Passage evaluation of radio-tagged Chinook and sockeye salmon after modifications at The Dalles and John Day Dams, 2014

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Report of research by

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Executive Summary

Adult salmon and steelhead migrating to natal streams in tributaries of the Columbia River must pass up to nine dams: four in the lower Columbia and Snake Rivers and five in the mid-Columbia River. Losses and delays in migration at each dam must be minimized to maintain native fish runs and to achieve the recovery goals outlined by the Northwest Power and Conservation Council (NWPCC) and by the National Marine Fisheries Service (NMFS).

This study addressed research related to improving passage and survival of adult salmonids, a research priority identified by state fish and wildlife agencies, the U.S. Army Corps of Engineers, tribal fish and wildlife agencies, and NMFS. For the Columbia River Federal Power System (FCRPS), these priorities are enumerated in the 2008 biological opinion on recovery of threatened and endangered Columbia and Snake River salmon and steelhead (NMFS 2008, 8-15).

At The Dalles and John Day Dams, major and minor fishway modifications have been completed recently to improve passage of adult Pacific lamprey and/or adult salmonids. Structural and operational changes to improve juvenile salmonid survival were also completed recently. As with any significant changes, these modifications must be evaluated for effectiveness and to ensure that adult salmonid passage is not adversely affected.

At ***The Dalles Dam***, construction of a ~145-m spill wall 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 behavior and passage time of radio-tagged adult and jack spring and summer Chinook salmon *Oncorhynchus tshawytscha* and sockeye salmon *O. nerka* in 2014. Passage metrics for these fish were compared with metrics in previous years to determine whether fish were affected by three factors: 1) a recently constructed spill wall, 2) changing spill volumes, and 3) a spill pattern that directs most water though the northern-most spillbays. We focused analyses on factors affecting use of the north fishway.

Radio-tagged salmon used the north side of the river less frequently than the south side; this trend intensified as fish migrated from the tailrace to the base of The Dalles Dam. In 2010, a majority of tagged adults swimming up the north shore crossed the river to the south before approaching a powerhouse fishway opening, particularly during periods of higher spill. In 2014, we did not estimate how far fish migrated on the north shore prior to switching sides, but over 84% of adult Chinook salmon that were on the north shore switched to the east fishway prior to approaching the dam.

This behavior pattern was also observed for 92% of jack Chinook salmon and 93% of sockeye salmon. Our results indicated that spill was the only factor related to use of the north ladder for all groups in 2014, and its influence was negative. Unlike Jepson et al. (2011), who found low entrance efficiency at the north fishway opening, we found high entrance efficiency for all groups at both fishways.

The new spill wall and 2014 spill pattern did not appear to impede the ability of tagged salmon to seek and find alternate passage routes, even when approaches at the north fishway did not result in a fishway entry. Salmon recorded on the north shore that subsequently switched sides had median fishway entry times similar to those of fish that did not switch sides. Adult Chinook salmon that switched sides entered a fishway 1 h faster on average, while sockeye salmon that switched were 0.6 h slower on average than those that did not switch.

Dam passage times for adult radio-tagged Chinook salmon in 2014 (median = 16.1 h, n = 393) were about average relative to those in the 11 years for which comparison data are available. When data were separated by month, fish passing in July were among the fastest of the 11 years.

At ***John Day Dam***, several structural modifications were made to the north fishway entrance in winter 2012 and 2013 to improve passage of adult salmonids and Pacific lamprey *Entosphenus tridentatus*. These modifications included the removal of lower fishway weirs, closure of one of two entrance slots, and installation of a variable-width entrance weir, bollard field, and lamprey passage system (LPS). Structural modifications were also made to the upper north ladder in 2010 that included the removal of concrete weirs; replacement of a bulkhead, crowder, light box, and picket leads near the count window; and installation of a window washer on the count window.

We evaluated how these modifications may have affected behaviors and passage times of radio-tagged adult and jack spring and summer Chinook salmon by comparing behavior and passage-time data from post-modification years (2013-2014) to similar data collected in pre-modification years (1997-1998 and 2000-2006). Jack Chinook salmon sampling began in 2013; thus jack data was not available for pre-modification years.

Use of the John Day north fishway by spring and summer Chinook salmon in 2013-2014 was consistent with patterns of use observed in pre-modification years. Post-modification fishway entrance and passage efficiency were either within the range of pre-modification values or higher. For adult Chinook salmon, fishway exit ratios (exit to the tailrace) in 2013-2014 were similar to those in prior years for the spring run and lower than those in prior years for the summer run. Jack Chinook salmon had considerably lower exit ratios than adults.

We also found that salmon passage times were similar to or faster than those from estimates prior to the north fishway modifications. Approach-to-entry times were significantly faster in 2013-2014 than in pre-modification years, while entrance-to-ladder-base times were similar to previous results. The percentage of Chinook salmon that required more than 1 h to pass these segments was much lower in 2013-2014 than in most pre-modification years.

Salmon passage time through the north ladder (from base to ladder exit) was significantly shorter for adult spring and summer Chinook in 2013-2014 than in previous years. Jacks passed the ladder more slowly than adults in spring, but at rates similar to those of adults in summer. All of the passage metric results suggest that recent north fishway modifications had no adverse effect on the passage behavior of Chinook salmon, with some passage metrics indicating a benefit.

In 2013-2014, we also monitored sockeye salmon passage through the John Day north fishway. Limited pre-modification data exists for sockeye salmon passage, making evaluation of the north ladder modifications on sockeye salmon difficult. Nevertheless, we present data collected on sockeye salmon in the north ladder in 2013-2014 to serve as a baseline for any future modifications.

Entrance, fishway, and dam passage efficiencies for sockeye salmon passage in the John Day north fishway were all high (> 85%), while exit ratios were low (≤ 25%). Median passage times throughout the fishway were low, and few fish required more than 1 h to enter the fishway and migrate through lower sections of the ladder.

Contents

The Dalles Dam

Introduction

At The Dalles Dam, construction of a ~145-m spill wall was completed in April 2010. This wall was placed at the western base of the dam and designed to improve the survival of spillway-passed juvenile salmonids by directing them toward deeper water with fewer predators (Figure 1). In addition to installation of this spill wall, spillway discharge was to be directed through the northernmost spill bays. The new spill pattern raised concerns that migration of adult salmon and steelhead might be slowed because fish would have difficulty finding and/or using the north-shore fishway opening.

Post-modification behavior and passage metrics of adult Chinook salmon at The Dalles Dam were evaluated in spring and summer 2010 using radio-tagged adult spring-summer Chinook salmon (Jepson et al. 2011). Results from that study showed that adult Chinook salmon had low entrance efficiency at the north-shore fishway under high spill conditions. In fact, many salmon migrating along the north shoreline below The Dalles Dam crossed the river to the east fishway (located on the south side of the river) when spill levels were high (Jepson et al. 2011).

In 2011-2012, fish count data indicated very low proportions of adult passage at The Dalles Dam north fishway, particularly during high spill conditions and for smaller adult fish, such as jack Chinook and sockeye salmon.

This report addresses concerns raised in 2010-2012 regarding the effects of fish size on behavior and passage time for radio-tagged adult Chinook salmon. In addition to radio-tagging 600 adult spring and summer Chinook salmon for passage evaluation, we further evaluated size effects on passage by radio-tagging 300 jack Chinook and 399 sockeye salmon for use in species and size comparisons. These evaluations replicate and build on studies conducted in 2013. Specific objectives for these tagging studies at The Dalles Dam in 2014 included:

1. Evaluate adult passage-route selection based on water temperature, date, time of day, flow, spill volume, dissolved gas, and fish size.
2. Evaluate adult travel times based on these same environmental conditions and biological traits.
3. Estimate adult fishway entrance efficiency at both the north and east ladder entrances.

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

Methods

Study Fish and Monitoring Systems

For studies at both The Dalles and John Day Dams, we collected and tagged 600 adult Chinook salmon and 300 jack Chinook salmon at Bonneville Dam from 8 April through 15 July 2014.

In 2014, we distinguished between jack and adult males using a combination of length, jaw and head morphology, and body shape. This method of distinction differed from the strict size criterion of 60 cm fork length, which was used in previous study years. This change was made in an effort to minimize sample bias in either group, for which individuals of 60-65 cm fork length posed the greatest concern.

Individuals classified as jacks were less than ~64 cm, had longer jaws and snouts, and were generally thinner in overall body shape than individuals classified as adults. To evaluate the accuracy of this classification, we will compare classes assigned during tagging to those determined from scale analysis (not included in this report).

We tagged and released 399 sockeye salmon from 6 June through 15 July 2014. All fish were trapped and gastrically tagged at the Bonneville Dam Adult Fish Facility and released approximately 9 km downstream from the dam at sites on both sides of the Columbia River. Samples tagged in 2014 were nearly identical to those tagged during 2013, as reported by Burke et al. (2014).

A total of 284,882 adult and 47,346 jack Chinook salmon were counted passing Bonneville Dam during the tagging period for these fish. Radio-tagged Chinook salmon represented ~0.2% of the adult salmon and ~0.6% of the jack salmon counted at the dam during this period.

During the sockeye salmon tagging period, a total of 586,046 adult sockeye salmon were counted passing Bonneville Dam; radio-tagged sockeye represented less than 0.1% of this total.

A description of the fish collection and tagging methods we followed is presented by Keefer et al. (2004) and Jepson et al. (2011). Details specific to the 2014 sampling effort at Bonneville Dam include transmitter specifications, anesthesia, data collection, and data coding methods; these are described in a companion report (Johnson et al. 2015).

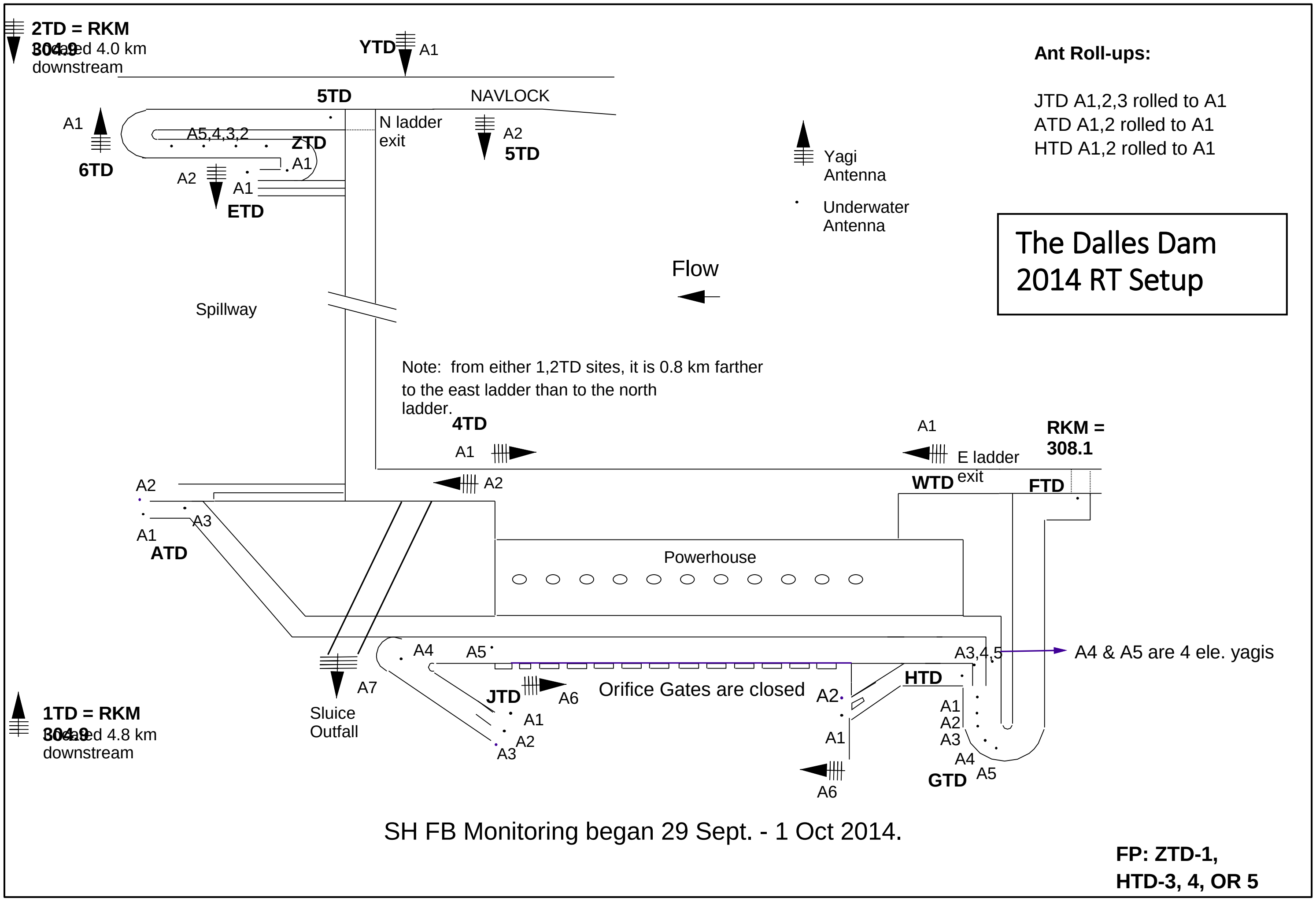

Figure 2. Plan view of radio antennas deployed at The Dalles Dam in 2014 (drawing not to scale).

We used an array of fixed-site radio receivers to monitor locations of tagged fish at The Dalles Dam. Receiver deployments were similar to those in previous years to facilitate comparison of estimated passage metrics among years. The tailrace was monitored with aerial antennas positioned on both sides of the river (Figure 2).

Primary fishway openings were monitored inside and outside with underwater coaxial cable antennas. Additional underwater antennas were used to monitor collection channels, transition areas between collection channels and overflow weir sections of the ladders, and near top-of-ladder exits to the dam forebay.

One difference at The Dalles Dam in 2013 and 2014 compared to some previous years was that we did not deploy aerial (Yagi) antennas just downstream from the north ladder entrance (see Jepson et al. 2011, Figure 2 for comparison). Other among-year differences in monitoring effort were minor, and an effort was made to standardize specific antenna sites used for all comparative analyses across years.

Data Analysis

Route-Specific Time to Enter—For each fish, we calculated the time from first detection in the tailrace (F1) to first detection at a fishway entrance (E1) as a measure of tailrace travel time. If the new spillway wall had a deleterious effect on travel time, we might expect to see longer travel times for fish entering the north vs. the east ladder. We also compared travel time between fish that switched sides (i.e., crossed the tailrace) and those that did not. Due to the importance of time in this analysis, we excluded any fish that had an uncertain time stamp for either tailrace or fishway entrance record.

For all analyses, we used an accelerated failure time (AFT) model with parametric baseline hazards (Zabel et al. 2014). This approach is similar to Cox proportional hazard models, but explicitly states a parametric baseline (in this case, we used a Weibull distribution). Using AFT models allowed us to quantify the effects of covariates on time-to-event data, such as time from tailrace to fishway entrance (F1 to E1). The AFT model also allowed for time-varying covariate data, so that covariates such as spill or temperature, which change during the time a fish is in the tailrace, could be evaluated appropriately. Because the response among species may differ, we ran separate models for each group of fish (adult and jack Chinook and sockeye salmon).

By including fishway entrance (i.e., north, east) as a covariate in the model, we were able to quantify the relative impact on travel time for fish entering the north ladder vs. the east ladder, after having taken into account all of the other environmental effects. We used Akaike's information criterion (AIC) to determine model fit, and we report results only from the best-fitting model. Therefore, if AIC did not suggest clear support for a covariate, it was not kept in the model, and the parameter estimate was not reported in the results.

Proportional Ladder Use—Fish choice of one of the two ladders at The Dalles Dam was modeled as a binomial process (two potential outcomes). We therefore used logistic regression to characterize the probability of salmon using the north vs. east ladder. To maintain consistency among analyses, we also refer to the two sides of the river downstream of the dam (at the F1 antenna sites) as north or east. We estimated the proportion of fish using the north ladder, and then used logistic regression to estimate the effect of various covariates that may have influenced that proportion.

For adult Chinook salmon, Chinook salmon jacks, and sockeye salmon, we tested for effects of daytime vs. nighttime passage, fork length, date, spill, water temperature, dissolved gas (we used gas pressure in mmHg, as some of the percent saturation data were missing), and river discharge (sometimes referred to as flow; kcfs). We included in the analysis all fish that were known to first approach or enter a specific ladder, even if the exact time of the event was not known. Including fish with an uncertain time stamp could influence the estimated impact of time of day on proportion of fish using the north side of the river because estimated time would be biased later (although we think this effect would be very small). We expected that bias from these fish would be minimal on all other covariate estimates.

All environmental data were obtained from the Columbia River Data Access in Real Time database (CR DART 1996). Although there was potential for interactions among environmental variables, we did not test for interaction effects. However, we also did not test any two variables that were highly correlated in a single model. For example, discharge and spill in the jack Chinook salmon dataset had a correlation coefficient (*r*) of 0.92, and therefore were not both included in the same model. We used AIC to determine the best set of covariates and reported results for only the best-fitting models.

Side Switching—If the presence of the new spill wall (or any other feature of a particular ladder) results in reduced guidance, attraction, or entry of salmon to the north ladder, salmon could switch sides of the river. We analyzed the propensity to switch sides of the river between first detection in the tailrace (F1) and first detection at a fishway entrance (E1) as a function of environmental covariates.

Just as ladder use could be modeled as a binomial process (north or east), so could side-switching (switched or not). We used logistic regression to characterize switching behavior. Fish could switch either from the north to the south side of the river or from the south to the north. We analyzed these two behaviors separately because they may be related to different environmental factors. For the side-switching analysis, we tested the same set of covariates used for proportional ladder use, and we included all fish known to first approach or enter a specific fishway, even if the exact time of the event was not known.

Fishway Entrance Efficiency—For both the north and east fishway, we calculated the proportion of fish first approaching a fish ladder that also first entered that ladder to determine whether there were any issues related to fishway entrance. We ran these analyses for each ladder separately. Sample sizes for this analysis were too low to allow modeling of entrance efficiency as a function of environmental variables, particularly at the north ladder entrance. We included all fish that were known to first enter a specific ladder, even if the exact time of the entrance was not known.

Results

Environmental Data

Columbia River water temperature at The Dalles Dam increased steadily during the 2014 study period (8 April–31 July) with a mean of 15.0°C (range 8.34-21.06°C, Figure 3). Spillway discharge averaged 98.3 kcfs (range 62-135 kcfs), and mean dissolved gas levels were 840.6 mmHg (range 795-887 mmHg; Figures 4-5).

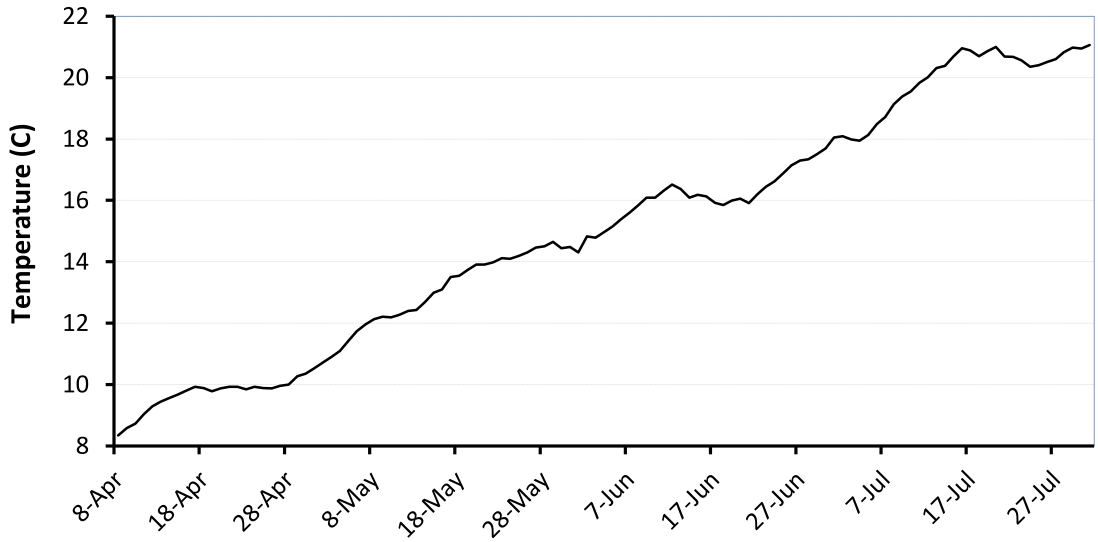

Figure 3. Daily average water temperature recorded at The Dalles Dam from April through July 2014 (CRDART 1996-).

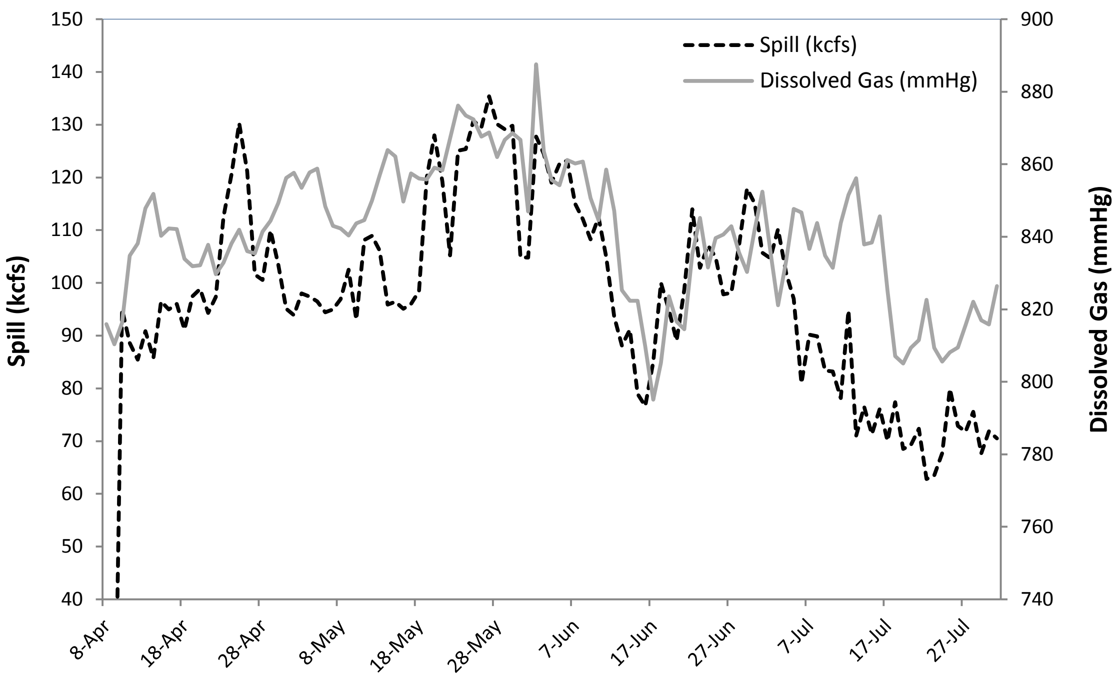

Figure 4. Daily spill and dissolved gas (in-water pressure, in mmHg) recorded at The Dalles Dam from April through July 2014 (CRDART 1996-).

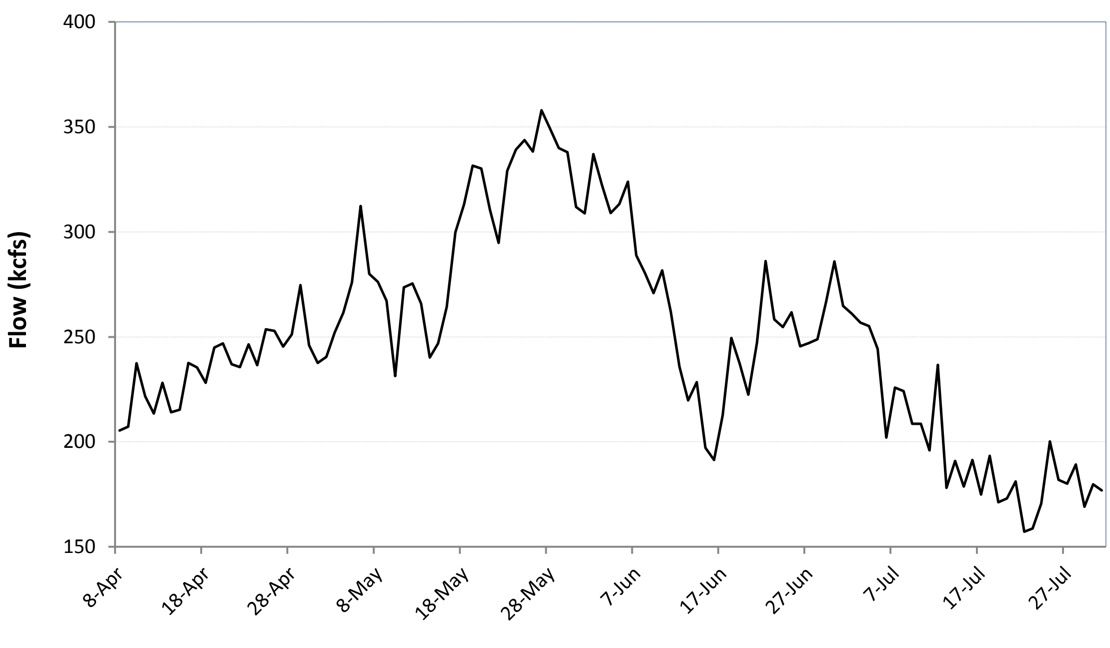

Figure 5. River discharge (outflow) recorded at The Dalles Dam from April through July 2014 (CRDART 1996-).

Summary of Detections at The Dalles Dam

We tagged fish from a wide range of sizes in 2014, with sockeye and Chinook jack sizes overlapping at respective fork lengths of less than 60 and 40-65 cm (Figure 6). Adult Chinook salmon ranged 61-97 cm fork length. Of the 600 adult Chinook salmon tagged and released downstream from Bonneville Dam, 490 (82%) were recorded at The Dalles Dam (Table 1). Similarly, of the 300 jack Chinook salmon tagged and released downstream of Bonneville Dam, 263 (88%) were recorded at the Dalles Dam. Initial detection dates at The Dalles Dam ranged 13 April-18 July for adult Chinook and 6 May-16 July for jack Chinook salmon.

A total of 229,339 adult Chinook salmon were counted passing The Dalles Dam during the initial detection period; our tagged salmon represented ~0.2% of this total. During the initial detection period for jack Chinook salmon at The Dalles Dam, a total of 34,918 jacks were counted passing the dam; tagged jack Chinook salmon represented ~0.8% of this total.

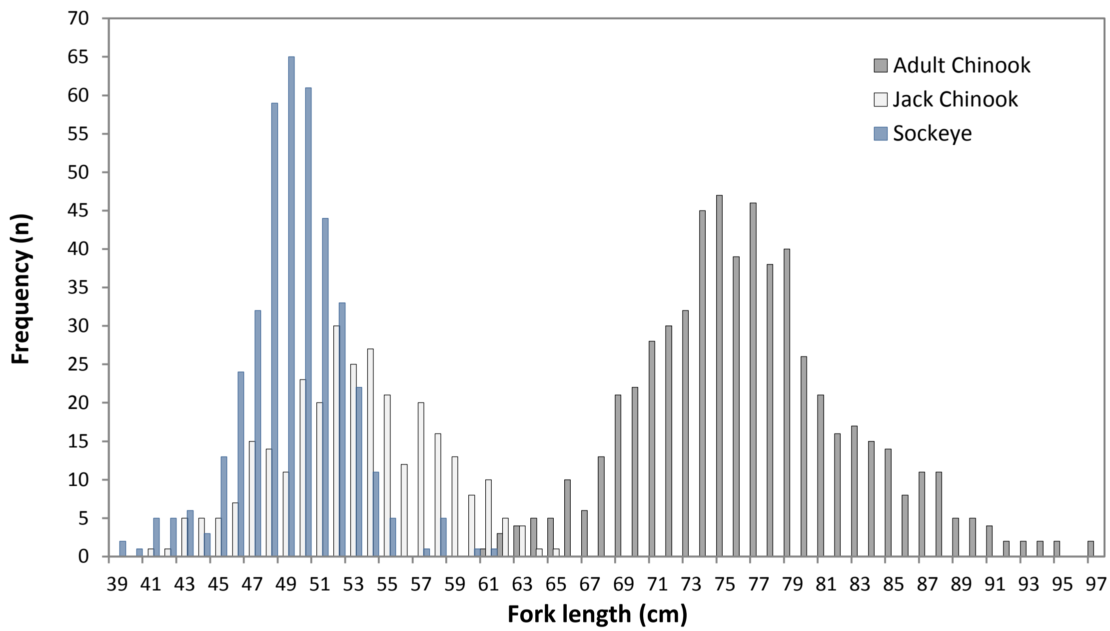

Figure 6. Distribution of fork lengths of radio-tagged spring/summer Chinook and sockeye salmon detected at The Dalles Dam in 2014.

Of the 399 sockeye salmon tagged and released below Bonneville Dam, 347 (87%) were initially detected at The Dalles Dam from 9 June to 17 July 2014. During this period, a total of 562,560 sockeye salmon were counted passing the dam; tagged sockeye salmon represented ~0.06% of this total.

Table 1. Number and percent of radio-tagged jack and adult Chinook salmon and sockeye salmon at The Dalles Dam. Numbers shown are detections recorded, known to pass the dam, recorded on first passage of the tailrace, first approach at a fishway opening, and first fishway entry, as well as the number recorded passing the ladder tops.

Radio-tag detections at The Dalles Dam			
		Fish detected	
Fish group	Passage metric	(n)	(%)
Jack Chinook salmon	Recorded at dam	263	100
	Known to pass dam	255	97.0
	Recorded first tailrace passage	187	71.1
	Recorded first (known) fishway approach	213	81.0
	Recorded first (known) fishway entrance	195	74.1
	Recorded ladder exit	255	97.0
Adult Chinook salmon	Recorded at dam	490	100
	Known to pass dam	471	96.1
	Recorded first tailrace passage	410	83.7
	Recorded first (known) fishway approach	470	95.9
	Recorded first (known) fishway entrance	461	94.1
	Recorded ladder exit	469	95.7
Sockeye salmon	Recorded at dam	347	100
	Known to pass dam	343	98.8
	Recorded first tailrace passage	315	90.8
	Recorded first (known) fishway approach	330	95.1
	Recorded first (known) fishway entrance	322	92.8
	Recorded ladder exit	341	98.2

Proportional Ladder Use

Spring/Summer Chinook salmon—With few exceptions, daily counts of adult Chinook passing the dam via the east ladder exceeded those of adults passing via the north ladder (Figure 7). For Chinook jacks there were no exceptions to this passage pattern during the migration season (Figure 8). Of the 490 radio-tagged Chinook salmon adults recorded at The Dalles Dam, 469 passed the dam (Table 1). Of these 469, 77 (~16%) passed via the north ladder and 392 (84%) via the east ladder. Of the 263 radio-tagged Chinook jacks recorded at The Dalles, 255 passed the dam. Of these 255, 22 (9%) passed via the north ladder and 233 (91%) via the east ladder.

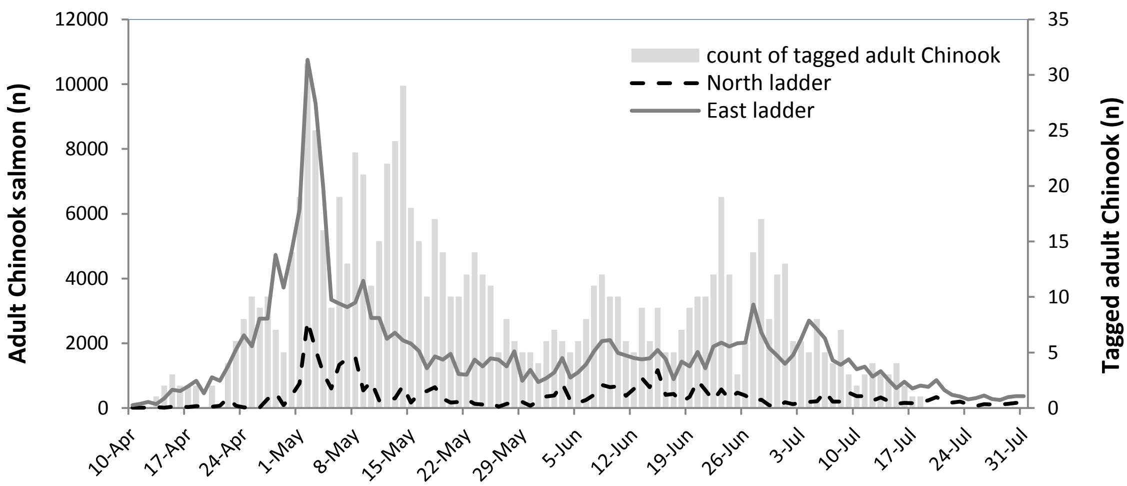

Figure 7. Detections of radio-tagged adult Chinook salmon at The Dalles Dam relative to overall adult Chinook salmon passage counts by ladder in 2014.

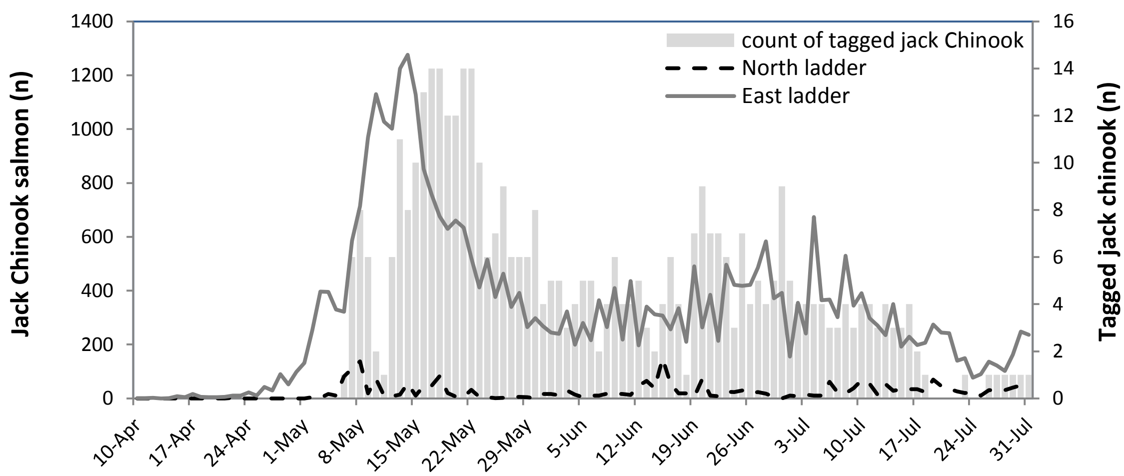

Figure 8. Detections of radio-tagged Chinook jacks at The Dalles Dam relative to overall Chinook jack passage counts by ladder in 2014.

Detection efficiencies were high for most passage metrics at The Dalles Dam (Table 1). A total of 18 fallback events were recorded for 15 unique radio-tagged adult Chinook salmon (fallback percentage 3.2%), while 11 fallback events were recorded for 10 unique radio-tagged Chinook jacks (fallback percentage 3.9%). For adult Chinook salmon, 14 first-time fallbacks were preceded by dam passage via the east ladder (3.6% of east ladder first-passage events). One first fallback was preceded by dam-passage via the north ladder (1.3%). Among first fallbacks observed for Chinook jacks, one followed dam passage via the north ladder (4.5%), and 9 followed dam passage via the east ladder (3.9%). No post-fallback data were evaluated for this study.

Sockeye Salmon—Sockeye salmon passed The Dalles Dam primarily using the east ladder (Figure 9). Of the 347 adult radio-tagged sockeye detected, 341 passed The Dalles Dam (Table 1). Of these 341, 26 (7.6%) passed via the north ladder and 315 (92.4%) via the east ladder. Passage behavior metrics such as tailrace entrance and ladder passage had high rates of detection for these fish (Table 1).

A total of 8 fallback events were recorded for radio-tagged sockeye salmon, with no individual falling back more than once (fallback percentage 2.3%). All fallback events by sockeye salmon were recorded after fish passed via the east ladder. No post-fallback data for sockeye salmon were evaluated for this study.

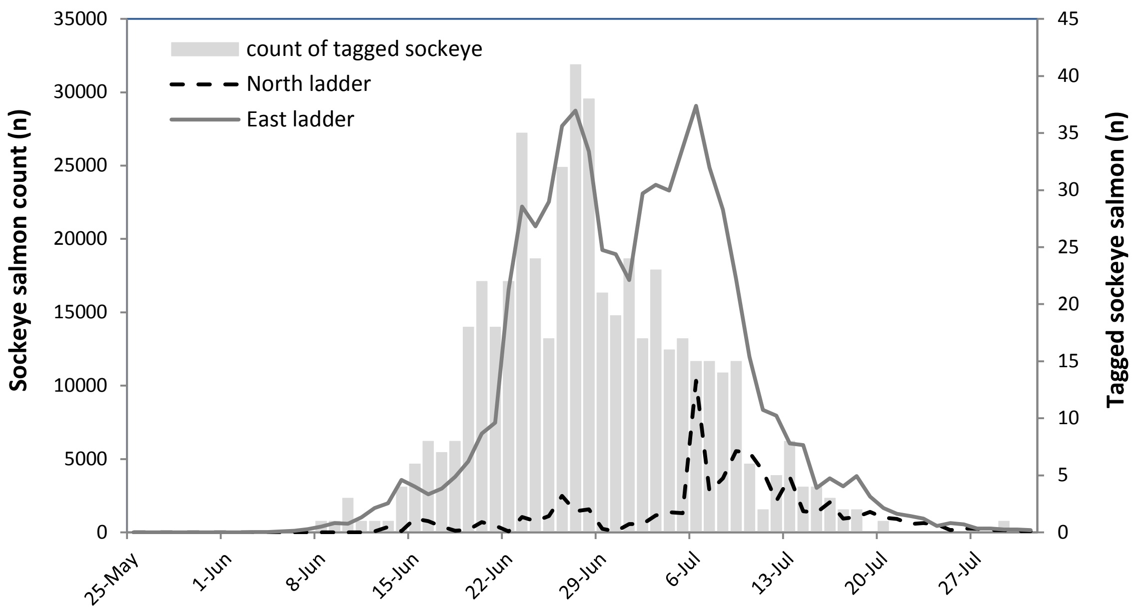

Figure 9. Count of radio-tagged sockeye salmon at The Dalles Dam in 2014 relative to overall sockeye passage counts by ladder.

Environmental Predictors and Passage Time

For adult Chinook salmon, median time from first tailrace detection to first detection on a fishway approach was 4.4 h (n = 185) in May, 3.3 h in June (n = 124), and 3.2 h (n = 44) in July 2014 (Table 2). Average approach times during June were among the shortest of all 12 study years. In July 2014, median time for adult Chinook salmon to pass The Dalles Dam (first tailrace detection to ladder top) was among the shortest of all study years.

For Chinook salmon jacks and sockeye salmon, passage times through the various segments tended to fall within the range of values for adult Chinook salmon. For Chinook jack and sockeye salmon, there was little data for comparison with previous years. However, passage times for these fish in 2014 were generally similar to those in previous years for which data were available.

Passage times from tailrace to first fishway entrance were associated with the time of day during which salmon were first detected in the tailrace, as shown in Figure 10 for adult and jack Chinook and adult sockeye salmon. As in 2013, median time between first detection in the tailrace and first detection in a fishway entrance was shorter for fish detected in the tailrace before 1600 PDT than for those detected after 1600, regardless of study group. A higher proportion of fish from all study groups entered the tailrace before 1600 as well.

For adult Chinook salmon first detected in the tailrace before 1600 in 2014, median time from tailrace to first entrance was 4.8 h (n = 262) vs. 12.9 h (n = 135) for those first detected after 1600. For jack Chinook salmon detected on tailrace monitors before 1600, median time to first approach was 4.6 h (n = 133) compared with 12.7 h for those first detected after 1600 (n = 50). Likewise, sockeye salmon with first tailrace detections before 1600 had a median time to entry of 4.4 h (n = 235), while those with first tailrace detections after 1600 had a median time to entry of 10.8 h (n = 77). These patterns are consistent with those observed in 2013.

Table 2. Median time for adult radio-tagged spring/summer Chinook salmon from first detection in the tailrace to first detection on a fishway approach, fishway entrance, or ladder exit (indicating passage at The Dalles Dam). Time from first detection at a fishway approach to first detection at a fishway entrance is also shown by month during spring/summer migration period. Rank among years is shown at right for 2014 values, with 1 being the shortest time and 11 being longest.

	Median time for adult spring/summer Chinook salmon passing The Dalles Dam (h)																									
	1997		1998		2000		2001		2002		2003		2004		2007		2009		2010		2013		2014		
	N	Med	N	Med	N	Med	N	Med	N	Med	N	Med	N	Med	N	Med	N	Med	N	Med	N	Med	N	Med	Rank
Tailrace to first approach																									
April	125	11.6	147	5.2	199	7.1	295	4.2	147	9	179	4.7	56	3	2	8.2	1	12	51	2.9			38	5.3	6
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	138	3.8	185	4.4	9
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	93	5	114	3.6	124	3.3	2.5
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	31	2.9	44	3.2	8.5
Tailrace to first entry																									
April	101	71.1	132	20	172	22.8	271	13.8	140	27	165	11.2	48	4.1	2	11.6	1	17.1	45	3.6			38	12.1	5
May	186	33.8	203	10.1	200	12.1	186	6.8	300	12	156	5.3	112	4	62	5.5	221	9.3	99	4.2	82	5.8	182	9.5	8
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	77	6	124	5.1	4
July	100	3.1	58	4.1	53	5.3	114	3.6	92	6	135	4.2	52	3.1	3	5.8	9	6.2	5	5.8	21	3.8	44	4.1	5.5
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			37	16.8	4
May	221	53.1	222	22	205	22.3	238	19.7	304	19.8	160	13.5	121	13	100	14.6	223	15.6	127	11.3	171	19.3	185	17.5	6
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	139	20.7	126	17.9	5
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	40	9.4	44	10.6	2
First approach to first entry																									
April	101	41.2	133	8.6	172	11.4	271	4.1	140	14.8	218	3	60	0.2	8	<0.1	1	5.1	72	0.2			44	2.7	4
May	186	21	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	110	0.9	228	1.6	7.5
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	103	0.6	135	0.6	9.3
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	37	0.1	56	0.2	5.3

* Data for 1997-1998 and 2000-2001 from Keefer et al. (2007); for 2002 from Wilson et al. (unpublished data); for 2003 from Boggs et al. (unpublished data); for 2004, 2007, and 2009-2012 from Jepson et al. (2011).

Table 3. Median time (h) from first detection in the tailrace to first detection on a fishway approach, fishway entrance, or ladder exit (indicating passage) at The Dalles Dam for sockeye salmon and Chinook salmon jacks. Also shown is time from first detection on a fishway approach to first fishway entry by month of first detection at the Dalles Dam in 2013 vs. 1997.

	Sockeye						Jack Chinook			
	1997*		2013		2014		2013		2014	
	N	Med	N	Med	N	Med	N	Med	N	Med
Tailrace to first approach										
May							62	4.1	72	5.0
June	120	2.4	110	4.1	208	3.7	45	3.8	58	3.7
July	211	2.7	55	4	95	3.6	14	6.1	29	3.9
Tailrace to first entry										
May							41	5.4	63	7.2
June	104	2.4	65	5	202	4.9	27	4.7	52	4.6
July	181	2.7	33	3.5	94	5.1	8	6.6	29	4.9
Tailrace to ladder exit										
May							92	17.1	89	14.8
June	152	9.3	200	11.9	213	11.4	61	13	61	14.4
July	258	7.3	100	10.6	97	10.7	22	12.2	31	12.2
First approach to first entry										
May							68	0.4	91	0.2
June			74	0.4	210	0.4	37	1.1	71	0.3
July			40	<0.1	112	0.2	13	0.1	34	0.2

* 1997 data from Keefer et al. (2005)

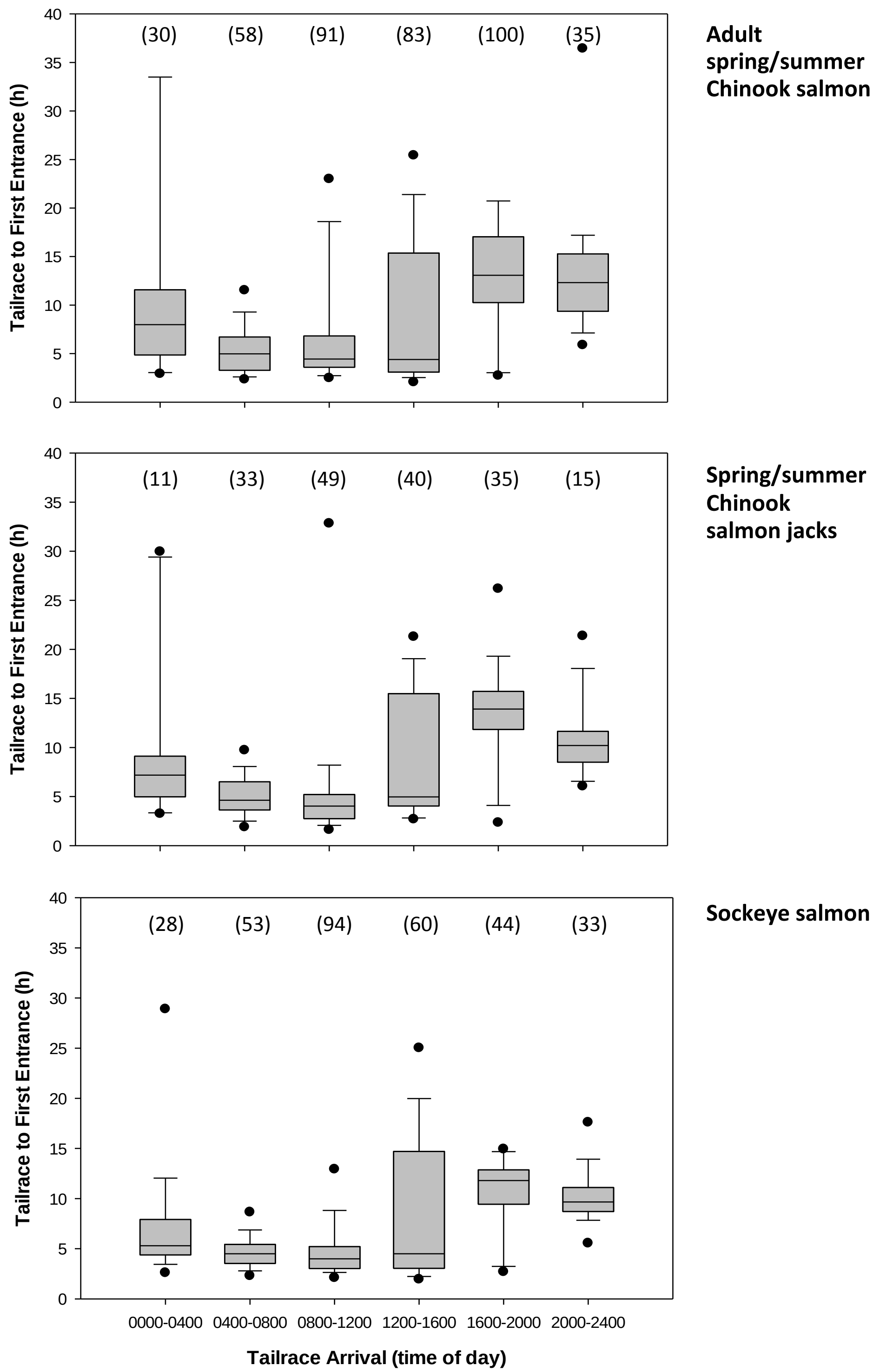

Figure 12. Passage time (h) as a function of time of day from entry in the tailrace to first detection in a fishway at The Dalles Dam, 2014. Boxes indicate quartiles, lines indicate median, whiskers indicate 10th and 90th percentiles, and dots (•) indicate 5th and 95th percentiles. Sample sizes are shown above boxes.

Route-Specific Time to Enter

Distance between the north shore tailrace antenna and north fishway opening was about 3.1 km. This was about 2.5 km shorter than the distance between the south shore tailrace antenna and east fishway opening (about 5.6 km). Therefore, we expected travel times from F1 to E1 to be longer for fish moving along the south shore. Indeed, in all three groups analyzed, travel times were about twice as long as on the south side of the river (Figure 13, Table 4).

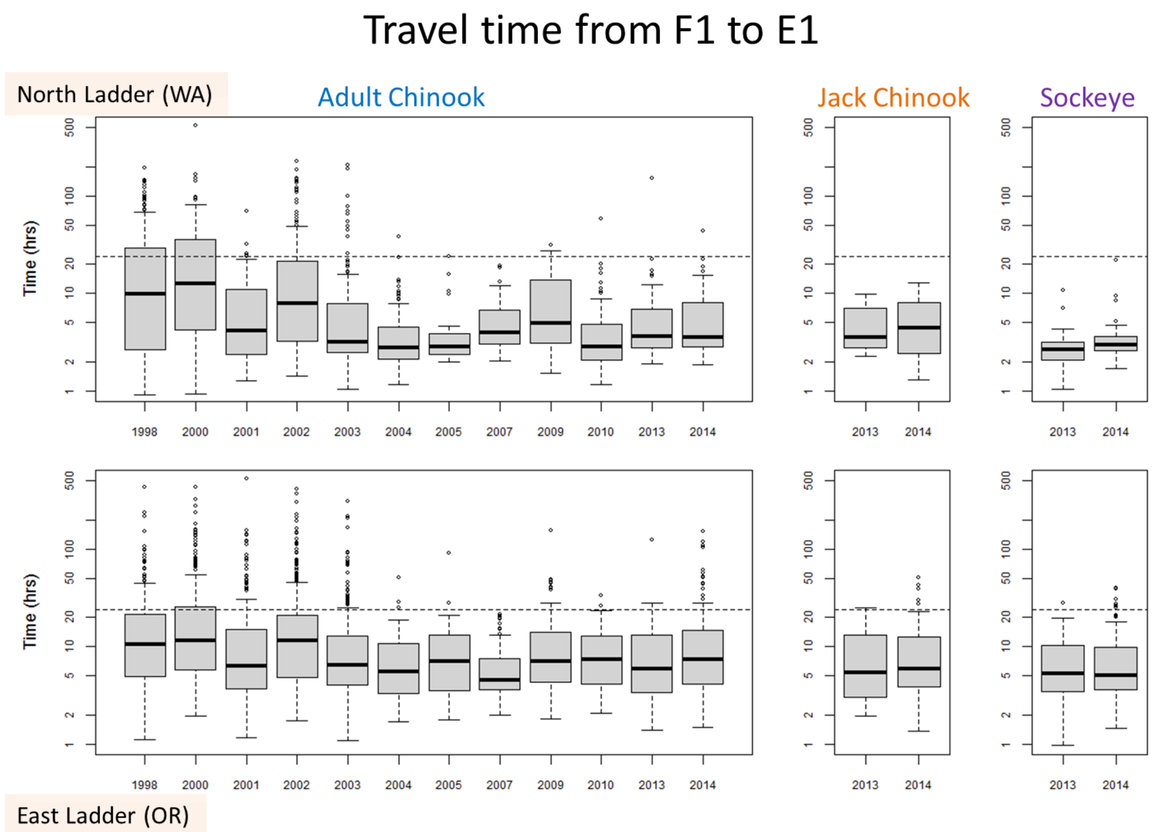

Figure 13. Travel time between first detection at a tailrace entry and first detection at a fishway entrance for fish that entered the north vs. east ladder at The Dalles Dam in prior study years vs. 2013-2014. Most fish traveled along the south shoreline before entering the east fishway, and the distance between these points was shorter on the Washington shore. Dotted lines represent travel time of 24 h.

Among all groups, travel time was longer for fish that entered the tailrace at night (Table 4). Adult and jack Chinook salmon passage time were both associated with temperature, but in opposite directions: at higher temperatures, adult Chinook were faster, while jacks were slightly slower. There was a seasonal effect for adult Chinook and sockeye, with fish that arrived late traveling slightly faster than those that arrived early in the migration period. Finally, adult Chinook traveled slightly slower with increased dissolved gas, and sockeye traveled slightly slower with increased flow.

Table 4. Covariate parameter estimates from accelerated failure time (AFT) models of travel time from first detection in the tailrace (F1) to first fishway entrance (E1) at The Dalles Dam. *Time ratio* is the proportional change in travel time for a given unit change in the covariate value. For example, adult Chinook salmon travel time from F1 to E1 was 95% of travel time for cohorts that entered the previous day, and entry time in the north ladder was about 51% of entry time in the east ladder. Only covariates that were in the best model (i.e., the model with the lowest AIC) are shown.

Factors affecting travel time from tailrace to fishway entrance at The Dalles Dam, 2014									
	Adult Chinook (N = 395)			Chinook jacks (N = 183)			Sockeye (N = 312)		
	Estimate	SE	Time ratio	Estimate	SE	Time ratio	Estimate	SE	Time ratio
Date	-0.06	0.01	0.95				-0.01	0.01	0.99
Night	1.15	0.12	3.17	1.21	0.18	3.34	1.01	0.11	2.74
North fishway	-0.68	0.12	0.51	-0.51	0.23	0.60	-0.65	0.15	0.52
Switched									
Length									
Spill									
Temperature	0.38	0.10	1.46	-0.08	0.03	0.92			
Dissolved gas	-0.01	0.003	0.99						
Outflow							-0.003	0.001	0.99

Proportional Use of the North Fishway

The percentage of tagged Chinook salmon detected at the north fishway averaged 52% during 1997-2004 (range 43-67%, Figure 12). In contrast, percentages of adult Chinook detected at the north fishway were relatively small in 2007 and 2009 (14-18%) and were intermediate in 2010 (34%). Passage via the north fishway was also intermediate for adult Chinook in 2013, when they used this route 30% of the time; this rate dropped to 19% in 2014. Use of the north fishway by jack Chinook and sockeye salmon was minimal: 11% each in 2013 and less than 10% each in 2014 (Figure 12).

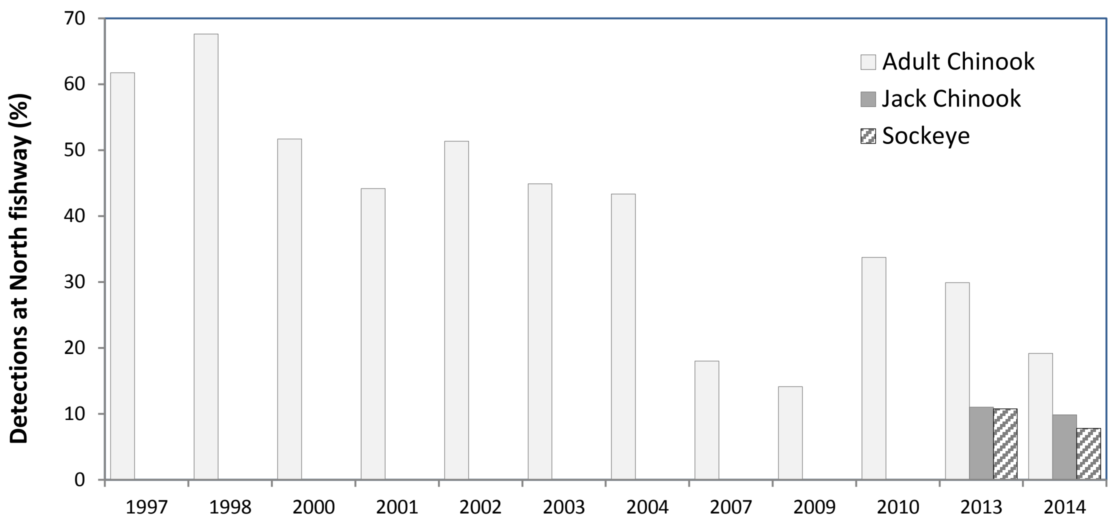

Figure 12. Percentage of radio-tagged adult spring-summer Chinook detected at The Dalles Dam north fishway in 2014 vs. 11 previous study years. Data for Chinook jacks and sockeye salmon in 2013 and 2014 are also shown.

Route-Specific Approaches and Entrances

The proportion of fish using the north side of the river downstream from the dam (at the F1 sites) varied by species and age class. About 15% of adult Chinook 36% of jack Chinook, and 26% of sockeye salmon used the north side of the river, based on first tailrace detections (F1 detections, Table 5). For adult Chinook salmon, the proportion on the north side dropped only slightly as fish progressed up to the dam and entered the fishway. However, for Chinook jacks and sockeye salmon, there was a larger drop in the proportion of fish on the north side for approaches and entrances into a fishway.

Table 5. Proportions of fish first detected on the north tailrace antenna (F1), at the north fishway opening during their first fishway approach (A1), and at the north fishway on their first fishway entrance (E1) in 2014. Signs indicate significantly higher (+) or lower (-) proportions than observed in 2013.

	Proportion detected (%)		
North fishway	Chinook	Chinook jack	Sockeye
First tailrace detection F1	0.15	0.36+	0.26-
First detection at fishway opening A1	0.11	0.05	0.06
First detection at fishway entrance E1	0.13	0.06	0.06

Several environmental covariates were associated with the proportion of fish that entered the tailrace on the north side of the river and first approached and entered the north fishway. For adult Chinook salmon, larger fish were more likely to approach on the north side of the river (Table 6). However, length was not important for Chinook jack or sockeye groups, nor was it important for any group first approaching the dam or entering the fishway. Unlike results from 2013, date did not influence the side of the river chosen by adults for upstream passage.

Spill was consistently related to lower use of the north side of the river based on both first fishway approaches (A1) and first fishway entrances (E1) for all three groups (Figure 13). Temperature was important in some models, but there was not a consistent response among species or activities.

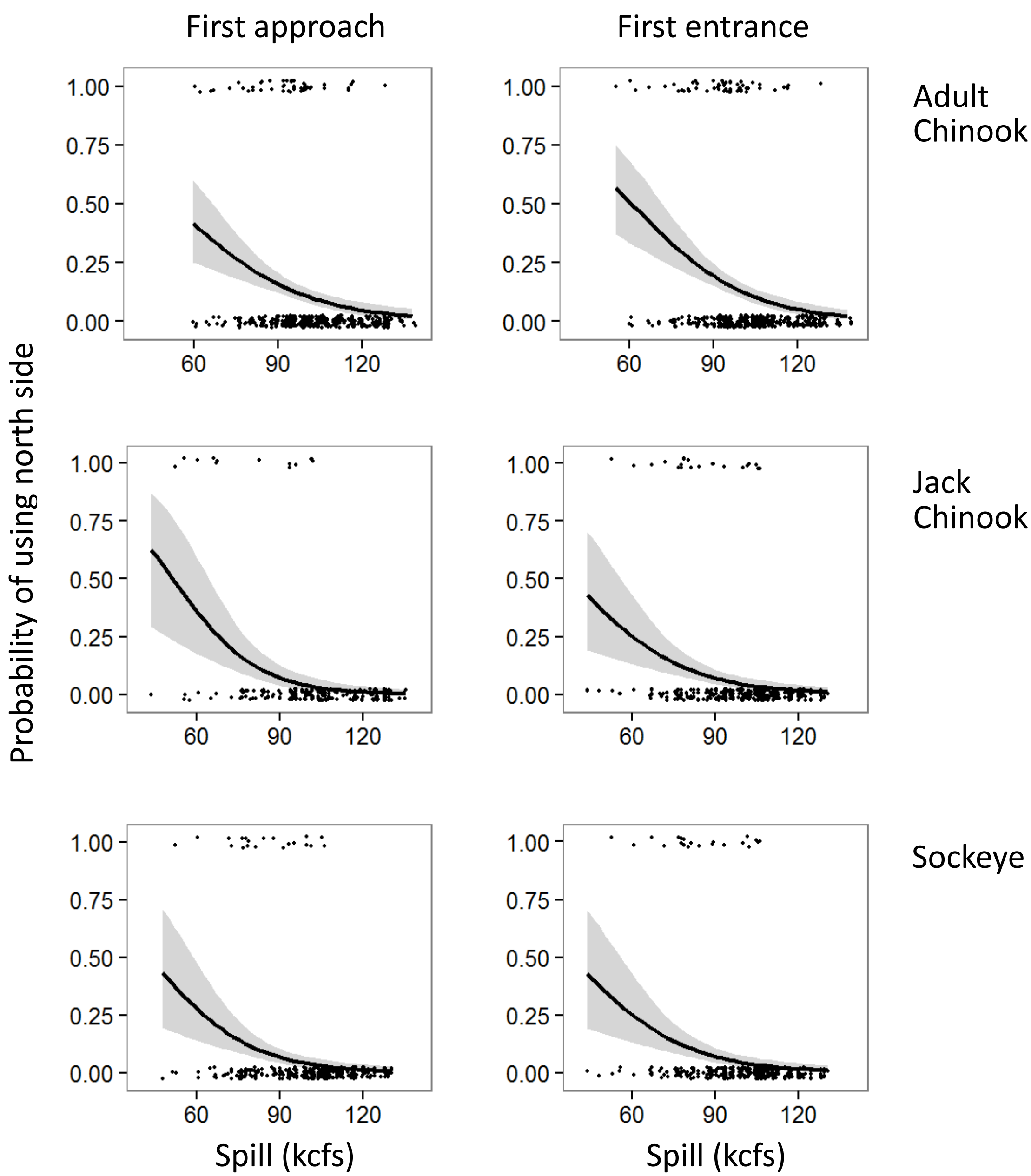

Figure 13. Predicted probability of first detection approaching (left) or entering (right) the north fishway at The Dalles Dam for adult Chinook, Chinook jacks, and sockeye salmon. Black dots represent individual fish first detected on the north side (jittered around 1 on the Y axis) and fish that were first detected on the east side (jittered around 0). Grey areas represent ±1 standard error. Black lines show mean predicted probability.

Estimated covariate values in Table 6 represent the expected change in proportion of fish using the north side per unit increase in value for each covariate. Therefore, these estimates cannot be compared across covariates. Most passage metrics were measured within a temperature range of 1-2°C, so the estimated parameter per unit (°C) was fairly large. For example, differences in fish length spanned over 30 cm, and there was a 7% increase in the proportion of adult Chinook using the north side per 1-cm increase in fish length. In contrast, there was a range of almost 100 kcfs in spill, so the per unit change in the proportion of fish using the north side was relatively small.

Table 6. Covariate parameter estimates from logistic regression models of the likelihood of first detection at the north tailrace or fishway approach and of first entrance at the north fishway. Each estimate is the expected change in probability of using the north side per unit change in the parameter. Only covariates fits from the best-fitting model are shown.

	Adult Chinook		Chinook jack		Sockeye	
North fishway	Estimate	SE	Estimate	SE	Estimate	SE
First detection at north tailrace (F1)						
Sample size	n = 387		n = 168		n = 315	
Length	0.07	0.02				
Night	0.61	0.31			-0.5	0.3
Date						
Temperature					0.21	0.14
Flow						
Spill					0.02	0.01
Dissolved gas	0.01	0.01			0.02	0.01
Passed	-1.36	0.57				
First detection at north fishway approach (A1)						
Sample size	n = 456		n = 227		n = 343	
Length						
Night						
Date						
Temperature						
Flow						
Spill	-0.04	0.01	-0.07	0.02	-0.06	0.01
Dissolved gas						
Passed						
First entrance at north fishway (E1)						
Sample size	n = 449		n = 226		n = 343	
Length						
Night						
Date						
Temperature						
Flow						
Spill	-0.05	0.01	-0.06	0.01	-0.05	0.01
Dissolved gas						
Passed						

We did not analyze the data in a way that would have standardized effect size across covariates because we wanted to keep measures of impact in the same units as the covariates themselves. Each value listed in Table 6 contributed significantly to model fit based on AIC—variables that did not improve AIC ranking (i.e., were not important in the model fit) were left blank.

Side Switching

In all three study groups, the vast majority (84-93%) of fish that entered the tailrace on the north side of the river switched sides in order to make their first entry at the east fishway (Table 7). Conversely, fish first detected on the east side were much less likely to switch sides before entering a fishway, particularly for jack Chinook and sockeye salmon.

Table 7. Proportion of fish that switched sides of the river between tailrace entry (F1) and first fishway entry (E1) at The Dalles Dam, 2014.

Direction of side-switch	Adult Chinook	Chinook jack	Sockeye
North to east	0.84	0.92	0.93
East to north	0.11	0.07	0.07

Several covariates were associated with side switching. Higher spill was associated with increased switching from north to east sides for both Chinook salmon; higher spill was associated with decreased switching from east to north for all three groups (Figure 14, Table 8).

Increased dissolved gas concentrations were related to decreased switching in both directions for adult Chinook salmon. For these fish, length was associated with increased switching from east to north, while date was associated with switching from north to east. Interestingly, adult Chinook switched from north to east more often at night than during the day, and jacks switched from east to north more often at night than during the day, all else being equal.

Table 8. Covariate parameter estimates from logistic regression models of the likelihood that salmon would switch the side of the river used between first detection downstream of the dam (F1) and first fishway entrance (E1). Each estimate is the expected change in the probability of switching for a unit change in the parameter (e.g., adult Chinook salmon were 13% more likely to switch sides from the north to the east for each 1-kcfs increase in spill). Only covariates that were in the best model (according to AIC) are shown. Sample size (*n*) is shown as the first value.

	Factors associated with side-switching at The Dalles Dam					
	Adult Chinook		Chinook jack		Sockeye	
	Estimate	SE	Estimate	SE	Estimate	SE
From north to east	n = 49		n = 64		n = 83	
Length (cm)						
Night*	2.97	1.60				
Date	0.16	0.09				
Temperature (°C)						
Flow (kcfs)						
Spill (kcfs)	0.13	0.08	0.06	0.03		
Dissolved gas (mmHg)	-0.21	0.10				
From east to north	n = 323		n = 100		n = 229	
Length (cm)	0.05	0.03				
Night*			1.32	0.85		
Date						
Temperature (°C)						
Flow (kcfs)						
Spill (kcfs)	-0.04	0.01	-0.07	0.03	-0.09	0.02
Dissolved gas (mmHg)	-0.02	0.01				

* Daytime passage was defined as fish detected between 0500 and 1700 PDT; nighttime passages was detection between 1700 and 0500 the following day.

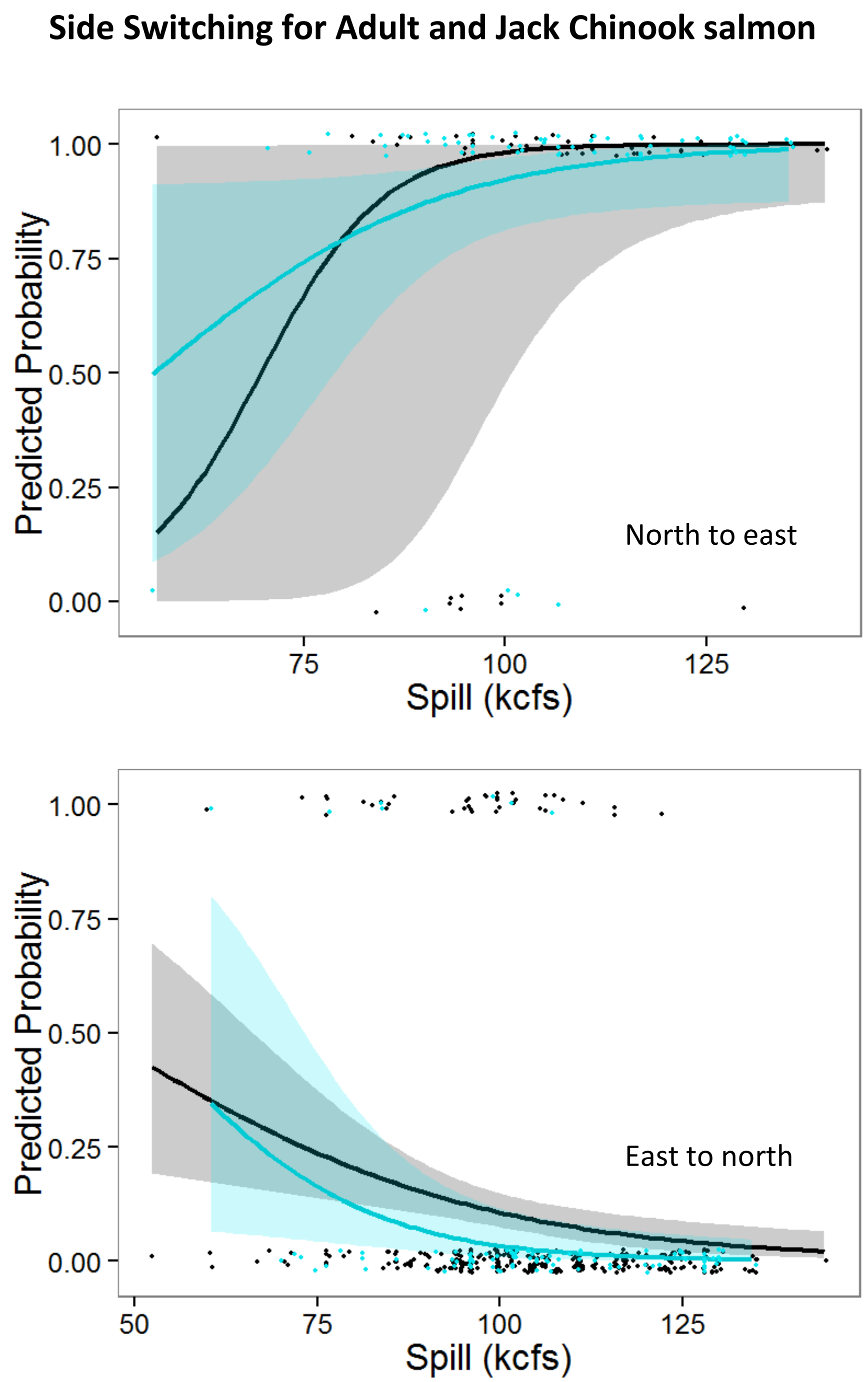

Figure 14. Top panel: Black lines show mean predicted probability of adult Chinook side-switching from north to east as a function of spill at The Dalles Dam. Teal lines show the same probability for Chinook jacks. Lower panel: Black and teal lines show the same probabilities for side-switching in the east to north direction. Dots represent individual fish that switched sides (jittered around 1 on the Y-axis) and fish that did not switch (jittered around 0). Shaded area around lines represents ±1 standard error.

North Fishway Entrance Efficiency

Of the 55 adult Chinook salmon recorded first approaching the north fishway in 2014, all first entered via the north fishway (entrance efficiency 100%, Table 9). Similarly, 12 of 13 Chinook salmon jacks that first approached the north fishway also first entered there (efficiency 92.3%). Entrance efficiency was also near 100% at the east fishway for both Chinook salmon groups. Sockeye salmon also exhibited entrance efficiency rates at or near 100% at both fishways (Table 9).

Pre-modification assessments have shown lower entrance efficiency for Chinook salmon at the north fishway when spill volumes were high (100-150 kcfs, Jepson et al. 2011). In both 2013 and 2014, high entrance efficiencies at both fishways for all groups precluded any analyses relative to environmental covariates. However, results suggest that tagged salmon had little or no difficulty entering the north fishway after approaching the fishway entrance.

Table 9. Entrance efficiency (first site entered/first site approached) for each fishway at The Dalles Dam in 2014.

		Number first approaching	Entrance efficiency (%)
North side	Adult Chinook	55	100.0
	Chinook jack	13	92.3
	Sockeye	20	100.0
East side	Adult Chinook	424	96.7
	Chinook jack	244	98.4
	Sockeye	323	99.7

Discussion

Results from these evaluations were broadly consistent with the hypothesis that high spill volumes at The Dalles Dam reduce use of the north fishway by Chinook and sockeye salmon. However, few fish used the north side of the river, even several kilometers downstream from the dam, based on detections at the tailrace monitoring site. Furthermore, even among the relatively small number of fish using the north side of the river, many switched to the east side, and this behavior was associated with high spill levels.

However, as Jepson et al. (2011) and Burke et al. (2014) reported, differences in fishway selection appeared to have relatively limited effects on overall fishway entrance efficiency or overall dam passage time. In previous studies of adult Chinook salmon, slowed passage at Columbia and Snake River dams has been associated with high spill volumes (Boggs et al. 2004; Keefer et al. 2004; Caudill et al. 2006) and with some spill patterns (Jepson et al. 2009).

Radio-tagged salmon used the north fishway less frequently in 2014, but they did not appear to spend undue amounts of time seeking and finding alternate passage routes, a finding consistent with that of Jepson et al. (2011) and Burke et al. (2014). Dam passage times for radio-tagged Chinook and sockeye salmon at The Dalles Dam in 2014 were about average relative to results from previous study years.

Of salmon detected on the north side of the river downstream from The Dalles Dam, 84% of adult Chinook, 92% of jack Chinook, and 93% of sockeye eventually switched sides and entered the east fishway. Proportions of fish that side-switched from approach on the east side to entrance at the north fishway were 11, 7, and 7%, respectively for adult Chinook, jack Chinook, and sockeye salmon. However, the new spill wall did not appear to excessively impede the ability of salmon to find alternate passage routes when traveling in either direction, even when spill volumes were high.

Salmon first detected in the tailrace on the north shore and subsequently detected at the east fishway entrance had median fishway entry times (F1 to E1) similar to those of fish that did not switch sides. For example, adult Chinook salmon that switched sides entered a fishway 1 h sooner than those that did not switch.

Our findings support the observation from window count data that smaller-bodied adults are less likely to use the north fishway. Model results indicated length was a predictive covariate of side-switching for adult Chinook, but only for the east to north direction. Had we modeled adults and the smaller jack Chinook and sockeye salmon together, the size effect may have been more pronounced.

Spill tended to have a more consistent effect on side switching for all three groups, with switching increasingly likely as spill increased. Reduced use of the north fishway is of concern to managers for small-bodied fish because approaches to the north fishway could be associated with passage delay or failure. The concern has been that smaller adults may be delayed by the search for an upstream passage route after not finding or rejecting the north fishway entrance.

However, we found little evidence that side-switching was associated with additional passage time. While passage times to the east ladder were slightly longer, they likely resulted from the longer distance between tailrace receivers and fishway entrances at the east ladder.

In a previous analysis (e.g., Bjornn et al. 2000), 9.2% of the north-ladder migrants fell back over the dam compared to 2.3% of the east ladder migrants. As in 2013 (Burke et al. 2014), we did not see this difference in fallback rates between fishways in 2014. Adult Chinook fallback rates were less than 4%, lower than the ~8% reported in 2013 (Burke et al. 2014). For Chinook jacks, fallback rates were ~4% after passage through from either fishway. As in 2013, no sockeye salmon fell back after passing the north ladder, while ~3% of sockeye fell back after passing the east ladder.

John Day Dam

Introduction

Several recent modifications have been made to the north fishway at John Day Dam. 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 existing sill gates and actuators
2. Construction of new concrete weirs
3. Modification of concrete baffles in the transition section located in the non-overflow portion of the fishway
4. Modifications to the floor, diffuser, and fish-counting building within the fish ladder
5. Replacement of the existing bulkhead, picket leads, crowder, and light box, and addition of a window washer for the fish-counting building

In winter 2011-2012 and 2012-2013, additional north fishway modifications were conducted to facilitate the upstream passage of adult salmonids and adult Pacific lamprey *Entosphenus tridentatus*. These modifications included:

1. Installation of a variable width entrance weir
2. Closure of one of the two fishway entrance slots
3. Installation of velocity-reducing bollards on the fishway floor just inside the entrance
4. Installation of a lamprey passage structure (LPS) on the north wall just upstream from the entrance
5. Removal of the first two concrete overflow weirs from the fishway and installation of new power-coated floor diffuser grating (Figure 15)

Our primary objectives at John Day Dam were to compare adult Chinook salmon passage times and behaviors at the north fishway in 2013-2014 to results from pre-modification years while simultaneously considering interannual variation in environmental conditions. Specific objectives included:

1. Evaluate salmon passage time through the north fish ladder, including passage by the modified count station.
2. Evaluate passage time at the north fishway opening and lower north fishway.
3. Estimate entrance efficiency and other passage metrics at the north ladder entrance.

Figure 15. Modifications to the John Day Dam north fishway entrance area; camera is facing upstream in all photos except A. From left to right, clockwise: A) downstream variable-width entrance weir, bollard field, and closed entrance slot (new concrete on left wall); B) lamprey passage structure (with bollard field in foreground); C) removal of concrete weirs; and D) completed fishway with concrete weirs removed.

Methods

Study Fish and Monitoring Systems

Study fish for evaluations at John Day Dam were the same as those used for evaluations at The Dalles Dam. As described in the methods section for The Dalles Dam, we collected 600 adult Chinook salmon and 300 jack Chinook salmon at Bonneville Dam from 8 April through 15 July 2014. Methods of collection and tagging are reported in the *Study Fish and Monitoring Systems* section for The Dalles Dam in this report.

We used an array of fixed-site radio receivers to monitor locations of tagged fish at John Day Dam. Receiver deployments were similar to those in previous years to facilitate comparison of estimated passage metrics among years. The tailrace was monitored with aerial antennas located on both sides of the river (Figure 16). Primary fishway openings were monitored inside and outside with underwater coaxial cable antennas. Additional underwater antennas were used to monitor collection channels, transition areas between collection channels and overflow weir sections of the ladders, and near top-of-ladder exits to the dam forebay.

Among-year differences in monitoring effort were minor, and an effort was made to standardize specific antenna sites used for all comparative analyses across years.

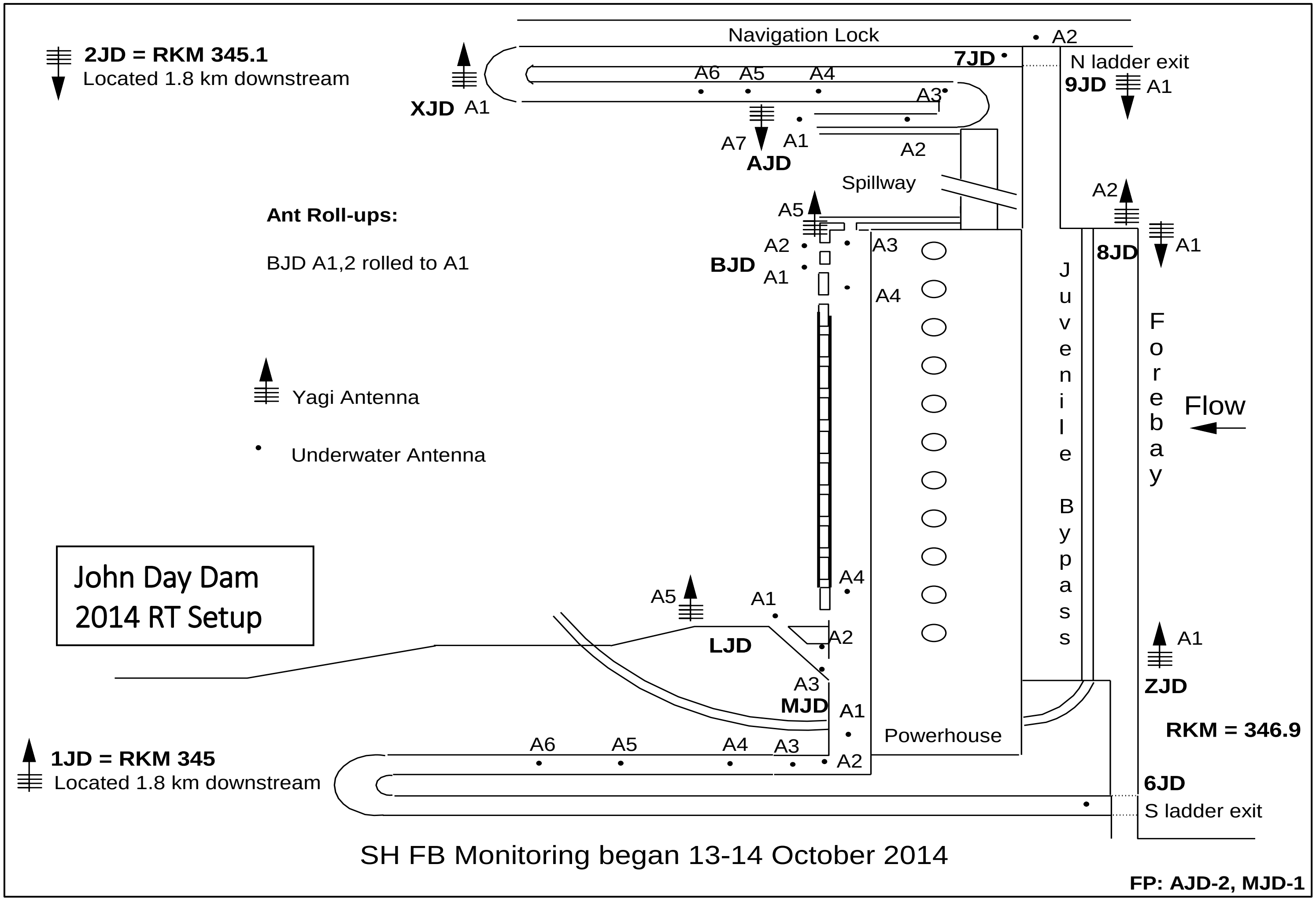

Figure 16. Plan view of radio antennas deployed at John Day Dam in 2014 (drawing not to scale).

North Fishway Passage Performance Metrics

At the John Day north fishway, we evaluated Chinook salmon passage time, entrance and passage efficiency, and behavior at the fishway opening in 2013-2014. Results from these evaluations were compared to similar metrics from radio-tagged adult Chinook salmon collected in 1997-1998 and 2000-2006. Variability in passage time among study years was evaluated to provide context for more specific evaluations of the lower north fishway.

Reporting in each year was separated into spring and early summer components of the adult migration. We used 5 June as the last date of the spring Chinook run to facilitate comparisons with data from past years by run. Note that this division of the spring vs. summer portion of the Chinook adult migration was not used for evaluations at The Dalles Dam. While early and late Chinook salmon runs were not inherently separated by time for data from The Dalles Dam, date was included as a covariate in the analyses.

We considered seven metrics, with three designed to evaluate passage efficiency and four to evaluate passage time. These metrics were used to assess potential effects on the behavior of adult and jack spring/summer Chinook salmon and sockeye salmon from modifications to the John Day north fishway entrance:

Passage efficiency metrics

Entrance efficiency	Ratio of unique fish recorded entering the north fishway to number of unique fish that approached the north fishway (entrances/approaches).
Exit ratio	Ratio of unique fish recorded exiting the north fishway to the tailrace to number that entered the north fishway (exits/entrances).
Lower fishway passage efficiency	Ratios of unique fish recorded passing the dam to number of unique fish that entered the north fishway (passes/entrances).

Passage time metrics

Entrance time	Time from first approach of the north fishway to first entrance into the north fishway.[a]
Entrance to ladder base	Time from first entrance into the north fishway to first detection in the transition pool[b] at the base of the ladder.
Extended passage time	Percentage of fish that required more than 1 h to swim through the two passage segments.
Ladder passage time	Passage time from the transition pool to exit from the top of the fishway.

[a] Defined as detection at antenna AJD-2

[b] Defined as detection on antenna AJD-5. Note that the AJD-5 antenna remained in the same position during all study years.

Data Analyses

To compare passage time metrics among years, we calculated median passage time. We focused on differences between pre-modification years (1997-1998 and 2000-2006) and post-modification years (2013-2014). A chi-squared (χ^2) test was used to investigate differences in Chinook salmon entrance efficiency, exit ratio, and lower fishway efficiency between pre- and post-modification years.

A Kruskal-Wallis test was used to evaluate differences in passage time among pre- and post-modification years for both spring and summer runs of Chinook salmon. For fish from the 2013-2014 migrations, we also ran pairwise comparisons of adult vs. jack Chinook to assess whether age/body size affected passage time.

We used correlation techniques to evaluate the degree of association between approach-to-entry time at the John Day north ladder and four environmental factors:

1. Total discharge or flow (kcfs),
2. Spillway discharge or spill (kcfs),
3. Water temperature (°C), and
4. Tailwater elevation (ft msl).

We also evaluated the degree of association between date and approach-to-entry time at the John Day north ladder.

Results

Environmental Data

During both spring and summer adult Chinook migration periods over the 10 study years, flow, spillway discharge, tailwater elevation, and water temperature varied considerably in the John Day Dam tailrace (Figure 17). This contributed to large interannual variation in Chinook salmon passage behaviors. For example, total river discharge (flow) ranged from near-record low levels in 2001 (mostly < 200 kcfs) to ~500 kcfs in 1997.

During the spring Chinook adult migrations of 2013-2014, environmental conditions at John Day Dam were near average compared with those of 1997-2006 (Table 10). Mean tailwater elevation and water temperature were similar between pre- and post-modification periods. Mean spill levels and flows were moderately higher than average in spring 2013-2014 vs. spring 1997-2006.

After 5 June, average environmental conditions during 2013-2014 were characterized by modestly higher-than-average total river discharge (Table 10 and Figure 17). Summer mean water temperatures in 2013-2014 (June to mid-July) were near pre-modification averages, at 18.45 vs. 18.32°C, as were tailwater elevations.

Table 10. Average environmental metrics at John Day Dam during the adult spring Chinook migrations of 1997-2006 vs. 2013-2014.

Conditions during adult Chinook salmon migration at John Day Dam		
	1997-2006	2013-1014
Average	Spring migration period	
Flow (kcfs)	245.7	270.4
Spill (kcfs)	64.8	87.6
Tailwater elevation (ft msl)	162.4	163.0
Temperature (°C)	11.46	11.26
	Summer migration period (6 June to mid-July)	
Flow (kcfs)	215.6	230.8
Spill (kcfs)	61.8	79.7
Tailwater elevation (ft msl)	161.5	162.3
Temperature (°C)	18.32	18.45

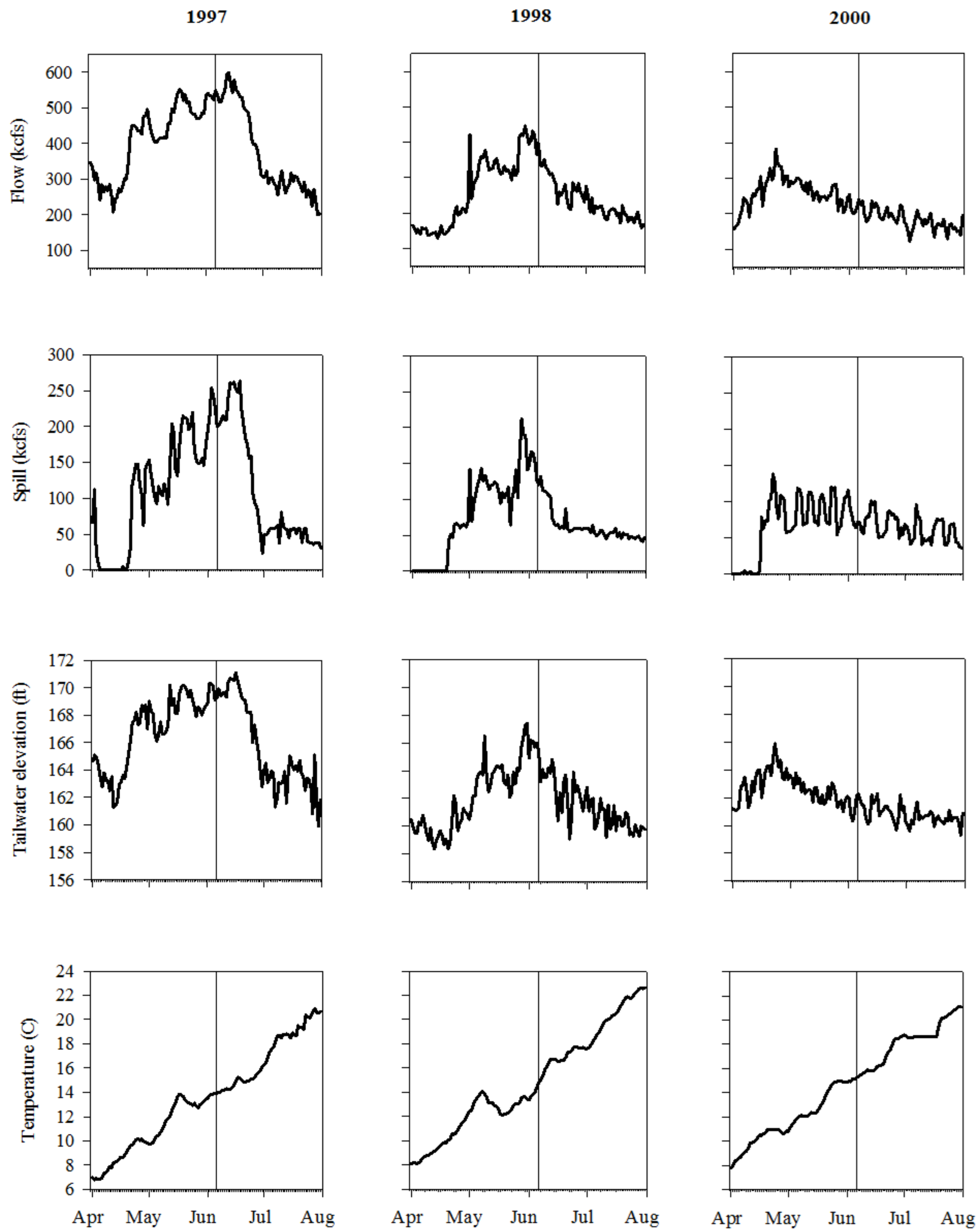

Figure 17. Mean daily flow, spillway discharge, and tailwater elevation and temperature at John Day Dam during the Chinook salmon run (April-Aug) 1997-1998, 2000-2006, and 2013-2014. Vertical line indicates the 5 June separation between spring and summer runs. In charts for 2013 and 2014, red lines represent pre-modification daily averages (1997-1998 and 2000-2006).

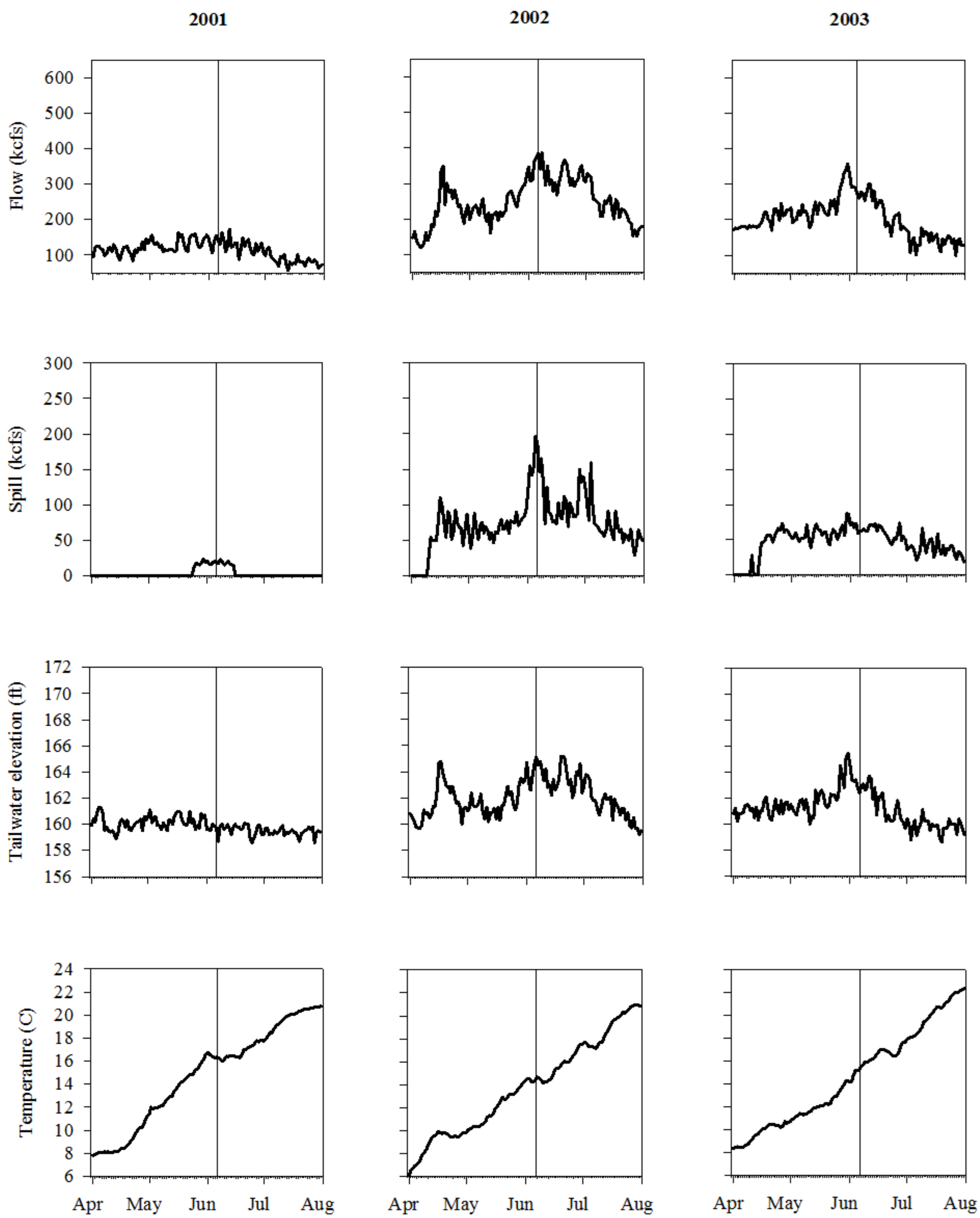

Figure 17. Continued.

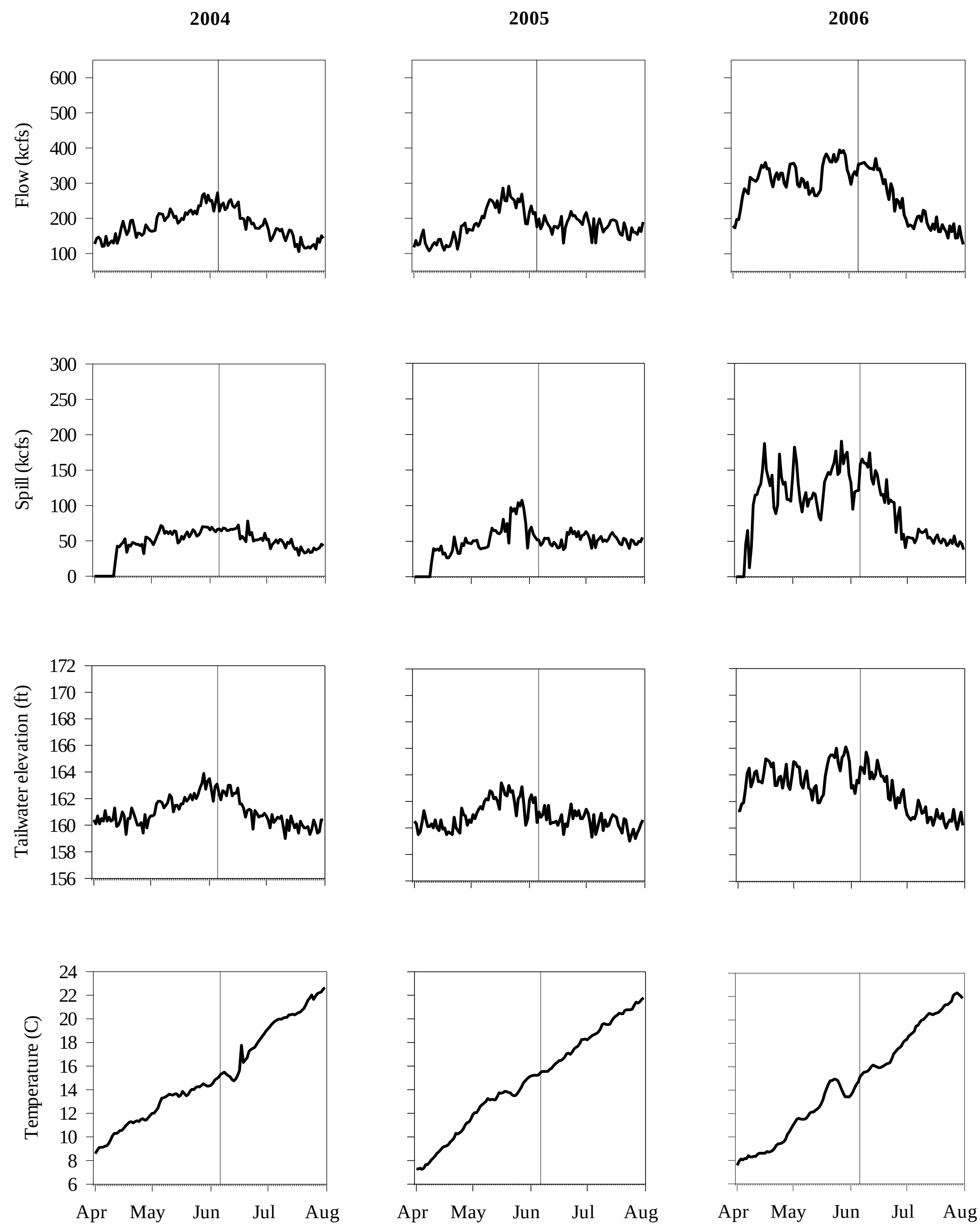

Figure 17. Continued.

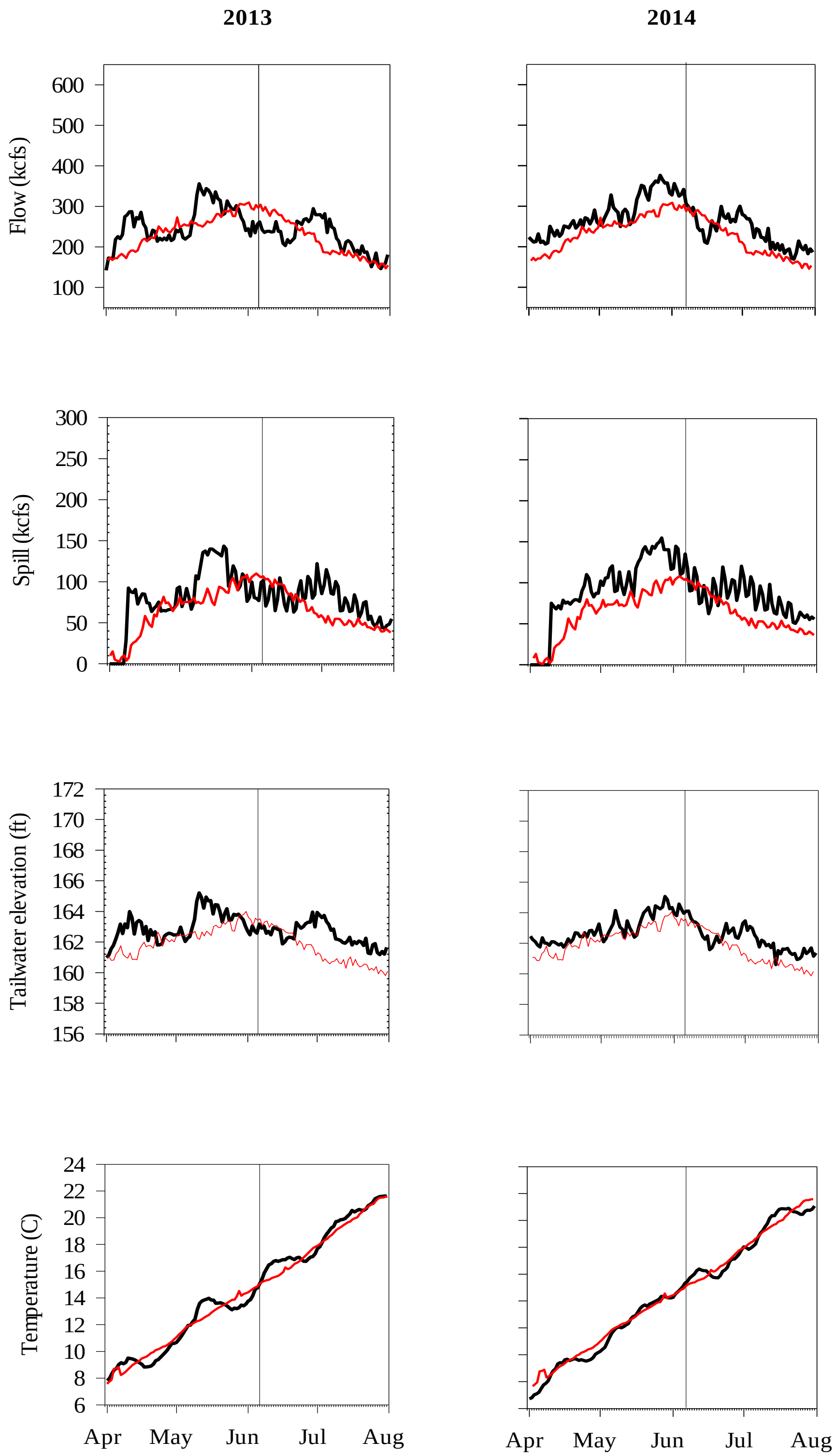

Figure 17. Continued.

Summary of Detections at John Day Dam

In 2014, 680 radio-tagged Chinook salmon were detected at John Day Dam, including 441 adults and 239 jacks (Figures 18-19). Based on dates of first detection, 265 (60%) of radio-tagged adult Chinook salmon that approached John Day Dam were part of the spring run, while 176 (40%) were summer-run fish. Jack Chinook salmon were split almost evenly between the spring (53%) and summer run (47%).

In 2013, 707 radio-tagged Chinook salmon were detected at John Day Dam, including 458 adults and 249 jacks (Figures 18-19). Spring and summer runs of Chinook were split nearly evenly, with 228 radio-tagged adults in the nominal spring run and 230 in the summer run, based on detection date at John Day Dam. Of the 249 Chinook jacks detected at John Day Dam in 2013, 61% were spring-run and 39% were summer-run.

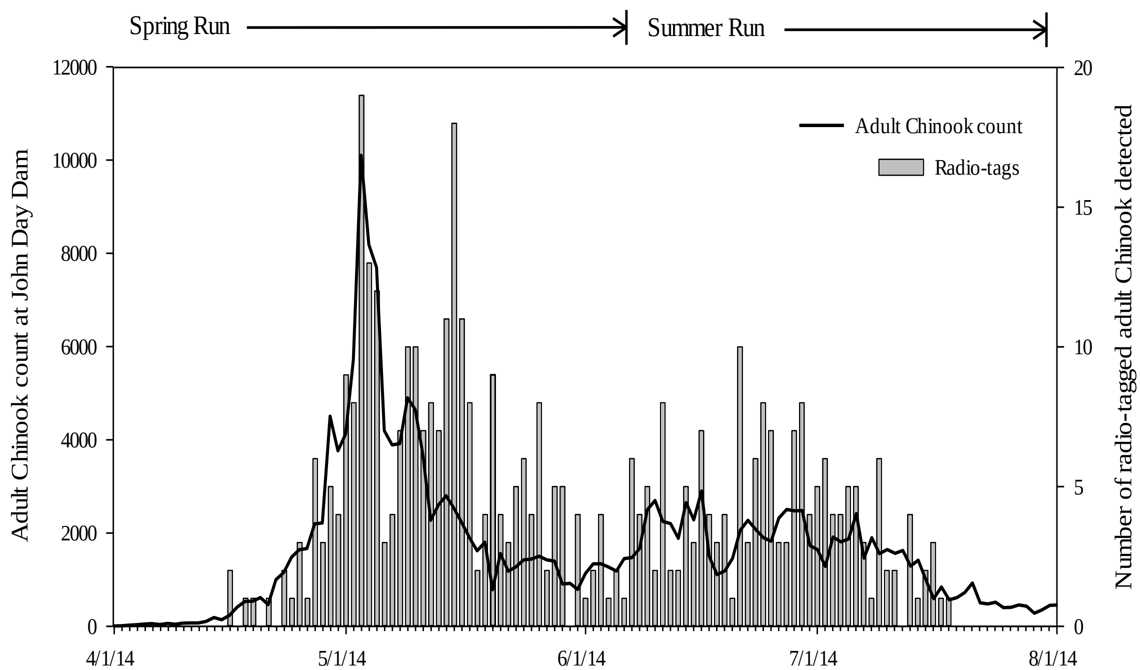

Figure 18. First detections of radio-tagged adult Chinook with total count of adult Chinook salmon at John Day Dam, 1 April-31 July 2014.

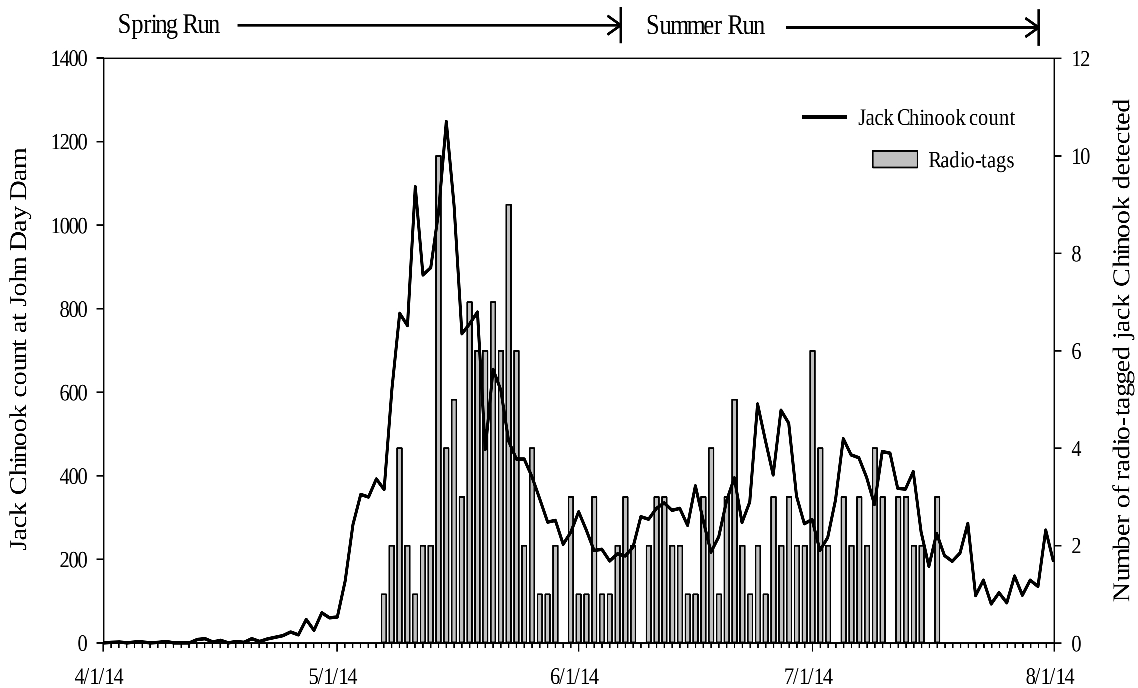

Figure 19. First detections of radio-tagged jack Chinook with total count of jack Chinook salmon at John Day Dam, 1 April-31 July 2014.

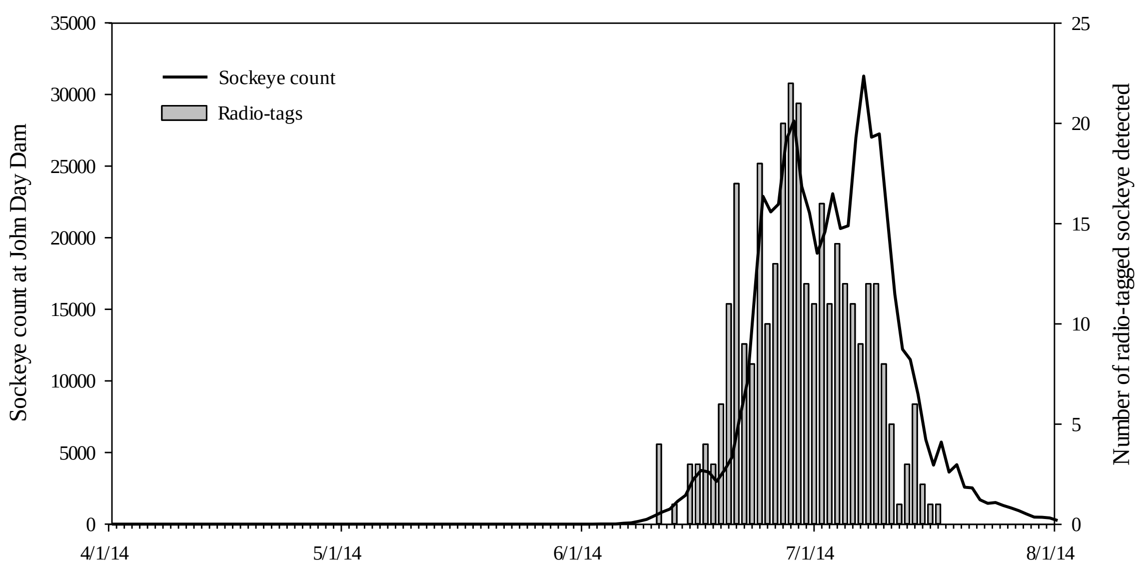

Figure 20. First detections of radio-tagged sockeye with the total count of sockeye salmon at John Day Dam, 1 April-31 July 2014.

During 1997-1998 and 2000-2006, detections of adult radio-tagged Chinook salmon ranged 130-989 (mean 595) at John Day Dam. Detections of spring-run Chinook salmon approaching the dam during these years ranged 20-685 (mean 370, Table 11). For summer-run Chinook over these same years, detections of radio-tagged adults have ranged 29-344 (mean 225, Table 12). Chinook salmon jacks were not tagged separately in study years prior to 2013.

In 2013, 325 radio-tagged sockeye salmon were detected at John Day Dam. In 2014, 330 radio-tagged sockeye salmon were detected at John Day Dam (Figure 20).

Table 11. Spring Chinook passage results at John Day Dam from radio tagging studies in 1997-1998, 2000-2006, and 2013-2014. Shown are numbers of radio-tagged fish that approached, entered, and exited the fishways; numbers that passed the dam; and estimates of fishway-entrance, fishway-passage, and dam-passage efficiency.

	Adult spring Chinook salmon dam-wide passage metrics						
	Unique passage events (n)				Efficiency (%)		
	Approached	Entered	Exited to tailrace	Passed dam	Entrance	Fishway passage	Dam passage
1997	398	386	165	384	0.97	0.99	0.97
1998	427	418	304	409	0.98	0.98	0.96
2000	417	409	243	404	0.98	0.99	0.97
2001	685	681	528	674	0.99	0.99	0.98
2002	564	562	293	555	0.99	0.99	0.98
2003	403	397	249	395	0.99	0.99	0.98
2004	234	233	177	231	0.99	0.99	0.99
2005	20	20	16	19	1.00	0.95	0.95
2006	184	182	94	181	0.99	0.99	0.98
2013							
Adult	228	227	158	221	0.99	0.97	0.97
Jacks	152	151	72	151	0.99	1.00	0.99
2014							
Adult	265	264	120	259	0.99	0.98	0.98
Jacks	131	131	40	128	1.00	0.98	0.98

Table 12. Summer Chinook passage metrics at John Day Dam from radio tagging studies in 1997-1998, 2000-2006, and 2013-2014. Shown are numbers of radio-tagged fish that approached, entered, and exited fishways; numbers that passed the dam; and estimates of fishway-entrance, fishway-passage, and dam-passage efficiency.

Adult summer Chinook salmon dam-wide passage metrics							
	Unique passage events (n)				Efficiency (%)		
	Approached	Entered	Exited to tailrace	Passed dam	Entrance	Fishway passage	Dam passage
1997	251	248	200	244	0.99	0.98	0.97
1998	229	227	203	218	0.99	0.96	0.95
2000	296	294	272	273	0.99	0.93	0.92
2001	304	302	289	295	0.93	0.98	0.97
2002	294	291	254	281	0.99	0.97	0.96
2003	344	342	315	320	0.99	0.94	0.93
2004	166	166	159	149	1.00	0.90	0.90
2005	110	110	100	108	1.00	0.98	0.98
2006	29	28	17	28	0.97	1.00	0.97
2013							
Adult	230	228	179	219	0.99	0.96	0.95
Jacks	97	96	55	95	0.99	0.99	0.98
2014							
Adult	176	176	133	174	1.00	0.99	0.99
Jacks	108	108	70	108	1.00	1.00	1.00

Passage Metrics for Chinook Salmon

Dam-Wide Efficiency Metrics—Estimated dam-wide entrance efficiency (entrances/approaches) was 0.99 for adult spring Chinook salmon in 2014 (Table 11). Passage efficiency for adults that entered a fishway was 0.98, as was passage efficiency for those that approached the dam. Mean post-modification efficiencies for adult spring Chinook salmon at John Day Dam overall were 0.99 for fishway entrance, 0.98 for fishway passage, and 0.975 for dam passage.

These values were within the range of dam-wide efficiency means observed for adult spring Chinook salmon in pre-modification years. During pre-modification years, fishway entrance efficiency ranged 0.97-1.00 (mean 0.99), fishway passage efficiency ranged 0.95-1.00 (mean 0.99), and dam passage efficiency ranged 0.95-0.99 (mean 0.97).

For spring Chinook jacks, dam-wide entrance efficiency was 1.00 in 2014, meaning all jacks that approached a fishway eventually entered. Fishway passage efficiency was 0.98 for jacks that entered a fishway, while dam passage efficiency was 0.98 for those that approached the dam (Table 11). These values were similar to those observed for jack spring Chinook in 2013, when dam-wide entrance efficiency was 0.99, fishway passage efficiency was 1.00, and dam passage efficiency was 0.99 (Table 11).

For adult summer Chinook salmon at John Day Dam in 2014, dam-wide entrance efficiency was 1.00 and fishway passage efficiency was 0.99 (Table 12); for those that approached, dam passage efficiency was 0.99.

For summer Chinook salmon during post-modification years, mean entrance efficiency was 0.99, mean fishway passage efficiency was 0.98, and mean dam passage efficiency was 0.97. These values fall within the ranges of corresponding dam-wide efficiency values observed for adult summer Chinook salmon in pre-modification years: entrance efficiency ranged 0.93–1.00 (mean 0.98), fishway passage efficiency ranged 0.90–1.00 (mean 0.96), and dam passage efficiency ranged 0.90–0.99 (mean 0.95).

For summer Chinook jacks, dam-wide entrance efficiency was 1.00, fishway passage efficiency was 1.00, and dam passage efficiency was 1.00 in 2014 (Table 12). These values were similar to those observed for jack summer Chinook in 2013 (Table 12).

North Fishway Passage Metrics—***Proportionate Use of the North Fishway***. Of the 265 adult spring Chinook salmon detected approaching the dam in 2014, 149 (56%) approached and 137 (52%) entered the north fishway at least once (Table 13). These percentages were slightly higher, but comparable to those observed in 2013 for adult spring Chinook approach (53%) and entry (46%) at the north fishway. They were also within range of the values observed during pre-modification years, when north fishway approach proportions ranged 42-83% (mean 66%) and entry proportions ranged 25-67% (mean 54%).

Of the jack Chinook salmon that approached John Day Dam in spring 2014, 62 (47%) were recorded approaching and 59 (45%) were recorded entering the north fishway (Table 13).

Table 13. Numbers and proportions of radio-tagged spring Chinook that approached and entered the John Day Dam north fishway in 1997-1998, 2000-2006, and 2013-2014.

	Spring Chinook salmon north fishway passage metrics					
	Unique passage events (n)			Proportion of dam-wide events occurring at the north fishway (%)		
	Approached	Entered	Passed dam	Approached	Entered	Passed dam
1997	166	98	384	0.42	0.25	0.17
1998	288	227	409	0.67	0.54	0.31
2000	280	228	404	0.67	0.56	0.39
2001	565	458	674	0.83	0.67	0.46
2002	374	303	555	0.66	0.54	0.42
2003	243	188	395	0.6	0.47	0.26
2004	179	152	231	0.77	0.65	0.36
2005	13	12	19	0.65	0.6	0.26
2006	120	99	181	0.65	0.54	0.44
2013						
Adult	120	105	221	0.53	0.46	0.28
Jacks	68	64	151	0.45	0.42	0.38
2014						
Adult	149	137		0.56	0.52	0.41
Jacks	62	59		0.47	0.45	0.41

Of the 176 summer Chinook salmon adults that approached John Day Dam in 2014, 148 (84%) approached and 139 (79%) entered the north fishway at least once (Table 14). These percentages were higher than in 2013 when 76% of adult summer Chinook approached and 70% entered the north fishway. Percentages observed in 2014 were within the range of values from pre-modification years, when 71-86% (mean 80%) were detected approaching the north fishway one or more times and 46-81% (mean 64%) were recorded entering the north fishway.

Of the 97 summer Chinook jacks that approached the dam in 2013, 48 (50%) approached and 44 (46%) entered the north fishway at least once (Table 14). Of the 108 summer Chinook jacks that approached the dam in 2014, 73 (68%) approached and 69 (64%) entered the north fishway at least once (Table 14). These percentages were considerably higher than those for summer Chinook jacks that approached (50%) and entered (46%) the north fishway in 2013.

Table 14. Numbers and proportions of radio-tagged summer Chinook that approached and entered the John Day Dam north fishway in 1997-1998, 2000-2006, and 2013-2014.

	Summer Chinook salmon north fishway passage					
	Unique passage events (n)			Proportion of dam-wide events occurring at the north fishway (%)		
	Approached	Entered	Passed dam	Approached	Entered	Passed dam
1997	178	160	70	0.71	0.65	0.29
1998	182	154	57	0.80	0.68	0.36
2000	253	238	136	0.86	0.81	0.50
2001	254	202	60	0.84	0.67	0.20
2002	252	207	92	0.86	0.71	0.33
2003	275	215	68	0.80	0.63	0.21
2004	133	104	39	0.80	0.63	0.26
2005	82	60	25	0.75	0.55	0.23
2006	23	13	9	0.79	0.46	0.32
2013						
Adult	175	159	106	0.76	0.70	0.48
Jacks	48	44	33	0.50	0.46	0.35
2014						
Adult	148	139	107	0.84	0.79	0.61
Jacks	73	69	47	0.68	0.64	0.44

North Fishway Entrance Efficiency. For radio-tagged adult spring Chinook salmon passing via the north fishway at John Day Dam, entrance efficiency estimates in pre-modification years ranged 0.59-0.92 (mean 0.80, Table 15b, Figure 21). The lowest entrance efficiency estimate was in 1997, when average river flow, spill, and tailwater elevation were at their highest levels of the 10 study years. The highest pre-modification entrance efficiency was estimated in 2005.

In 2013, entrance efficiency for adult spring Chinook salmon was estimated at 0.88, near the high end of the range from previous years. Average post-modification entrance efficiency at the north fishway for adult spring Chinook salmon was 0.90. Entrance efficiency during post-modification years was significantly higher than in pre-modification years (χ^2 = 16.4217, P < 0.0001). Entrance efficiency for spring Chinook jacks was also high, at 0.94 in 2013 and 0.95 in 2014; there were no previous jack study years for comparison.

Table 15a. Passage metrics for spring Chinook salmon at John Day north fishway, 1997-1998, 2000-2006, and 2013-2014. See Figure 16 for antenna locations.

Spring Chinook salmon passage at John Day north fishway										
	Unique fish detected (n)							Total events		
				Detection on antenna						
	Approach	Enter	Exit to tailrace	3	4	5	Passed	Approach	Enter	Exit to tailrace
1997	166	98	44	85	81	79	67	301	121	57
1998	288	227	149	214	209	145	127	780	368	238
2000	280	228	118	223	219	170	159	631	366	205
2001	565	458	261	424	411	318	307	1,461	718	414
2002	374	303	150	300	294	244	234	1,132	486	266
2003	243	192	124	186	180	117	104	609	328	226
2004	179	152	100	145	142	110	82	402	286	204
2005	13	12	10	11	11	8	5	34	24	19
2006	120	99	42	99	97	88	79	260	145	72
2013										
Adult	120	105	69	104	99	88	62	372	227	167
Jack	68	64	24	64	61	58	57	113	97	41
2014										
Adult	149	137	54	136	132	120	108	314	242	134
Jack	62	59	17	59	56	54	52	92	73	20

Table 15b. North fishway passage efficiency metrics for spring Chinook salmon, including entrance and exit efficiencies. Efficiency of each ladder in the collection channel is shown along with lower fishway passage efficiency.

	Spring Chinook passage efficiencies at John Day north fishway(%)							
	Entrance		Exit ratio		Collection channel			Lower fishway efficiency
	Unique	Total	Unique	Total	Ladder3	Ladder4	Ladder5	
1997	0.59	0.40	0.45	0.47	0.87	0.83	0.81	0.68
1998	0.79	0.47	0.66	0.65	0.94	0.92	0.64	0.56
2000	0.81	0.58	0.52	0.56	0.98	0.96	0.75	0.70
2001	0.81	0.49	0.57	0.58	0.93	0.9	0.69	0.67
2002	0.81	0.43	0.5	0.55	0.99	0.97	0.81	0.77
2003	0.79	0.54	0.65	0.69	0.97	0.94	0.61	0.54
2004	0.85	0.71	0.66	0.71	0.95	0.93	0.72	0.54
2005	0.92	0.71	0.83	0.79	0.92	0.92	0.67	0.42
2006	0.83	0.56	0.42	0.50	1.00	0.98	0.89	0.80
2013								
Adult	0.88	0.61	0.66	0.74	0.99	0.94	0.84	0.59
Jack	0.94	0.86	0.38	0.42	1.00	0.95	0.91	0.89
2014								
Adult	0.92	0.77	0.39	0.55	0.99	0.96	0.88	0.79
Jack	0.95	0.79	0.29	0.27	1.00	0.95	0.92	0.88

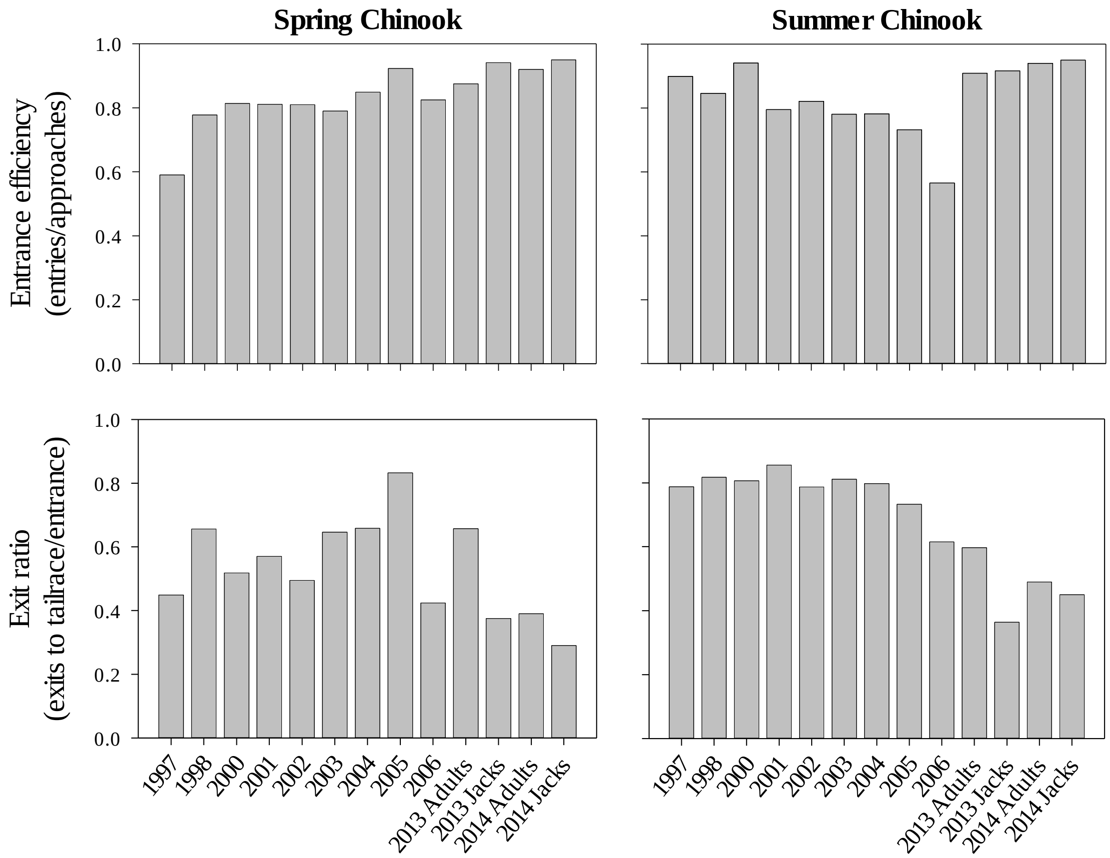

Figure 21. Unique fish entrance efficiencies (top panels) and exit ratios (bottom panels) for radio-tagged spring and summer Chinook salmon at the John Day north fishway in 1997-1998, 2000-2006, and 2013-2014.

For radio-tagged adult summer Chinook salmon, estimated entrance efficiency at the John Day north ladder has ranged from 0.57 in 2006 to 0.94 in 2000 (overall mean 0.80; Table 16a and 16b, Figure 21). Estimated entrance efficiency for adult summer Chinook salmon was 0.91 in 2013 and 0.94 in 2014, both at the high end of the range from previous years. Mean post-modification entrance efficiency for summer adult Chinook (0.93) was near the high end of the range of entrance efficiencies in pre-modification years. Entrance efficiency during post-modification years was significantly higher than in pre-modification years ($\chi^2 = 17.2017$, $P < 0.0001$). Estimated entrance efficiency for summer Chinook jacks was 0.92 in 2013 and 0.95 in 2014.

Table 16a. Numbers of unique summer Chinook salmon that approached and entered the John Day north fishway, exited to the tailrace, and were detected inside the north ladder, and that passed the dam via the north fishway in 1997-1998, 2000-2006, and 2013-2014. See Figure 16 for antenna locations.

	Summer Chinook salmon use of the John Day north fishway									
	Unique fish detected (n)							Total events		
				Detection on antenna						
	Approach	Enter	Exit to tailrace	3	4	5	Passed	Approach	Enter	Exit to tailrace
1997	178	160	126	151	143	87	70	957	555	478
1998	182	154	126	142	137	110	57	568	344	282
2000	253	238	192	232	223	142	136	1,390	926	792
2001	254	202	173	183	179	79	60	1,019	608	569
2002	252	207	163	202	164	121	92	1,574	685	594
2003	265	207	168	201	197	86	65	1,331	575	507
2004	133	104	83	102	101	42	39	992	281	242
2005	82	60	44	59	56	41	25	355	124	98
2006	23	13	8	13	13	10	9	195	46	38
2013										
Adult	175	159	95	158	154	150	106	632	367	253
Jack	48	44	16	43	40	40	33	84	61	27
2014										
Adult	148	139	68	139	135	129	107	580	380	271
Jack	73	69	31	67	67	64	47	125	98	50

Table 16b. North fishway passage efficiency metrics for summer Chinook salmon, including entrance and exit ratios. Efficiency of each ladder in the collection channel is shown along with lower fishway passage efficiency.

	Passage efficiency for summer Chinook salmon the John Day north fishway(%)							
	Entrance		Exit ratio		Collection channel			Lower fishway efficiency
	Unique	Total	Unique	Total	Ladder3	Ladder4	Ladder5	
1997	0.90	0.58	0.79	0.86	0.94	0.89	0.54	0.44
1998	0.85	0.61	0.82	0.82	0.92	0.89	0.71	0.37
2000	0.94	0.67	0.81	0.86	0.98	0.94	0.60	0.57
2001	0.80	0.60	0.86	0.94	0.91	0.89	0.39	0.30
2002	0.82	0.44	0.79	0.87	0.98	0.79	0.59	0.44
2003	0.78	0.43	0.81	0.88	0.97	0.95	0.42	0.31
2004	0.78	0.28	0.80	0.86	0.98	0.97	0.4	0.38
2005	0.73	0.35	0.73	0.79	0.98	0.93	0.68	0.42
2006	0.57	0.24	0.62	0.83	1.00	1.00	0.77	0.69
2013								
Adult	0.91	0.58	0.60	0.69	0.99	0.97	0.94	0.67
Jack	0.92	0.73	0.36	0.44	0.98	0.91	0.91	0.75
2014								
Adult	0.94	0.66	0.49	0.71	1.00	0.97	0.93	0.77
Jack	0.95	0.78	0.45	0.51	0.97	0.97	0.93	0.68

These results indicate that recent modifications to the north fishway opening did not have adverse effects on spring and summer Chinook salmon entrance efficiency. The significant increase in post-modification passage metrics for both spring and summer Chinook salmon indicated a potential benefit from the modifications.

North Fishway Exit Ratio. For radio-tagged adult spring Chinook salmon, exit ratios ranged 0.42-0.83 in pre-modification years (mean 0.58; Table 15b, Figure 21). In 2014, the estimated exit ratio fell slightly below this range (0.39), and the estimate for spring Chinook jacks was also low (0.29). The mean post-modification exit ratio for adult spring Chinook salmon was 0.53, within the range observed in pre-modification years. Exit ratios for adult spring Chinook during post-modification years were not significantly different from those in pre-modification years ($\chi^2 = 0$, $P = 1.0$).

Of the 137 adult spring Chinook that entered the north fishway in 2014, 54 exited back into the tailrace; of these 54 fish, 25 (46%) re-ascended and ultimately passed John Day Dam via the north fishway. Of the 59 spring Chinook jacks that entered the north fishway in 2014, 17 exited back into the tailrace; 10 of these 17 fish (59%) re-entered and passed the dam via the north fishway.

For adult summer Chinook salmon, exit ratios in previous years were generally higher than for adult spring Chinook salmon; summer ratios ranged 0.62-0.87 (mean 0.78; Table 15b, Figure 21). The 2014 estimate for Chinook summer adults was below this range (0.49), and the 2014 estimate for summer jacks (0.45) was also low. The mean post-modification exit ratio for adult summer Chinook salmon was 0.55, below the range observed in pre-modification years.

Exit ratios for adult summer Chinook during post-modification years were significantly lower than those of pre-modification years ($\chi^2 = 87.3657$, $P < 0.0001$). Of the 139 adult summer adult Chinook salmon that entered the north fishway in 2014, 68 exited back into the tailrace. Of these 68 adults, 37 (54%) re-ascended and ultimately passed the dam via the north fishway. Of the 69 summer Chinook jacks that entered the north fishway in 2014, 31 exited back into the tailrace; 10 of these 31 (32%) passed the dam via the north fishway.

Exit ratios at the lower north fishway in 2013 suggest that the modified opening, new bollard field and LPS inside the fishway opening did not result in increased turn-around behavior. Instead, it appears that the modifications may be associated with reduced fishway fallback for adult summer Chinook salmon. This is potentially due to the removal of the two lower weirs, but we could not specifically test for the mechanism.

Lower Fishway Passage Efficiency. To evaluate passage efficiency in the lower portion of the north fishway, we used detections at a series of additional antennas in the collection channel and transition area upstream from the overflow weir portion of the fishway (Figure 16). Lower fishway passage efficiency was estimated by dividing the number of unique detections on antennas 3, 4, and 5 by the number of unique detections of fish entering the fishway (Tables 15 and 16, Figure 22).

In pre-modification years, lower fishway passage efficiency from entry at antenna 2 to antenna 3 ranged 0.87-1.00 (mean 0.95) for adult spring Chinook salmon. In 2014, lower fishway efficiency in this segment was 0.99 (2013-2014 mean 0.99) for spring Chinook adults and 1.00 for spring Chinook jacks (2013-2014 mean 1.00). Lower fishway efficiency in this segment was significantly higher in post-modification than in pre-modification years for adult spring Chinook (χ^2 = 6.7939, P = 0.0091).

Efficiency from fishway entry to antenna 4 ranged 0.83-0.98 (mean 0.93) in pre-modification years. In 2014, efficiency in this segment was 0.96 for spring Chinook adults (2013-2014 mean 0.95) and 0.95 for jacks (2013-2014 mean 0.95). Lower fishway efficiency for adult spring Chinook in this segment was similar between pre- and pre-modification years (χ^2 = 2.4289, P = 0.1191).

Efficiency from entry to antenna 5 ranged from 0.61-0.89 (mean = 0.73) in pre-modification years. In 2014, estimates were 0.88 for spring Chinook adults (2013-2014 mean = 0.86) and 0.92 for spring Chinook jacks (2013-2014 mean = 0.92). Lower fishway efficiency for adult spring Chinook in this segment during post-modification years was significantly higher than in pre-modification years (χ^2 = 19.883, P < 0.0001).

In pre-modification years, lower fishway passage efficiencies from entry to antenna 3 ranged 0.91-1.00 (mean 0.96) for adult summer Chinook (Table 16, Figure 22). In 2014, fishway efficiency in this segment was 1.00 for summer Chinook adults and 0.97 for summer Chinook jacks. Lower fishway efficiency for adult summer Chinook in this segment during post-modification years was significantly higher than in pre-modification years (χ^2 = 10.4884, P = 0.0012).

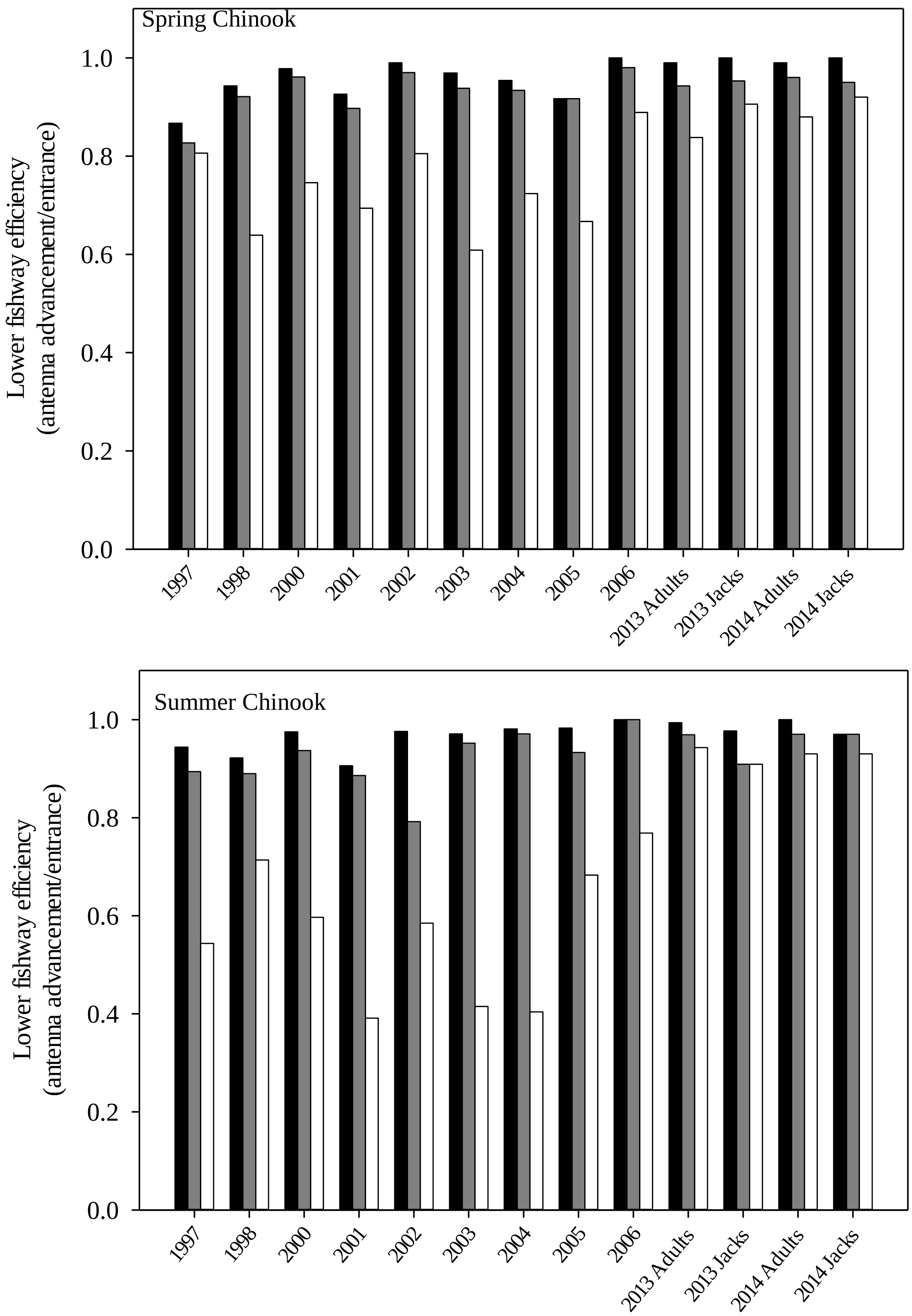

Figure 22. John Day north lower fishway efficiency for radio-tagged spring Chinook (upper panel) and summer Chinook salmon (lower panel). Black bars represent advancement to antenna 3 (transition pool), gray bars represent advancement to antenna 4, and white bars represent advancement to antenna 5.

Efficiency from fishway entry to antenna 4 ranged 0.79-1.00 (mean 0.92) in pre-modification years and was 0.97 for adults and 0.97 for jacks in 2014 (2013-2014 mean 0.97 and 0.94, respectively). Lower fishway efficiency in this segment was significantly higher for adult summer Chinook during post-modification years than during pre-modification years (χ^2 = 13.4999, P = 0.0002).

Efficiency from entry to antenna 5 ranged 0.04-0.77 (mean 0.57) in pre-modification years and was 0.93 for summer Chinook adults and 0.93 for summer Chinook jacks in 2014 (2013-2014 mean 0.94 and 0.92, respectively). Lower fishway efficiency in this segment was significantly higher during post-modification than during pre-modification years for adult summer Chinook (χ^2 = 163.8915, P < 0.0001).

In all cases, the 2013 and 2014 estimates and post-modification means exceeded or were near the high end of the range of estimates from previous years. These results suggested either a benefit or no adverse effects from modifications to the lower north fishway at John Day Dam. Consistently higher efficiencies to antenna 5 imply that removal of the lower weirs contributed to higher efficiencies through the transition area and into the ladder proper.

North Fishway Entrance Time. In pre-modification study years, median entrance time at the John Day north fishway ranged 8-47 minutes for adult spring Chinook (overall median 28 minutes; Figure 23). For spring Chinook salmon in 2014, median entrance time was 15 minutes for adults and 2 minutes for jacks. During post-modification years, overall median entrance time was 14 minutes for adults and 6 minutes for jacks. Kruskal-Wallis tests indicated a significant difference in medians between pre- and post-modification years (χ^2 = 78.1854, df = 1, ddf = 10, P < 0.0001). In a Kruskal-Wallis test restricted to adult vs. jack spring Chinook passage time during 2013-2014, jacks had faster approach-to-entry times (χ^2 = 12.4896, df = 1, ddf = 3, P = 0.0004).

In previous study years, median entrance time at the John Day north fishway has ranged 3-41 minutes (median 13 minutes; Figure 23) for summer Chinook adults. In 2014, median entrance time was 6 minutes for summer Chinook adults and 3 minutes for summer Chinook jacks. The overall median entrance time during post-modification years was 5 minutes for adults and 2 minutes for jacks. Results from a Kruskal-Wallis test indicated a significant difference between pre- and post-modification medians (χ^2 = 100.379, df = 1, ddf = 10, P < 0.0001). Summer jacks also had faster approach-to-entry times than summer adults (χ^2 = 5.0575, df = 1, ddf = 3, P = 0.0245).

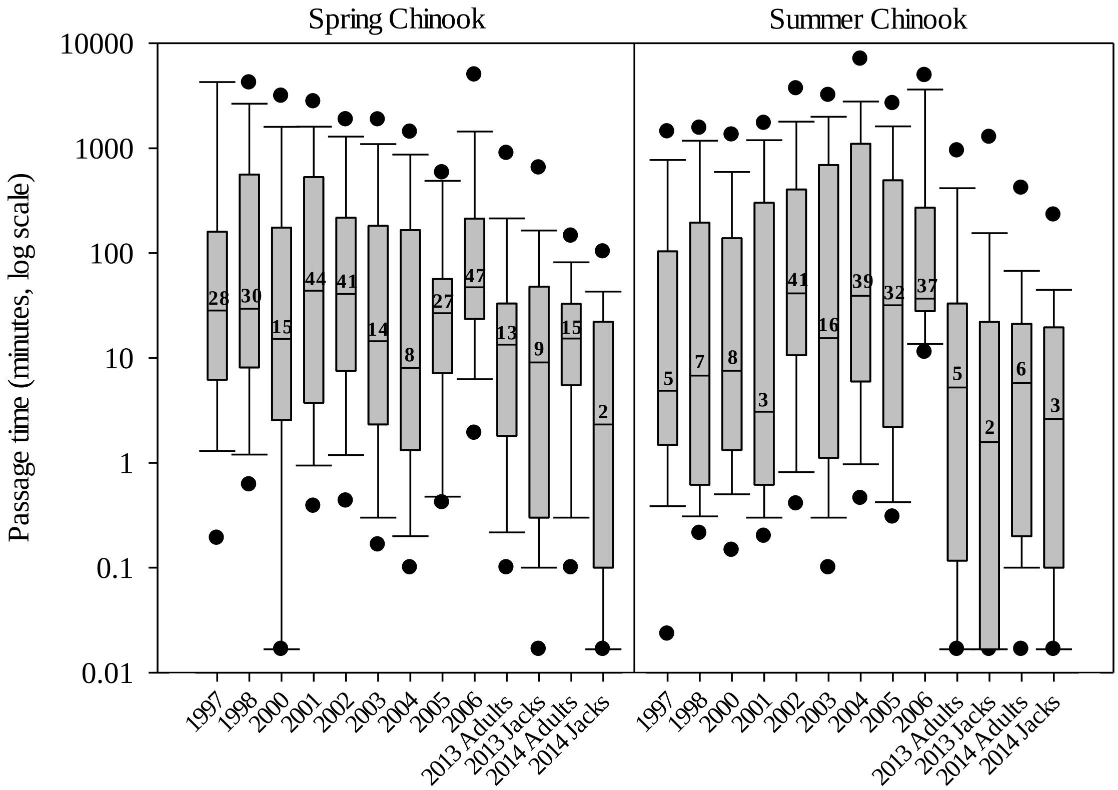

Figure 23. Spring and summer Chinook salmon passage time distributions (plotted on log scale) from approach to entry of the John Day north fishway in 1997-1998, 2000-2006 and 2013-2014. Distributions show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Numbers inside bars are median time in minutes.

These results indicate that modifications to the John Day north fishway did not result in passage delays or reduced median passage times for adult Chinook salmon in the entrance area.

Correlations between environmental conditions and entrance time for spring Chinook salmon at the John Day north fishway were weak, both during pre-modification years and in 2013 (Table 17). An exception was in 2001, when extremely low river flows and limited spill may have affected entrance time. In 2013, warmer water temperature was negatively correlated with entrance time for adults but not for jacks. For jacks, there were modest negative correlations in 2013 between passage time and river discharge, spill, and tailwater elevation; these correlations were not significant ($P > 0.05$).

Although no significant correlations were detected between environmental conditions and entrance time for spring Chinook adults in 2014, all environmental factors displayed significant negative correlations with passage time for jacks, with the strongest being temperature and flow. Rising spring temperatures may provide motivation or increase metabolic rates for spring Chinook salmon, and increased flow and spill also may increase attraction to the fishway. Date also had a strong negative correlation with passage time. When approach-to-entry times were considered for all years, a significant but relatively weak negative correlation was found between salmon passages times and all environmental conditions ($-0.29 \leq r \leq -0.11$).

Table 17. Correlation coefficients (*r*) between environmental conditions spring Chinook salmon encountered when they first approached the John Day north fishway and log transformed approach-to-entry times, by year. Shaded cells with bold typeface indicate $P < 0.05$.

Year	Flow	Spill	Tailwater elevation	Temperature	Date
1997	-0.03	-0.03	-0.04	0.01	-0.02
1998	-0.06	-0.02	-0.08	0.01	-0.06
2000	-0.08	-0.04	-0.12	**0.14**	**0.23**
2001	**-0.11**	**-0.16**	**-0.12**	**-0.26**	**-0.25**
2002	0.05	0.09	0.02	-0.10	-0.07
2003	-0.02	-0.11	<0.01	0.02	<0.01
2004	0.08	0.07	0.06	0.13	**0.17**
2005	-0.03	0.36	-0.25	-0.29	-0.41
2006	0.05	0.06	-0.01	0.13	**0.26**
2013					
Adults	-0.04	0.02	-0.01	**-0.33**	-0.03
Jacks	-0.22	-0.15	-0.20	0.04	0.09
2014					
Adults	-0.08	0.02	-0.17	-0.11	-0.05
Jacks	**-0.83**	**-0.57**	**-0.65**	**-0.83**	**-0.84**
All years	**-0.11**	**-0.15**	**-0.12**	**-0.29**	**-0.12**

For summer Chinook, correlations between approach-to-entry time and environmental conditions at the John Day north ladder were also weak during all pre-modification years except the unusually low-flow year of 2001 (Table 18). In 2013, water temperature and calendar date were negatively correlated with approach-to-entry times for adult summer Chinook. The same pattern was observed for 2013 summer jacks, but correlations were not significant ($P > 0.05$).

Significant correlations between all environmental conditions and approach-to-entry times were observed for both adult and jack summer Chinook. The strongest correlations for adults were positive associations with flow and spill. The strongest correlations for jacks were positive associations with spill and temperature. Increased flow and spill may energetically tax summer Chinook with extended passage times, especially when water temperatures are high. When approach-to-entry times were considered for all years, negative correlations were observed for all environmental variables ($-0.36 \leq r \leq -0.07$, except flow $r = 0.33$).

Table 18. Correlation coefficients (r) between environmental conditions encountered by summer Chinook salmon when they first approached the John Day north fishway and log-transformed entrance time, by year. Shaded cells with bold typeface indicate $P < 0.05$.

Year	Flow	Spill	Tailwater elevation	Temperature	Date
1997	<0.01	<0.01	-0.02	-0.03	-0.01
1998	0.02	0.04	0.02	-0.03	-0.04
2000	0.04	-0.07	0.06	-0.06	-0.01
2001	**0.19**	**0.15**	0.06	**-0.16**	**-0.17**
2002	0.07	0.03	0.10	0.01	<0.01
2003	0.07	0.10	0.05	**-0.15**	-0.13
2004	0.05	0.10	0.04	-0.10	-0.13
2005	**0.28**	**0.31**	0.14	**0.41**	**0.41**
2006	-0.17	<0.01	-0.31	0.28	0.23
2013					
Adults	-0.04	0.09	-0.05	**-0.22**	**-0.27**
Jacks	0.09	-0.04	0.04	-0.28	-0.25
2014					
Adults	**0.71**	**0.74**	**0.65**	**-0.53**	**-0.30**
Jacks	**-0.26**	**0.68**	**-0.30**	**0.54**	**0.65**
All years	**0.33**	**-0.36**	**-0.22**	**-0.35**	**-0.07**

Time from Entrance to Ladder Base. After radio-tagged spring Chinook salmon entered the north fishway, median time to reach antenna 3 near the ladder base ranged 1-8 minutes in pre-modification years. In 2014, median time from fishway entrance to ladder base was 2 minutes for adults and 4 minutes for jacks. During post-modification years (2013-2014), overall median time was 2 minutes for adults and 3 minutes for jacks. The shapes of distributions were similar to those in pre-modification years (Figure 24). Sample sizes for entrance-to-ladder-base metrics were slightly smaller than those for fishway entrance time because some fish did not reach the ladder antenna.

For summer Chinook salmon, median time from entrance to ladder base ranged 2-6 minutes in pre-modification years. Median time in 2014 was 2 minutes for both adults and jacks. Overall median time during post-modification years (2013-2014) was 2 minutes for both adults and jacks. Distributions were similar to those in earlier years (Figure 25). These results suggest that passage to the ladder base through the modified area (i.e., past bollards, new floor diffusers, and the LPS) was not slowed for adult or jack Chinook salmon.

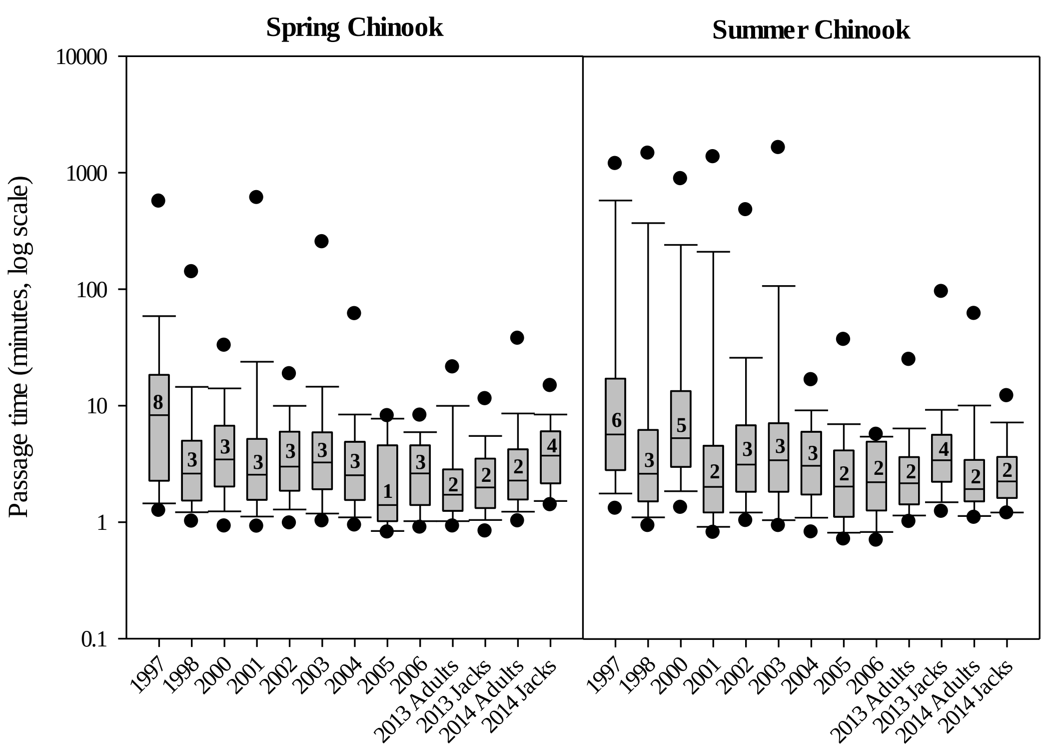

Figure 24. Spring and summer Chinook salmon passage time distributions (plotted on log scale) from entry to first transitional pool at the John Day north fishway. Distributions show 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles. Numbers inside bars are median time in minutes.

Extended Passage Time. As in pre-modification years, extended passage time was defined as that requiring more than 1 h for either entrance time (first approach to first fishway entrance) or entrance to ladder base (first fishway entrance to first detection at the ladder base). We calculated the percentages of radio-tagged spring and summer Chinook salmon with extended passage timing through either of these segments.

Over 9 previous study years at the John Day north fishway, fishway entrance time exceeded 1 h for 17-48% (mean 38%), and time from entrance to ladder base exceeded 1 h for 0-10% (mean 5%) of these of radio-tagged adult spring Chinook (Figure 25). In 2014, north fishway entrance time exceeded 1 h for 13% and entrance to ladder base exceeded 1 h for 4% of adult spring Chinook. During post-modification years, extended passage time was required for 13.5% of these fish from approach to entry and for 3.5% from entrance to base of the ladder. Both percentages were below the mean for pre-modification years.

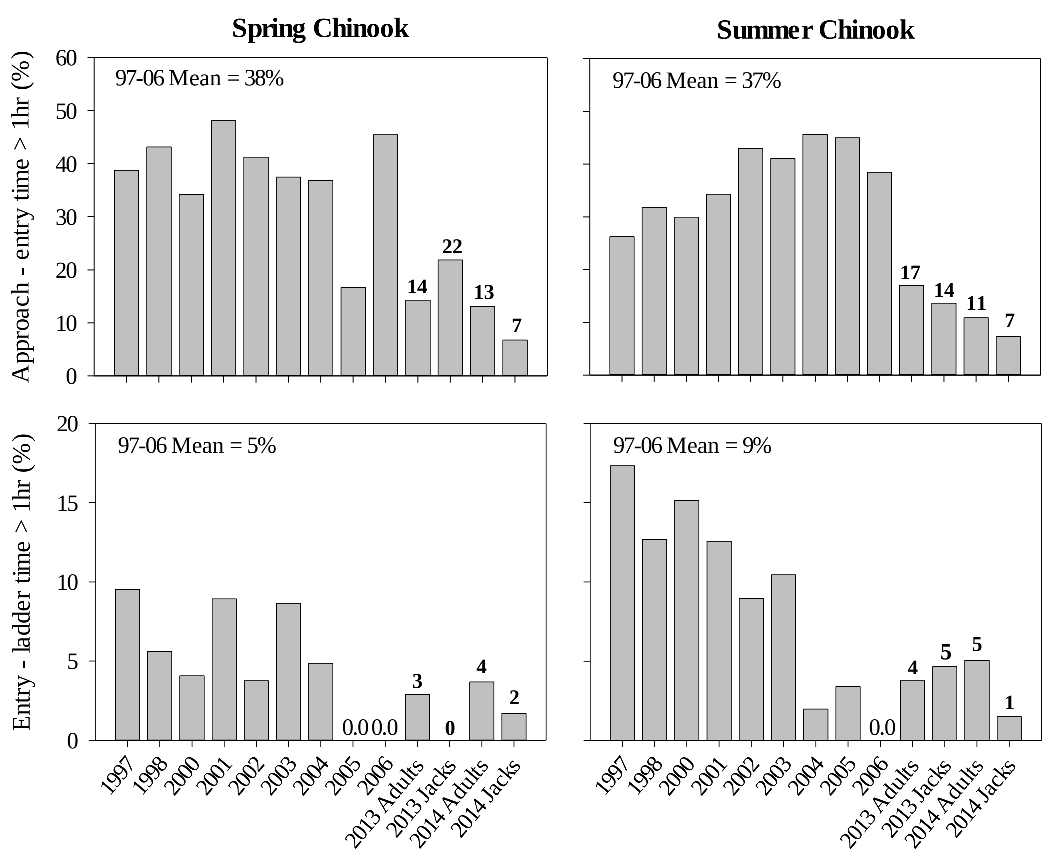

Figure 25. Percentages of radio-tagged spring and summer Chinook salmon that took more than 1 h to pass from the John Day north fishway approach to fishway entrance (top) and from entrance to the base of ladder antenna (bottom). Numbers above bars indicate number of fish with extended passage time.

For spring Chinook jacks in 2014, entrance time exceeded 1 h for 7% of fish, and only one fish (2%) exceeded 1 h for entrance to ladder base. Post-modification means for extended passage of these jacks were 14.5% from approach to entry and less than 1% from entrance to ladder base.

During pre-modification years, entrance time exceeded 1 h for 26-46% (mean 37%) of summer Chinook salmon, while entrance to ladder base time exceeded 1 h for 0-17% (mean 9%) of these fish (Figure 25). In 2014, 11% of adults required more than 1 h to traverse from approach to the north fishway entrance, and 5% took over 1 h to travel from the fishway entrance to the ladder base of the north fishway (14% and 4.5% respectively for 2013-2014 on average). Both of these values were below pre-modification means. In 2014, respective entrance time and entrance to ladder base time exceeded 1 h for 7 and 1% (one fish) of summer Chinook jacks. Post-modification means for these jacks were 10.5% for approach to entry and 3% for entrance to base of the ladder.

North Ladder Passage Time. North fishway ladder passage time was calculated from first detection within the ladder (at AJD-5) to last detection at the ladder top (7JD-1). For adult spring Chinook during pre-modification years, median passage time ranged 133-193 minutes (overall median 190 minutes; Figure 26) within this segment. In 2014, median north ladder passage time was 150 minutes for spring Chinook adults and 160 minutes for jacks. During 2013-2014, overall median passage time for the north ladder was 164 minutes for adults and 163 minutes for jacks.

Kruskal-Wallis tests indicated a difference in median passage times between pre- and post-modification years ($\chi^2 = 50.7809$, df = 1, 10, $P < 0.0001$). In a Kruskal-Wallis test comparing 2013-2014 adults and jacks, jacks took longer to pass the north ladder than adults ($\chi^2 = 9.8369$, df = 1, 3, $P = 0.0017$), a result that was driven by rapid passage of adults in 2013.

For summer Chinook salmon during pre-modification years, median north ladder passage time ranged from 127 min in 1998 to 222 min in 2002 (overall median 227 minutes; Figure 26). In comparison, median north ladder passage times for these fish in post-modification years were 203 min for 2014 adults and 174 min for 2014 jacks. The mean of median passage times for was 207 minutes for adults and 167 minutes for jacks in 2013-2014. Post-modification median ladder passage time was significantly lower than the pre-modification median ($\chi^2 = 8.1287$, df = 1, 10, $P = 0.0044$). In contrast to spring, summer jacks also had faster ladder passage times than summer adults ($\chi^2 = 8.4265$, df = 1, 3, $P = 0.0037$).

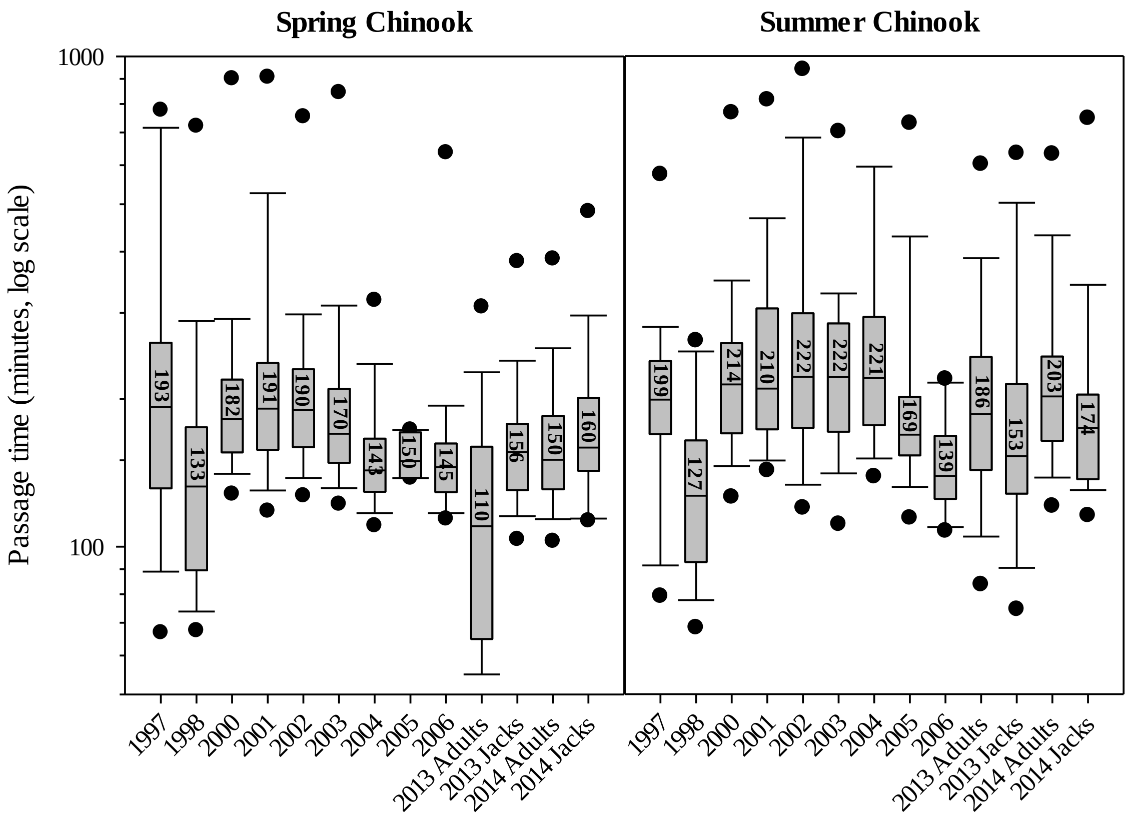

Figure 26. Spring and summer Chinook salmon passage time distributions (plotted on log scale) from antenna 5 to the top of the ladder at John Day north fishway in 1997-1998, 2000-2006 and 2013-2014. Distributions show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Numbers inside bars are median time in minutes.

These results suggest that recent modifications to the John Day north ladder have not adversely affected Chinook salmon passage times and rather reduced ladder passage times.

Passage Metrics for Sockeye Salmon

Dam-Wide Efficiency Metrics—Dam-wide entrance efficiency (entrances/approaches) estimates for sockeye salmon were 0.99 in both 2013 and 2014 (Table 19). Fishway passage efficiency was 0.99 in 2013 and 0.98 in 2014, and dam passage efficiency was 0.99 in 2013 and 0.97 in 2014 for sockeye salmon. For these fish during both years, mean entrance efficiency was 0.99, mean fishway passage efficiency was 0.99, and mean dam passage efficiency was 0.98.

Table 19. Numbers of radio-tagged sockeye salmon that approached, entered, and exited fishways at John Day Dam, the numbers that passed the dam, and calculated dam-wide fishway entrance, fishway passage, and dam passage efficiency metrics in 2013-2014.

	Dam-wide (unique n)				Dam-wide efficiencies		
	Approached	Entered	Exited to tailrace	Passed dam	Entered/ approached	Passed/ entered	Passed/ approached
2013	325	324	150	322	0.99	0.99	0.99
2014	330	327	142	321	0.99	0.98	0.97

North Fishway Passage Metrics—***Proportionate Use of the North Fishway***. Of the 325 sockeye salmon that approached the dam in 2013, 221 (68%) were recorded approaching and 207 (64%) were recorded entering the John Day north fishway at least once (Table 20). These percentages were slightly higher, but comparable, to approach and entrance efficiencies found for sockeye salmon in 2014 (55 and 44%, respectively). For both years, the mean percentage of total radio-tagged sockeye approaching the north fishway was 61.5%. The mean percentage of total radio-tagged sockeye entering the north fishway was 59%.

North Fishway Entrance Efficiency. Entrance efficiency estimates for sockeye salmon were 0.94 in 2013 and 0.97 in 2014 (Table 21, Figure 27a). Mean entrance efficiency at the John Day north fishway for sockeye was 0.96.

Table 20. Numbers and proportions of radio-tagged sockeye salmon that approached and entered the John Day north fishway and that passed the dam via the north fishway in 2013-2014.

	Radio-tag detections John Day north fishway					
	Unique fish (n)			Proportion of dam-wide detections (%)		
	Approached	Entered	Passed	Approached	Entered	Passed
2013	221	207	179	0.68	0.64	0.54
2014	181	176	156	0.55	0.54	0.49

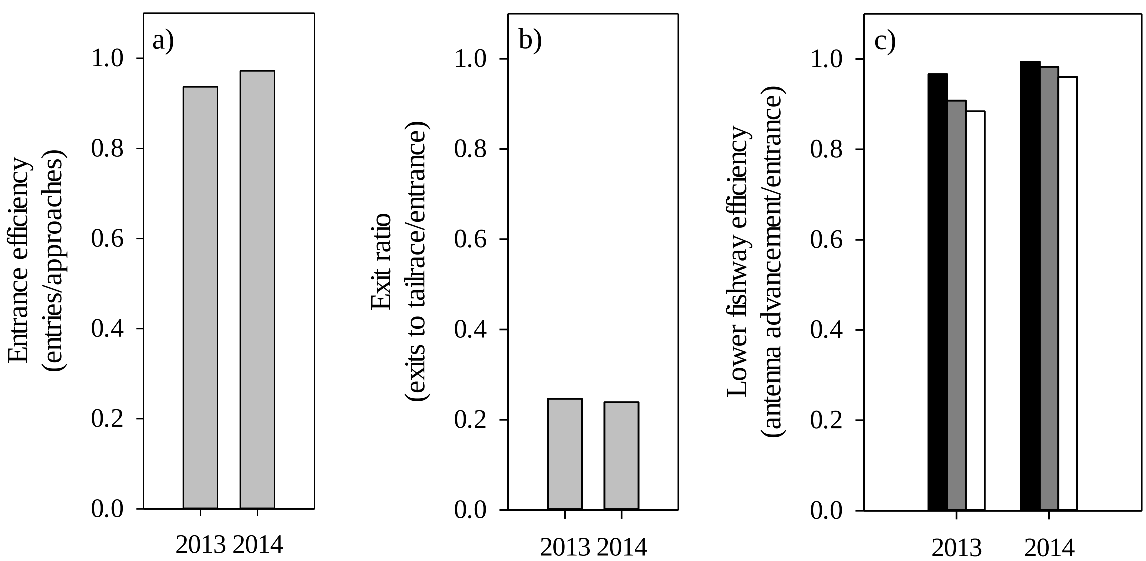

Figure 27. Unique fish entrance efficiencies (a), exit ratios (b), and collection channel efficiency (c) for radio-tagged sockeye salmon at the John Day north fishway in 2013-2014. For collection channel efficiency (c), black bars represent advancement to antenna #3 (transition pool), gray bars represent advancement to antenna #4, and white bars represent advancement to antenna #5.

North Fishway Exit Ratio Of the 207 sockeye salmon that entered the John Day north fishway in 2013, 51 exited back into the tailrace (0.25; Table 21, Figure 27b). Of these 51 fish, 23 (45%) re-ascended and ultimately passed the dam via the north fishway. In 2014, 42 of the176 sockeye salmon that entered this fishway exited back into the tailrace (0.24; Table 21, Figure 27b). Of these 42, 22 (52%) re-entered at the north fishway and passed John Day dam. The mean exit ratio for sockeye salmon was 0.25.

Lower Fishway Passage Efficiency. To evaluate passage efficiency in the lower fishway, we used detections at the series of additional antennas in the collection channel and transition area up the overflow weir portion of the fishway (see Figure 16). Lower fishway efficiency was estimated as the number of unique fish detected sequentially at antennas 3, 4, and 5 divided by the number of unique fish that entered the fishway. We calculated lower fishway efficiency to evaluate salmon passage through the lower portion of the John Day north fishway (Tables 21 and 22, 27c).

Table 21. Numbers of unique sockeye salmon that approached and entered the John Day North fishway, exited to the tailrace, were detected at antennas 3, 4, and 5 inside the north ladder, and passed the dam via the north fishway in 2013-2014. See Figure 16 for antenna locations.

	Sockeye passage events at John Day north lower fishway									
	Detections of unique fish (n)							Total events (n)		
				Antenna no.			Passed			
	Approach	Enter	Exit	3	4	5	dam	Approach	Enter	Exit
2013	221	207	51	200	188	183	179	1,137	671	313
2014	181	176	42	175	173	169	156	1,109	636	277

Table 22. Entrance efficiencies, exit ratios, collection channel efficiencies at antennas 3, 4, and 5 inside the north ladder, and total fishway passage efficiencies of unique sockeye salmon via the north fishway in 2013-2014. See Figure 16 for antenna locations.

	Sockeye passage metrics at John Day lower north fishway							
	Entrance efficiency		Exit ratio		Collection channel efficiency			Fishway passage efficiency
	Unique (n)	Total	Unique (n)	Total	Antenna 3	Antenna 4	Antenna 5	
2013	0.94	0.59	0.25	0.47	0.97	0.91	0.88	0.86
2014	0.97	0.57	0.24	0.44	0.99	0.98	0.96	0.89

Lower fishway efficiency from entry (at antenna 2) to antenna 3 for 2013 sockeye salmon was 0.97. Lower fishway efficiency from entry to antenna 4 for 2013 sockeye salmon was 0.91 and was 0.88 from entry to antenna 5. In 2014, lower fishway efficiency for sockeye salmon from entry to antennas 3, 4 and 5 were 0.99, 0.98, and 0.96, respectively. Mean lower fishway efficiencies for sockeye from entry to antennas 3, 4, and 5 were 0.98, 0.95, and 0.92 respectively.

North Fishway Entrance Time. The median John Day north approach-to-entry time for sockeye salmon was less than 1 min in both years (Figure 28a). Correlations between sockeye salmon approach-to-entry times at the John Day north fishway and environmental conditions were generally weak in both years (Table 23).

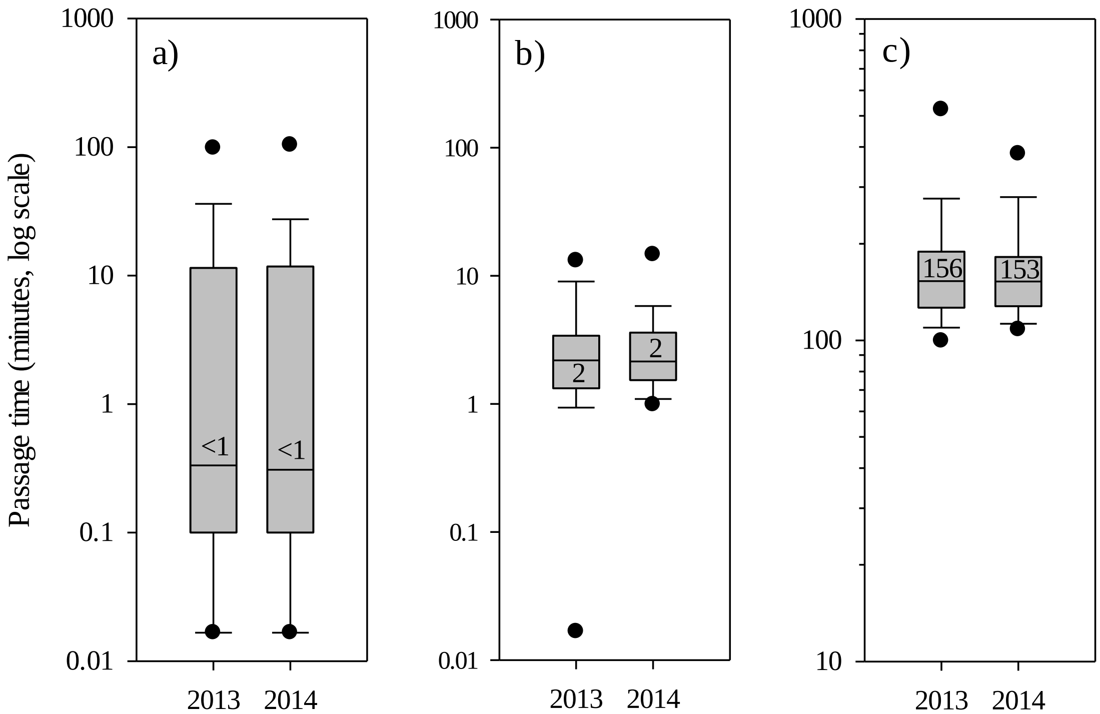

Figure 28. Sockeye salmon passage time distributions (plotted on log scale) from fishway approach to fishway entry (a), entry to first transitional pool (b), and from antenna 5 at John Day north to top-of-ladder (c) at the John Day north fishway in 2013-2014. Distributions show 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles. Numbers inside bars are median times, in minutes. Note differences in scale.

Table 23. Correlation coefficients (*r*) between environmental conditions sockeye salmon encountered when they first approached the John Day north fishway and log-transformed approach-to-entry times, by year. Bold indicates $P < 0.05$.

	Year vs. environmental variable (*r*)				
Year	Flow	Spill	Tailwater elevation	Temperature	Date
2013	<0.01	-0.06	-0.12	**-0.17**	**-0.17**
2014	0.04	0.07	0.01	-0.09	**0.17**
All years	0.02	<0.01	-0.06	**-0.12**	0.02

A significant negative correlation was observed between approach-to-entry times in 2013 and temperature; no significant relationship with temperature was observed in 2014. When approach-to-entry datasets from both years were combined, there was a weak but significant negative correlation with temperature (r = -0.12). The relationships between date and passage time were mixed between years; when data from both years were pooled, there was no significant relationship between passage times and date.

Time from Entrance to Ladder Base. After radio-tagged sockeye salmon entered the John Day north fishway, median time to reach the antenna near the ladder base (antenna 3) was 2 min in both 2013 and 2014 (Figure 28b). Sample sizes for the entrance-to-ladder base metrics were slightly smaller than those for fishway approach-to-entry because some fish did not reach the ladder antenna.

Extended Passage Time. In 2013, 6% of sockeye salmon took over 1 h from the John Day north approach to the entry, and 2% took more than 1 h to travel from the entrance to the base of the ladder (Figure 29). In 2014, 6% of sockeye salmon took >1 h from the John Day north approach to the entry, and none took more than 1 h to travel from the entrance to the base of the ladder. On average, 6% of sockeye exhibited extended passage times for approach to entry and 1% exhibited extended passage times for entrance to base of the ladder during 2013 and 2014.

North Ladder Passage Time. Median ladder passage time (from the first detection at AJD-5 to the last detection at the ladder top at 7JD-1) was 156 min for 2013 sockeye salmon and 153 min for 2014 sockeye (Figure 28c). The mean of the medians was 155 min.

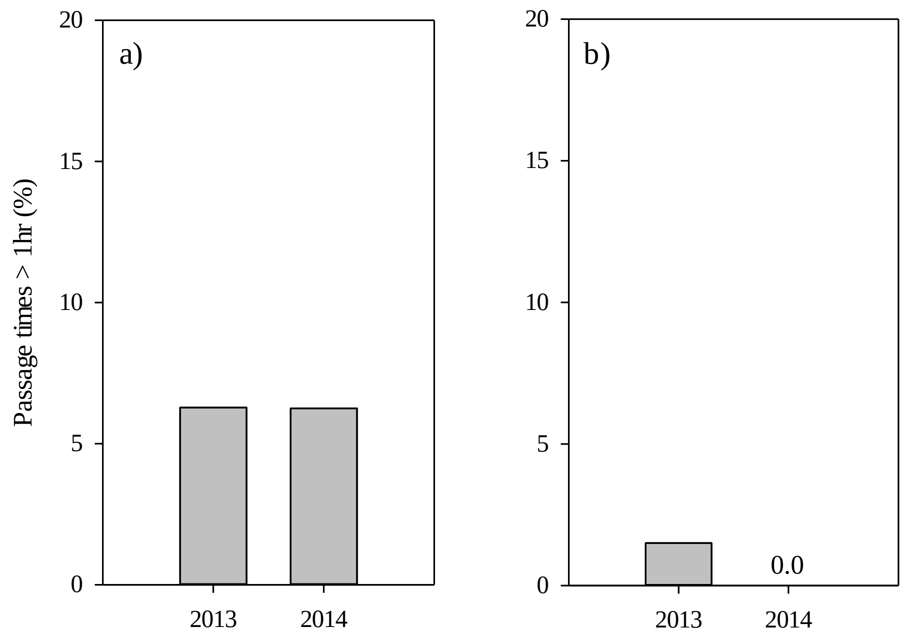

Figure 29. Percentages of radio-tagged sockeye salmon that took >1 h to pass from the John Day north fishway approach to fishway entrance (a) and from entrance to the base of ladder antenna (b) in 2013-2014.

Discussion

Primary objectives of the evaluation were to test for any negative effects of modifications to improve passage for lamprey and adult salmon in and near the John Day north fishway opening, and to evaluate effects on adult Chinook salmon passing the modified upper north ladder. Due to logistical constraints (e.g., winter de-watering schedules), several lower fishway modifications were conducted simultaneously. During winter 2011-2012 and 2012-2013, the entrance weir was rebuilt, bollards were installed, two concrete weirs were removed in the transition area, new diffuser grating was installed in the lower fishway, and a new lamprey passage structure was installed.

Modifications near the entrance had the potential to affect salmonid behavior by changing the hydraulic and/or olfactory environment at the opening or in the attraction plume outside the fishway opening. The variable-width weir had the highest potential to affect hydraulics outside the opening. Bollards placed inside the fishway opening were designed to reduce velocity and increase turbulence near the bottom for Pacific lamprey. To a lesser degree, these bollards could potentially affect flow conditions outside the opening by decreasing mean velocity or increasing turbulence in the lower layer of the attraction plume.

Installation of the lamprey passage structure was not expected to substantially affect hydraulic conditions. However, all modifications in the fishway opening could potentially affect the olfactory environment, particularly in the first year after installation. Lamprey have been observed to more readily use new structures as they become "seasoned" through leaching of fabrication coatings and the accumulation of biofilms.

In the transition area, removal of the two weirs was intended to improve attraction flow (e.g., Naughton et al. 2007). Modifications within the upper section of the north ladder also had the potential to affect salmonid behavior and passage by altering flows and/or the olfactory environment. These modifications included the removal and construction of new concrete weirs, modifications to concrete baffles, and modifications around the count window (replacement of existing bulkhead, picket leads, crowder, and light box and addition of a window washer).

All of the John Day north fishway modifications were non-experimental and could not be evaluated independently. Consequently, this evaluation relied on a post-hoc observational approach to assess the combined effects of all the modifications simultaneously by comparing passage metrics at the John Day north entrance to those during pre-modification years.

Entrance and lower fishway passage efficiencies for post-modification runs of Chinook salmon (2013-2014) indicated no adverse effects from north fishway modification. Entrance efficiencies in 2013 and 2014 for both spring- and summer-run adult Chinook were at the high end of the pre-modification range or above. These results suggest that the introduction of a variable-width weir did not deter Chinook salmon from entering the north fishway. Indeed, installation of the new weir and closure of the northern fishway entrance to the John Day north fishway may have improved attraction and guidance into the fishway compared to the pre-modification condition.

Fishway exit ratios in 2013 and 2014 were also within the range of pre-modification values for both spring and summer-run adult Chinook salmon. In 2013 and 2014, spring and summer jack Chinook salmon had high entrance efficiencies and very low exit ratios. Low rates of exit back into the tailrace after entering the fishway in 2013-2014 suggests that the entrance weir, bollard field, and lamprey passage structure had little or no negative effects on Chinook salmon passage near the John Day north fishway entrance area. The general positive effects provided no evidence that the new structures inhibited salmon through olfactory cures.

Farther up the north ladder in the lower fishway, post-modification passage efficiencies were within pre-modification ranges or higher. For both spring and summer run Chinook salmon (adults and jacks), post-modification passage efficiencies to antennas 3 and 4 were comparable to those in previous years. Post-modification efficiencies past antenna 5 were higher than in previous years. Removal of the concrete weirs within the lower north fishway seems to have had no adverse effects on Chinook passage through these segments in 2013 and 2014. Rather, the data suggest potential benefits of improved hydraulics in the transition area (e.g., Naughton et al. 2007).

In the entrance area, both passage time metrics (approach-to-entry and entrance-to-base-of-ladder) suggested no negative effects of the recent modifications to the John Day north ladder entrance area. Post-modification entrance-to-base-of-ladder times remained consistent with salmon passage times from pre-modification years. Furthermore, approach-to-entry times were faster in 2013-2014 for both spring- and summer-run adults, and were also rapid for jack Chinook salmon.

The prevalence of extended passage times (> 1 h) in both 2013 and 2014 were also below pre-modification means for both approach-to-entry and entrance-to-ladder-base times. These findings further suggest that the variable-width weir, closure of the north opening, and any alteration of the olfactory environment, did not have a detrimental effect on entrance of Chinook salmon into the John Day north fishway.

Because of relatively little difference in entrance-to-base-of-ladder times across years, we also conclude that the hydraulic effects of the floor-mounted bollards and the new lamprey passage structure inside the north fishway had little or no effect on salmon passage behavior under the conditions fish encountered during the study.

Modifications farther up the John Day Dam north fishway also showed no evidence of slowing Chinook salmon passage. Ladder passage times (from antenna AJD-5 to top-of-ladder) for both spring and summer Chinook were slightly faster during post-modification years than during pre-modification years. These results indicate that the combined modifications to the upper north fishway had little or no negative effect on Chinook salmon passage. Our results support the findings of Jepson et al. (2011), who also found that modifications around the John Day north count window had no adverse effects on spring and summer migrants.

We found some evidence for an age effect in Chinook salmon (adults vs. jacks) in the John Day north fishway in 2013-2014. Entrance efficiencies were slightly higher for jack Chinook salmon, and jacks had significantly faster entrance area passage times than adults during the spring and summer runs in 2013-2014. Exit ratios were also considerably lower for spring and summer jacks than for adults in 2013. However, differences in exit ratios between age classes were less pronounced in 2014. Ladder passage times (from lower ladder to top-of-ladder) were significantly faster for adult Chinook salmon than for jacks in the spring of 2013-2014, but summer-run jacks had faster ladder passage times than summer adults.

Previously we cautioned against drawing conclusions based on one year of post-modification data that show improvement, given the large interannual variation in river conditions and operations. After collecting additional post-modification data in 2014, however, we are more confident in concluding that the bollards, lamprey passage structure, variable-width weir, lower fishway weir removals, and ladder modifications did not appear to appreciably impede salmon passage. In fact, these modifications appear to offer some passage benefits (i.e., increased entrance efficiencies) for adult Pacific lamprey (Clabough et al. 2011; Kirk et al. 2014).

The sockeye salmon passage metrics estimated in 2013 and 2014 also support our conclusions. While there is limited pre-modification sockeye salmon data for comparison, results from our analysis indicated that passage times and efficiencies for sockeye salmon were equal to or faster than those for Chinook salmon in the post-modification years. We note that environmental conditions were near long-term averages in 2013 and 2014, and salmon behavior may be different in years with unusual river conditions.

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