 (left panel) and linear regression scatterplot of north fishway use versus mean daily flow (right panel).

Of the 464 radio-tagged salmon recorded at The Dalles Dam, 443 passed the dam; 144 (~33%) via the north ladder and 297 (67%) via the east ladder (Table 1). Two tagged salmon (<1%) likely passed the dam via the unmonitored navigation lock. Seventy percent of tagged salmon were recorded on the tailrace receivers, 82% had their first fishway approach recorded, 69% had their first fishway entry recorded, and 84% were recorded at the ladder exit. A total of 30 fallback events were recorded by 24 unique, radio-tagged salmon (fallback percentage = 24 unique salmon / 443 unique salmon passed = 5.4%). Twenty fallback events (67%) were preceded by dam passage events via the east ladder and ten (33%) were preceded by dam passage events via the north ladder. No post-fallback data were evaluated as part of this report.

Table 1. Number and percent of adult radio-tagged Chinook salmon recorded at The Dalles Dam that were recorded on their first passage of the tailrace, first approach at a fishway opening, first fishway entry, and exit from the top of a ladder.

2010	Freq.	Percent
Recorded at dam	*464*	*100*
Known to pass dam	*443*	*95*
Recorded first tailrace passage	*327*	*70*
Recorded first (known) fishway approach	*380*	*82*
Recorded first (known) fishway entrance	*320*	*69*
Recorded ladder exit	*392*	*84*

Environmental Data

Mean daily river discharge averaged 229 kcfs (*range* = 94-391 kcfs) during the 2010 study period (Figure 8). Spillway discharge averaged 89 kcfs (*range* = 37-138 kcfs). Mean daily river temperature increased steadily during the study, with a minimum of 9.3 ºC in mid-April and a maximum of 17.2 ºC in early July. Tailwater elevation generally increased as flow and spill increased, and ranged from 76 to 86 feet above mean sea level.

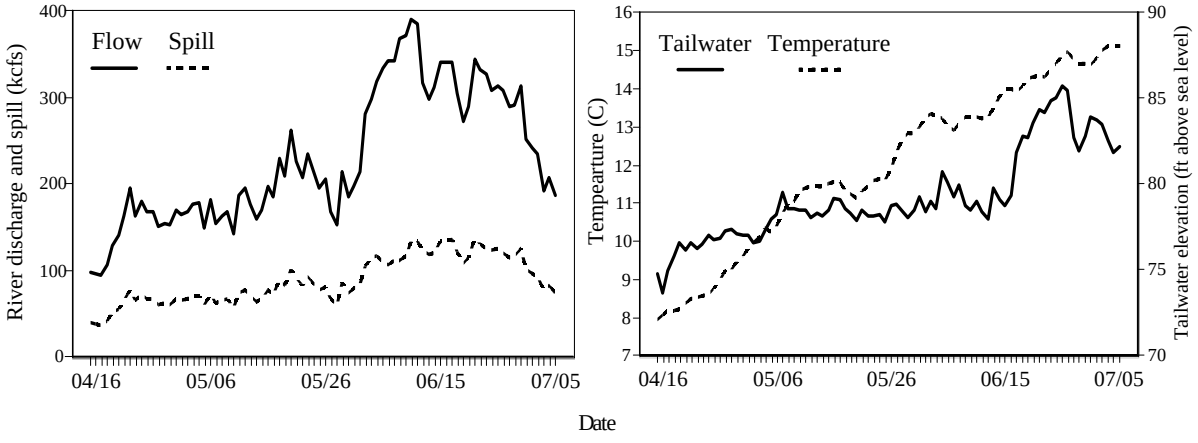


Figure 8. Mean daily river and spillway discharge (left panel), mean daily river temperature, and tailwater elevation (right panel) at The Dalles Dam from 10 April through 6 July 2010.

Passage Times and Environmental Predictors

The median times from first tailrace record to first fishway approach for tagged salmon in 2010 were 2.9 h (n = 51) in April and 3.3 h (n = 122) in May (Table 2). These were the fastest and third fastest times, respectively, recorded in the ten study years. In contrast, the median time in June 2010 (5.0 h, n = 93) was the slowest recorded among years. The median first approach time for tagged salmon in July 2010 (3.5 h, n = 5) also ranked as one of the slowest medians among years. Similarly, the median times from first tailrace record to first fishway entry in April- May 2010 were the fastest or second fastest among all study years whereas the median times in June and July 2010 ranked as some of the slowest. The median times for radio-tagged Chinook salmon to pass The Dalles Dam (tailrace to ladder top) in April-July 2010 were the fastest among all study years. The monthly median times from first fishway approach to fishway first entry in 2010 were some of the fastest among all years.

In linear regression models, water temperature, date, flow, and spill were all significant predictors of log^e-transformed tailrace to first fishway entry times (Figure 9), but low r^2 values indicated that little variation (<13%) in passage times was explained by these environmental factors.

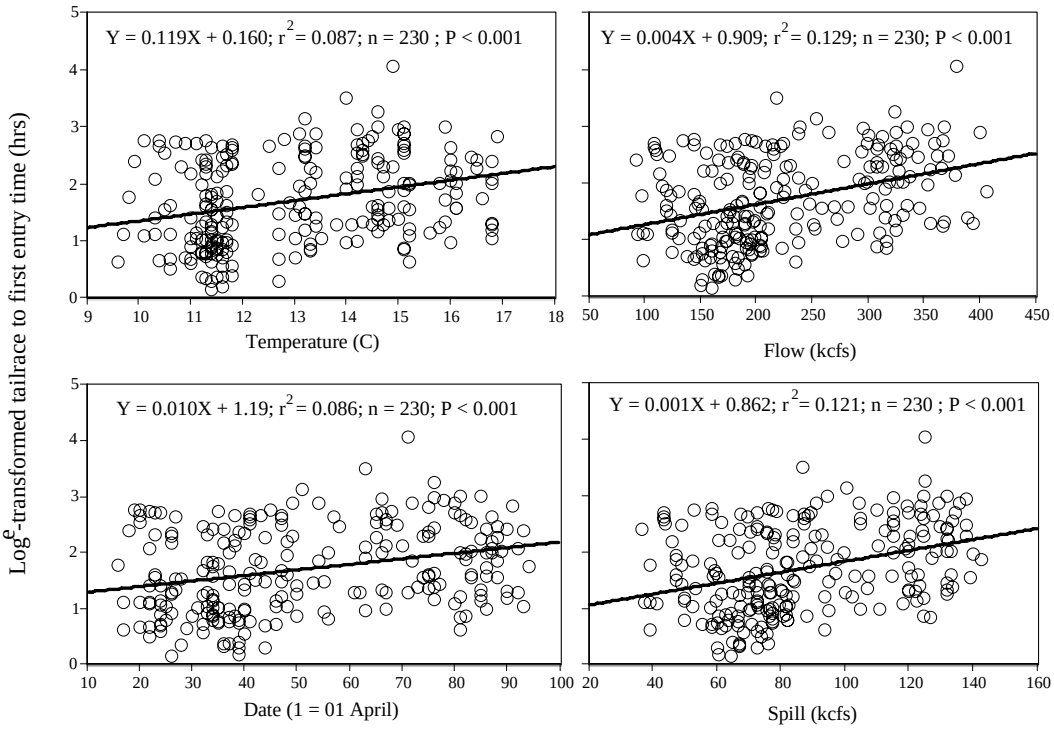


Figure 9. Linear regression scatterplots of water temperature, date, total river flow, and spill versus log^e-transformed first tailrace to first fishway entry times by radio-tagged spring–summer Chinook salmon at The Dalles Dam in 2010.

Table 2. Number of adult, radio-tagged, spring–summer Chinook salmon and median times to pass (h) 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. Rankings for 2010 values (1 = slowest time and 10 = fastest time) are listed to the right.

	1997[1]		1998[1]		2000[1]		2001[1]		2002[2]		2003[3]		2004		2007		2009		2010		
Tailrace to 1st approach	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**	N	**Med.**	**N**	**Med.**	**N**	**Med.**	**Rank**
April	125	**11.6**	147	**5.2**	199	**7.1**	295	**4.2**	147	**9.0**	179	**4.7**	56	**3.0**	2	**8.2**	1	**12.0**	51	**2.9**	**10**
May	242	**6.2**	229	**3.1**	210	**4.3**	238	**3.7**	311	**4.1**	158	**3.4**	121	**3.1**	66	**4.7**	212	**4.8**	122	**3.3**	**8**
June	87	**3.6**	100	**3.7**	96	**3.4**	136	**2.8**	155	**3.6**	135	**3.4**	92	**3.3**	115	**3.8**	170	**4.0**	93	**5.0**	**1**
July	118	**2.6**	67	**2.5**	54	**3.2**	114	**2.7**	94	**3.5**	136	**3.1**	53	**2.8**	3	**2.9**	7	**4.5**	5	**3.5**	**2.5**
Tailrace to 1st entry																					
April	101	**71.1**	132	**20.0**	172	**22.8**	271	**13.8**	140	**27.0**	165	**11.2**	48	**4.1**	2	**11.6**	1	**17.1**	45	**3.6**	**10**
May	186	**33.8**	203	**10.1**	200	**12.1**	186	**6.8**	300	**12.0**	156	**5.3**	112	**4.0**	62	**5.5**	221	**9.3**	99	**4.2**	**9**
June	68	**5.5**	72	**8.8**	94	**5.2**	136	**4.1**	149	**5.8**	132	**4.3**	88	**5.7**	96	**4.2**	172	**5.7**	81	**7.6**	**2**
July	100	**3.1**	58	**4.1**	53	**5.3**	114	**3.6**	92	**6.0**	135	**4.2**	52	**3.1**	3	**5.8**	9	**6.2**	5	**5.8**	**3.5**
Tailrace to ladder exit																					
April	118	**98.2**	141	**47.1**	198	**34.1**	290	**24.7**	144	**41.1**	182	**17.4**	56	**9.4**	9	**8.8**	1	**28.5**	45	**8.5**	**10**
May	221	**53.1**	222	**22.0**	205	**22.3**	238	**19.7**	304	**19.8**	160	**13.5**	121	**13.0**	100	**14.6**	223	**15.6**	127	**11.3**	**10**
June	83	**18.1**	98	**20.3**	96	**12.8**	138	**15.1**	154	**20.6**	136	**18.1**	92	**20.5**	112	**19.8**	177	**15.7**	107	**13.8**	**9**
July	133	**12.7**	69	**14.3**	55	**15.2**	111	**14.6**	95	**17.6**	139	**13.4**	53	**11.6**	2	**29.7**	17	**13.6**	6	**11.7**	**9**
1st approach to 1st entry																					
April	101	**41.2**	133	**8.6**	172	**11.4**	271	**4.1**	140	**14.8**	218	**3.0**	60	**0.2**	8	**< 0.1**	1	**5.1**	72	**0.2**	**8.5**
May	186	**21.0**	203	**3.6**	200	**5.6**	186	**1.6**	300	**3.7**	224	**0.9**	127	**0.5**	105	**0.1**	230	**1.2**	142	**0.2**	**8**
June	68	**0.5**	72	**0.2**	94	**0.5**	136	**0.2**	149	**0.6**	192	**0.3**	99	**0.7**	155	**< 0.1**	183	**0.3**	98	**<0.1**	**9.5**
July	99	**0.2**	58	**<0.1**	53	**0.4**	114	**0.3**	92	**1.2**	170	**0.2**	54	**0.2**	3	**2.9**	10	**0.1**	7	**0.1**	**8.5**

[1] – from Keefer et al. (2007).
[2] – from Wilson et al. *In review.*
[3] – from Boggs et al. *In review*

Passage times from tailrace to first fishway entry were associated with the time of tailrace entry (Figure 10). Tagged salmon first detected in the tailrace before 1600 hrs had a median time from tailrace to first entry of 3.9 h (*n* = 149). In contrast, tagged salmon detected in the tailrace after 1600 hrs each day had a median time from tailrace to first entry of 10.6 h (n = 81).

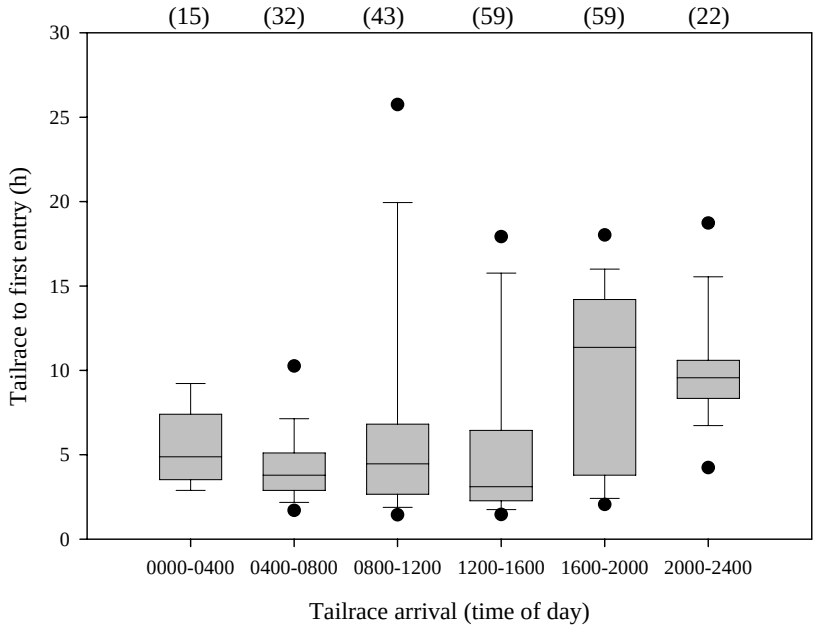


Figure 10. Median (line), quartile (box), 5th and 95th (points), and10th and 90th (whiskers) percentile of times (h) for radio-tagged spring–summer Chinook salmon to pass from the tailrace to first fishway entry at The Dalles Dam in 2010. Panels depict passage times for tagged salmon entering the tailrace during different times of day. Sample sizes are shown above bars.

Percentages of tagged salmon recorded at the North fishway

The percentage of tagged Chinook salmon detected at the North fishway in1997-2004 averaged 52% (*range* = 43-67%) (Figure 11). In contrast, a relatively small percentage of tagged salmon were detected at the North fishway in 2007 and 2009 (*range* = 14-18%). There was an intermediate percentage (34%) of tagged salmon detected at the North fishway in 2010.

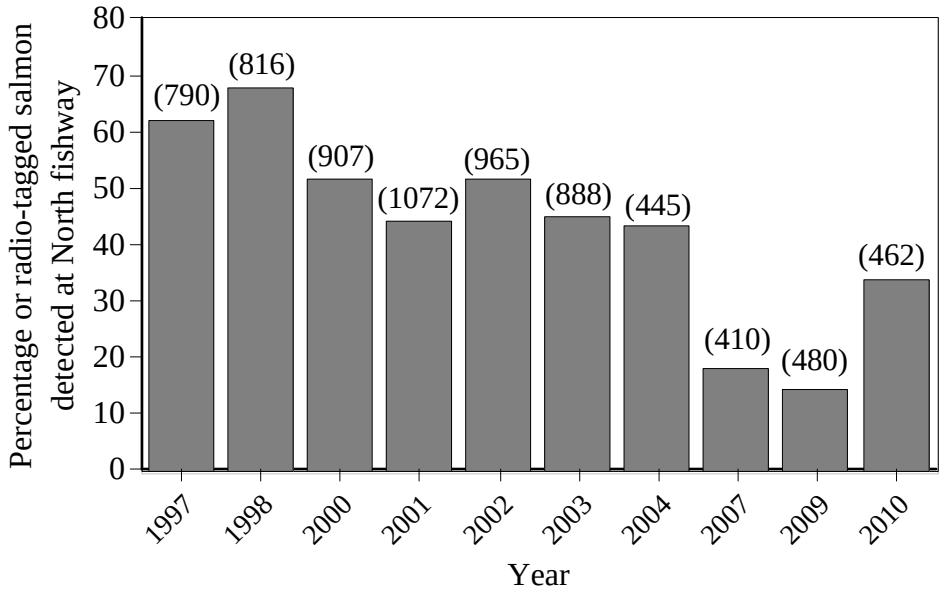


Figure 11. Percentage of radio-tagged spring–summer Chinook detected at The Dalles Dam that were recorded at the north fishway in 1997-1998, 2000-2004, 2007, and 2009-2010. Sample sizes are in parentheses above each bar.

Behavior of Tagged Salmon Recorded Downstream from Spillbays 1-8

A total of 217 tagged salmon were detected on a spillway receiver before their first fishway approach. The majority (63%) of detections occurred when spill volumes were medium (>50-100 kcfs), 28% occurred when spill was high (>100-150 kcfs), and 9% occurred when spill was low (0-50 kcfs) (Figure 12). This distribution mirrored proportions of tagged salmon first entering the tailrace under the three spill categories (9% low, 60% medium, and 31% high). Median spillway residency times were 15 to 24 minutes across spill categories, with tagged salmon initially detected during medium flows having the longest median time. Tagged salmon detected during high flows had the highest variation in spillway residency times, but there was little evidence that residency times in any spill category resulted in excessive spillway or tailrace residency times.

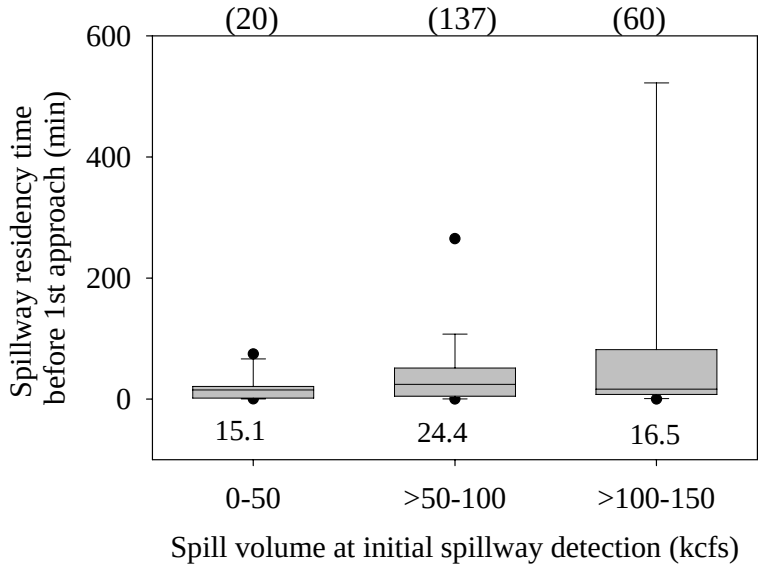


Figure 12. Median (line), quartile (box), 5th and 95th (dots), and 10th and 90th (whiskers) percentile residency times of radio-tagged spring–summer Chinook salmon downstream from The Dalles Dam spillway before first fishway approach versus spill volume at time of first detection (upper panel). Sample sizes are listed in parentheses above bars. Median times are listed below bars.

Seventy-five percent of the tagged salmon initially detected on spillway receivers during low and medium spill volumes made their first recorded fishway approach at the north fishway opening while smaller percentages (<15%) first approached at the powerhouse fishway openings (Figure 13). In contrast, only 8% of the tagged salmon recorded on spillway receivers during high spill first approached the north fishway. Half of the tagged salmon experiencing the high spill category first approached at the east fishway and 30% first approached at the west fishway.

Tagged salmon that initially experienced low or medium spill volumes and made their first fishway approach at the north fishway used relatively little time to find the fishway opening after being recorded on a spillway receiver. Salmon from these spill categories that first approached at a powerhouse opening used modestly longer times to first approach. Generally, tagged salmon that experienced high spill volumes had the longest first spillway to first fishway approach times (Figure 13).

Tagged salmon recorded on spillway receivers during high spill that subsequently first approached at the powerhouse used approximately 5 hrs on median (n = 55) to leave the spillway area and first approach a powerhouse fishway opening. The median dam passage times for these tagged salmon was 15.8 hrs (n = 47).

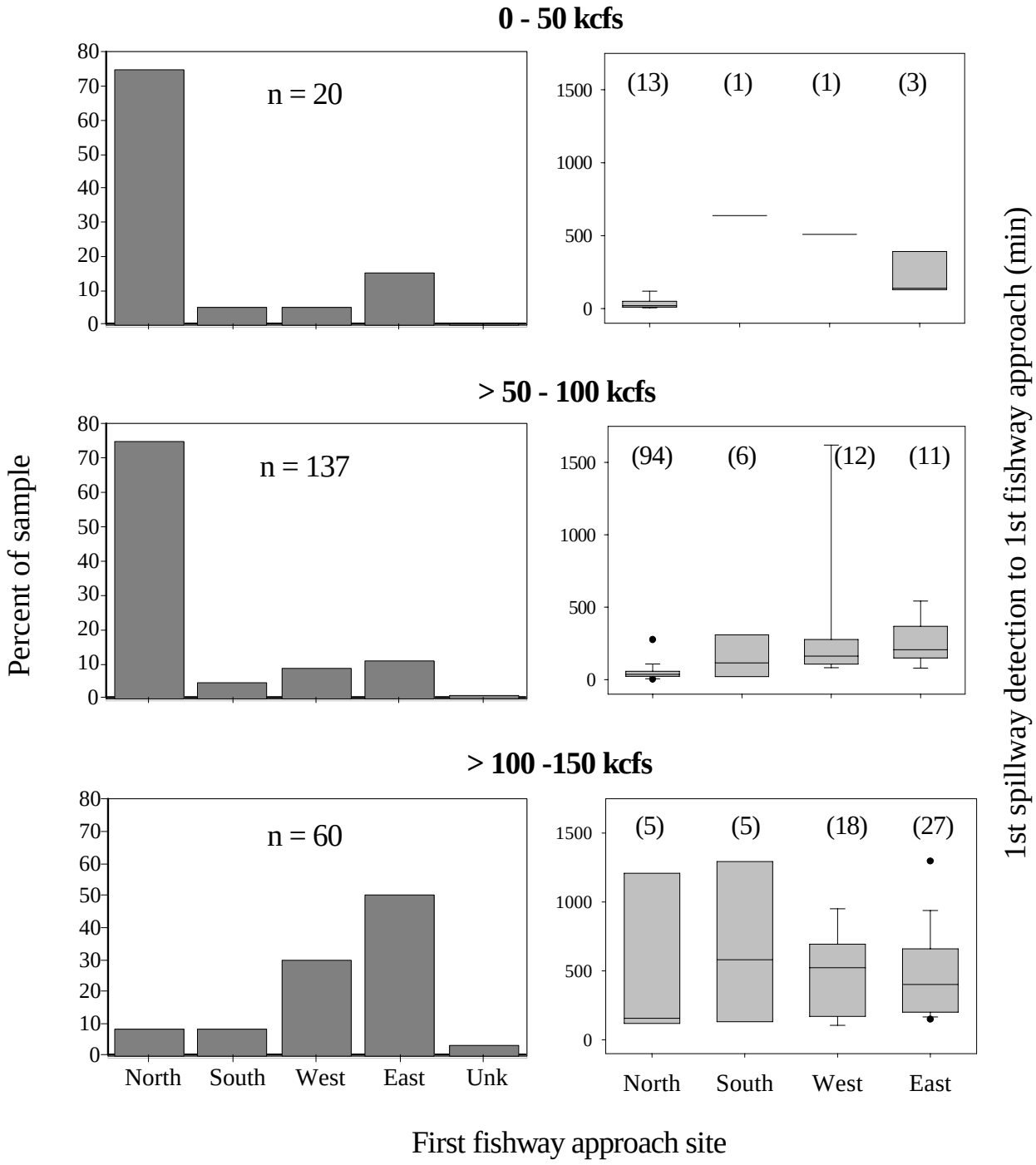


Figure 13. Distributions of first fishway approach sites (left panel) and median (line), quartile (box), 5th and 95th (dots), and 10th and 90th (whiskers) percentile passage times from first spillway record to first fishway approach (right panel) by radio-tagged spring–summer Chinook salmon versus spill volume experienced at the time of first spillway receiver detection at The Dalles Dam in 2010. Sample sizes for time distributions are shown above bars.

North Fishway Entrance Efficiency in Relation to Spill Volume

A total of 193 (known) approaches were recorded at the north fishway opening by 142 unique radio-tagged salmon and 75% of the approaches occurred when spill volume was between 50-100 kcfs (Figure 14). Equally high percentages (*range* = 95-96%) of fishway approaches resulted in entries when spill volumes were between 0-50 kcfs and >50-100 kcfs but entrance efficiency (# entries/# approaches) decreased to 67% when spill volume exceeded 100 kcfs at the time of approach. This supports the hypothesis that tagged salmon had difficulty locating and entering the north fishway when spill volume exceeded 100 kcfs.

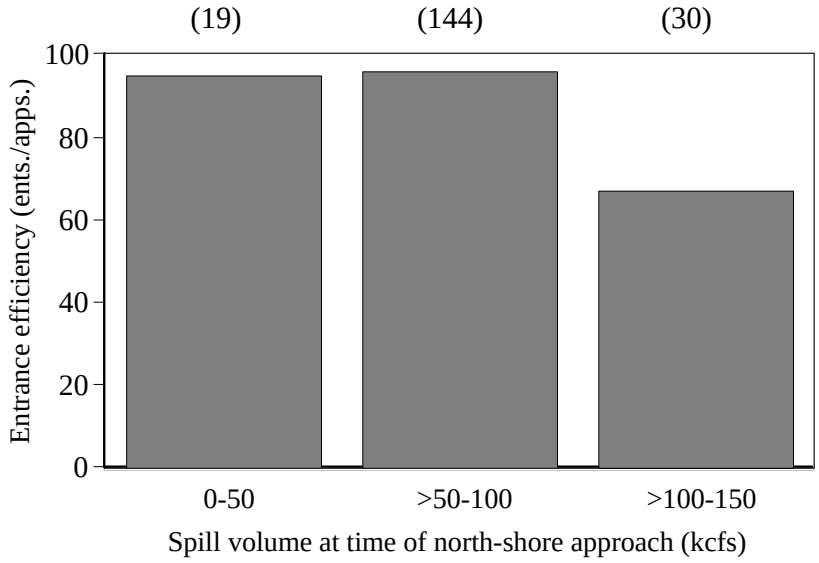


Figure 14. Entrance efficiency of radio-tagged Chinook salmon at the north fishway of The Dalles Dam versus spill volume at the time of approach in 2010. Sample sizes (i.e., number of unique approaches) are shown at the top.

Approach routes inferred from aerial Yagi antennas

Approach routes taken by tagged salmon initially recorded on spillway receivers during low and medium spill volumes were generally consistent with the hypothesis that salmon were swimming upstream along the north shore (i.e., serial detections on increasingly upstream receivers) and subsequently approached the north fishway. Approach routes taken during high spill periods were consistent with this hypothesis but were characterized by an absence of detections on the most upstream spillway receiver. This is consistent with the high percentage of salmon that first approached powerhouse fishways, the low entrance efficiency at the north fishway, and the low daily Chinook salmon counts at the north ladder during periods of high spill.

Fishway-specific dam passage times

The median dam passage time for tagged salmon that passed via the north fishway in 2010 was approximately 6 h faster than the median value for east fishway migrants (Table 3). Overall,

the median dam passage time in 2010 was the fastest among previous study years. Tagged salmon that experienced spill volumes > 100 kcfs at the time of their first tailrace detection and passed the dam via the north fishway had a median dam passage time (17.4 hrs) approximately three times higher than medians from tagged salmon that experienced spill volumes < 100 kcfs (Figure 15). Median dam passage times for east ladder migrants were similar among all spill volume classes.

Table 3. Fishway-specific and combined median dam passage times (first tailrace record to last record at ladder top) and sample sizes for radio-tagged adult spring–summer Chinook salmon recorded passing The Dalles Dam, 1996-1998, 2000-2004, 2007, and 2009-2010.

Year	East fishway migrants	n	North fishway migrants	n	All migrants	n
1996	22.7	234	18.9	115	21.7	349
1997	27.9	333	40.7	223	31.1	556
1998	23.9	280	24.0	251	23.9	531
2000	21.6	325	22.4	234	22.3	559
2001	20.0	676	23.8	155	20.4	831
2002	22.1	430	20.0	274	21.5	704
2003	16.3	441	12.8	173	15.5	614
2004	13.8	228	10.1	114	13.0	342
2007	17.4	195	24.7	28	17.9	223
2009	15.2	371	18.3	43	15.3	418
2010	13.3	215	6.7	70	12.1	285

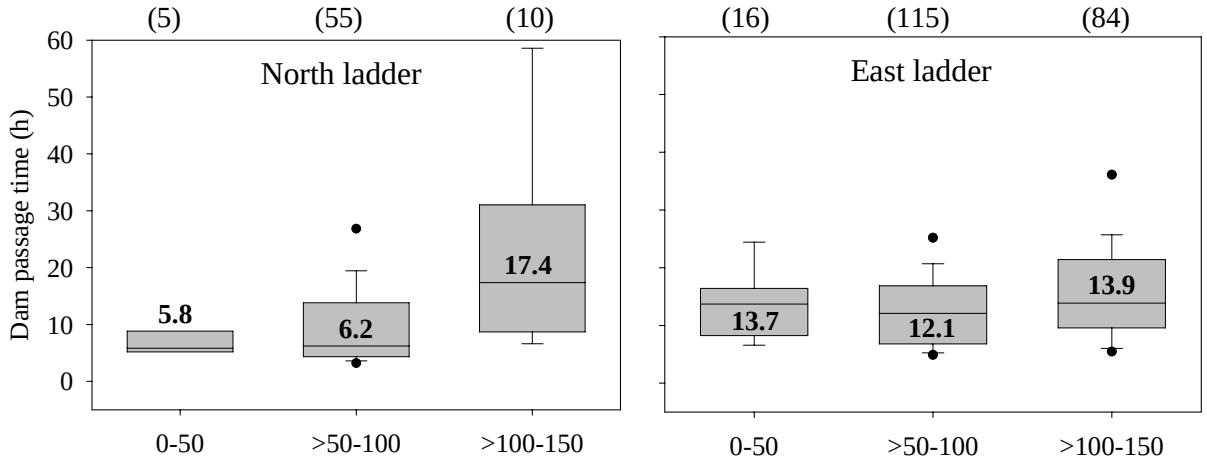


Figure 15. Median (line), quartile (box), 5th and 95th (dots), and 10th and 90th (whiskers) percentile dam passage times (tailrace to ladder exit) of radio-tagged spring–summer Chinook for north (left panel) and east ladder (right panel) migrants versus spill volume at time of first detection at The Dalles Dam in 2010. Sample sizes are shown at top and medians are shown in bold inside bars.

Salmon Size in Relation to Route Selection and Passage Times

Our results suggested that smaller Chinook salmon may have had difficulty approaching and subsequently using the north fishway to pass the dam at both flow and spill categories, which may also present similar challenges for jack Chinook salmon and other smaller salmonids (i.e., sockeye salmon). Larger tagged Chinook salmon tended to arrive at The Dalles Dam later in the season (Figure 16). At the highest flow and spill volumes, there was very little use of the north fishway by tagged salmon in any size class (Figure 17). When flow and spill volumes were low, large salmon first approached the north fishway at higher percentages than small or medium salmon. In contrast, medium salmon had the highest percentage of first approaches at the north fishway when flow and spill volumes were high, although there was no significant ($P > 0.05$) difference among size classes.

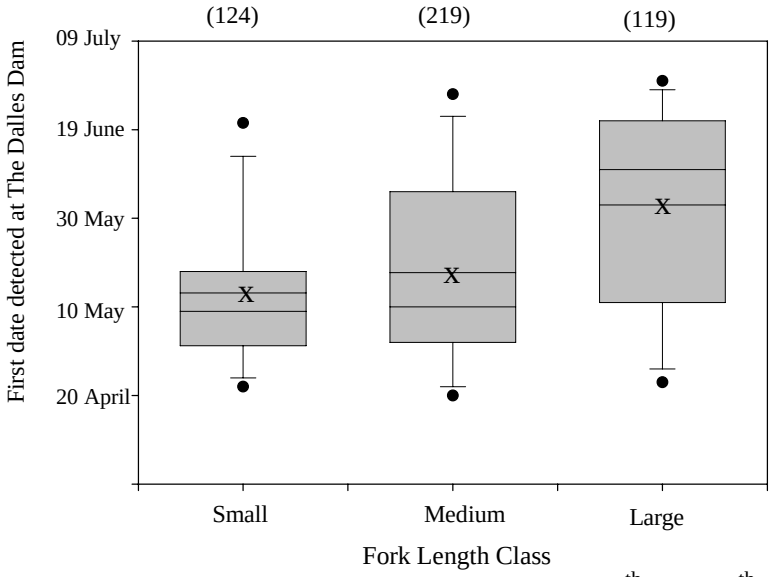


Figure16. Median (line), mean (line with X), quartile (box), 5th and 95th (dots), and 10th and 90th (whiskers) percentile of the date of initial detection of radio-tagged spring–summer Chinook salmon detected at The Dalles Dam in 2010 by fork length class. Sample sizes are shown at top.

As with first fishway approaches at the north-shore, large salmon passed the dam via the north fishway at higher percentages when flow and spill volumes were low. When flow and spill volumes were high, there were no significant differences among the percentages of size classes using the north fishway to pass the dam, although small fish tended to use the north fishway to pass the dam the least at all flow and spill volumes.

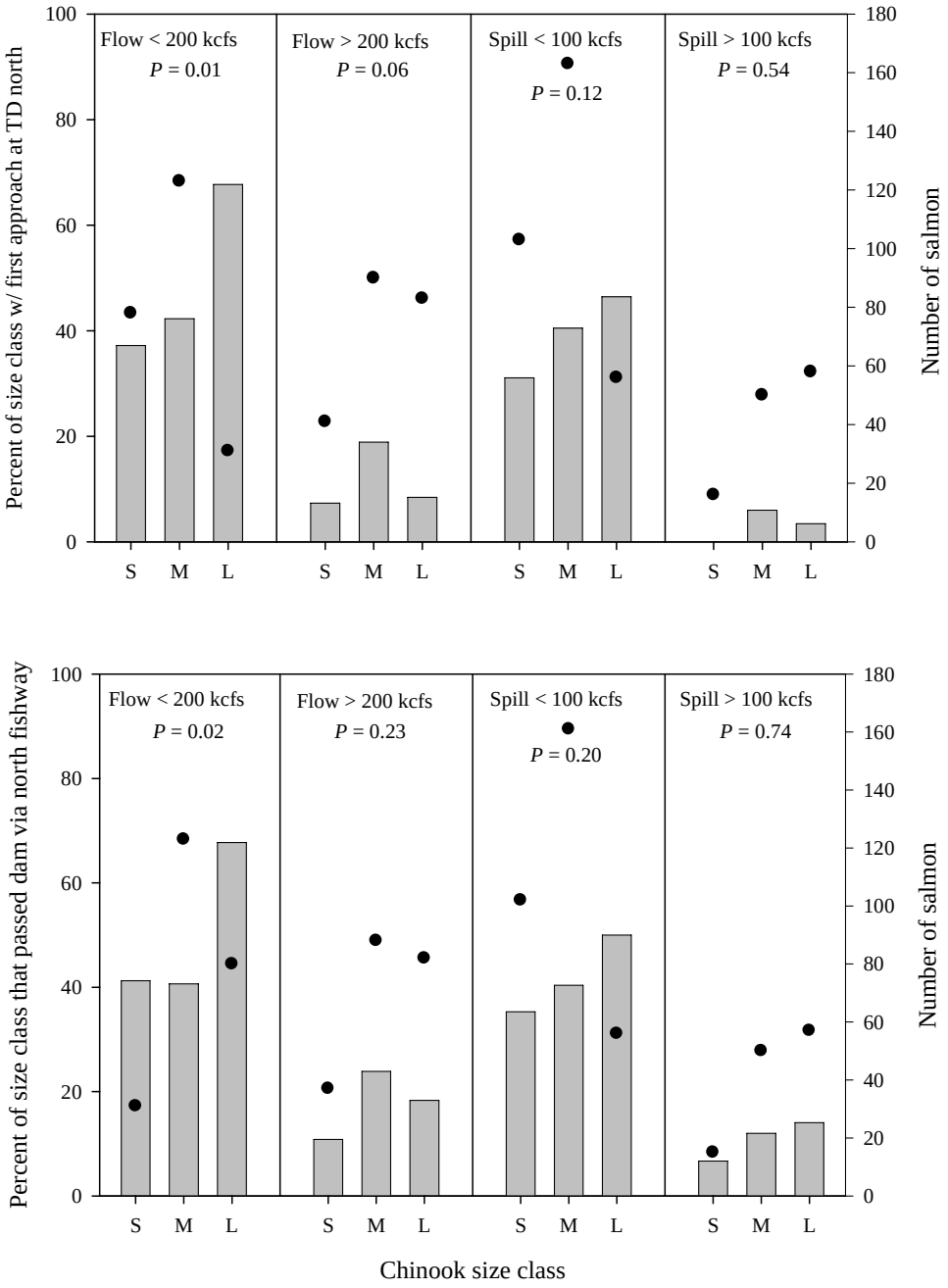


Figure 17. Percentage (bars) and frequency (dots) of radio-tagged salmon that first approached The Dalles Dam at the north fishway (upper) or passed the dam (lower) by fish size class and total flow and spill categories on date of first fishway approach or date of dam passage. *P*-values are for Chi-square tests of differences among size classes.

Fork length was not a significant predictor of log^e-transformed first tailrace to first fishway entry times when all fishway openings were included (Figure 18). Similarly, fork length was not a significant predictor of north fishway passage based on a univariate logistic regression model (P = 0.91).

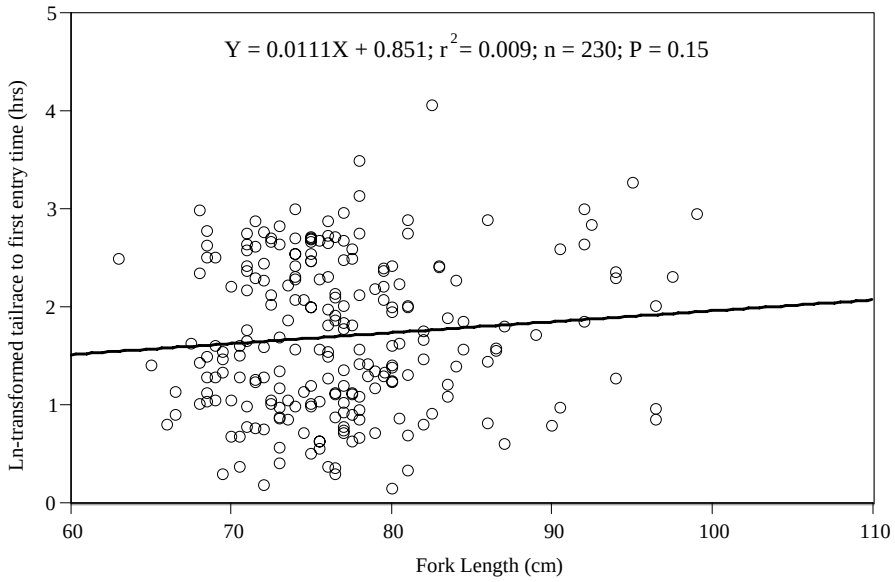


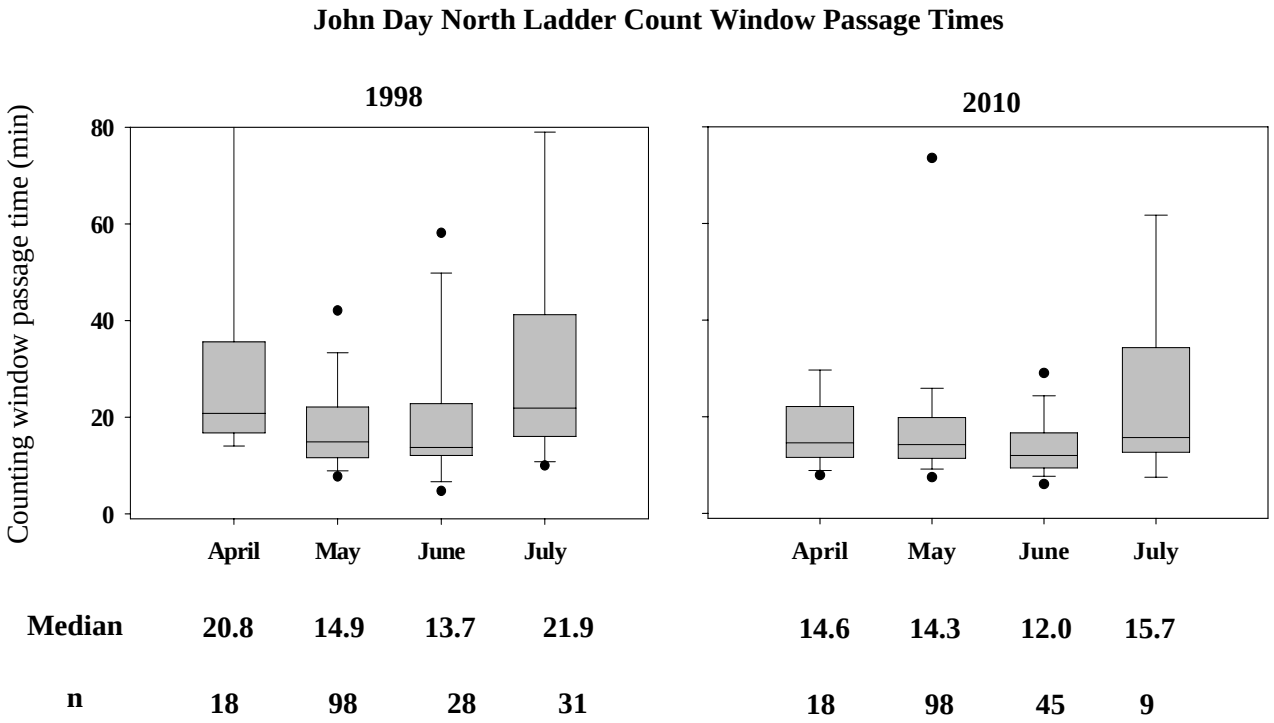
Figure 18. Linear regression scatterplot of fork length versus log^e-transformed first tailrace to first fishway entry times by radio-tagged spring–summer Chinook salmon at The Dalles Dam in 2010

Evaluation of Passage through the Upper John Day North Fishway

Ninety-nine percent of the 178 tagged salmon detected downstream from the north counting window in 1998 passed the dam via the north fishway. Two of these tagged salmon swam upstream from the window and were then detected on the downstream antenna (i.e., exhibited 'up-and-back' behavior), exited the north fishway, and re-ascended the dam via the north fishway. Two tagged salmon exhibited up-and-back behavior, did not exit the fishway, held in the ladder overnight, and passed the dam via the north ladder the ensuing morning. Two tagged salmon approached the north counting window and exited the fishway. One of these fish passed the dam via the south ladder and the other did not pass the dam.

In 2010, a total of 139 tagged salmon were detected downstream from the north fishway counting window and all of them (100%) passed the dam via the north ladder. Two tagged salmon exhibited up-and-back behavior at the counting window. One swam downstream from the counting window for approximately ten minutes before resuming its upstream migration past the window to exit the ladder top. The other exhibited the up-and-back behavior, likely exited the fishway (it was not detected elsewhere at the dam but our coverage was scant), re-entered the north fishway the ensuing day and passed the dam.

Window passage times were defined as the interval between the first detection on the underwater antenna immediately downstream from the window to the last detection on the antenna immediately upstream from the window. In all monthly comparisons, median window passage times from the post-modification year were faster than those from the pre-modification year (Figure 19).



	1998				2010			
Median	**20.8**	**14.9**	**13.7**	**21.9**	**14.6**	**14.3**	**12.0**	**15.7**
n	**18**	**98**	**28**	**31**	**18**	**98**	**45**	**9**

Figure 19. Distributions of passage times by radio-tagged adult Chinook salmon at the north-shore counting window in 1998 and 2010. Distributions show 5th, 10th, 25th, 50th, 75th, 90^{th,} and 95th percentiles; medians and sample sizes are listed below the box and whisker plots.

Discussion

The results of these evaluations were broadly consistent with the hypothesis that high spill volumes (>100 kcfs) directed through spillbays 1-8 at The Dalles Dam likely reduces use of the north fishway by adult spring–summer Chinook salmon. However, differences in fishway selection appeared to have relatively limited effects on overall dam passage times. In previous studies, high spill volume (Boggs et al. 2004, Keefer et al. 2004, Caudill et al. 2006) and some spill patterns (Jepson et al. 2009) have had deleterious impacts on adult Chinook salmon passage at Columbia and Snake River dams.

At spill volumes less than 100 kcfs, tagged salmon had little apparent difficulty locating and using the north fishway. This was supported by the high entrance efficiency observed at the

north fishway (~95%) when spill volumes were < 100 kcfs. At high spill volumes, tagged salmon used the north fishway less frequently but did not appear to spend undue amounts of time seeking and finding alternate passage routes. Dam passage times for radio-tagged Chinook salmon at The Dalles Dam in 2010 were the fastest among all nine comparison years. One reason the 2010 radio-tagged salmon may have had the fastest dam passage times among comparison years was because approximately two-thirds of the tagged salmon passed the dam by 1 June 2010, a period when mean daily spill volumes were less than 100 kcfs (*mean* = 66 kcfs). 100 kcfs. Based on the 2000-2009 average, spill levels at the Dalles Dam were ~80 kcfs from mid-April to mid-May, increased to ~100 kcfs through mid-June, and declined steadily to a minimum of ~60 kcfs at the end of July. Because high spill volumes were not released until relatively late in the 2010 Chinook run, we might expect higher dam passage times in future years when the timing of spill volumes released is closer to the average or in years with higher total average river discharge and spill.

Only 8% of the tagged salmon recorded on spillway receivers during high spill first approached at the north fishway. However, the new spill wall did not appear to excessively impede the ability of salmon to find alternate passage routes when spill volumes were high. Salmon recorded on spillway receivers that subsequently first approached at the powerhouse used approximately 5 hrs to leave the spillway area and make their first approach at the powerhouse. This comprised approximately one-third of this group's median dam passage time and it is not likely an effect that was biologically significant.

Our findings suggest there may be some justification for concerns that smaller fish may be unable to successfully use the north fishway when most or all spill volume is directed through spillbays 1-8. The smallest tagged Chinook salmon at The Dalles Dam in 2010 was 63 cm, far larger than jacks and bigger than many adult sockeye salmon. Effects of this spill pattern have not been directly evaluated on smaller fish, including sockeye salmon. In 1997, however, a high flow year when spill was distributed across most spillbays, approximately 40% of radio-tagged sockeye salmon passed the Dalles Dam via the north fishway (Bjornn et al. 2000). Interestingly, 9.2% of the north-shore migrants fell back over the dam compared to 2.3% of the east ladder migrants. We speculate that if there is less use of the north fishway by salmonids during periods of high spill given the 2010 spill pattern, there may be some net benefits in terms of reduced fallback rates.

Our ability to evaluate the effects of structural modifications at the north shore fishway of John Day Dam is hindered by a single year pre-modification and a single year of post-modification data as well as a limited telemetry array at this site. Nevertheless, radio-tagged Chinook salmon consistently used less time to pass the counting window in 2010 compared to monthly median passage times recorded in 1998 and these available data suggest the modifications had little or no adverse affects on adult salmon passage. There are a number of modifications designed to improve adult Pacific lamprey passage (i.e., the installation of bollards and the removal of weirs #155-157), that are scheduled to be made to the north shore fishway in 2012-2013. Any radiotelemetry evaluation of the new entrance modifications at John Day Dam could be coupled with further evaluation of the north shore counting window modifications.

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