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An Evaluation of Adult Chinook Salmon and Steelhead Behavior at the North-shore Counting Window of Lower Monumental Dam using Radiotelemetry: 2004

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Abstract

We used radiotelemetry to evaluate the behavior of adult steelhead and spring, summer, and fall Chinook salmon swimming past the counting window and its first upstream pool in the north-shore fishway at Lower Monumental Dam during 2004. We combined spring and summer Chinook runs for these analyses. Salmon and steelhead used for this evaluation were outfitted with radio transmitters at either Bonneville or Ice Harbor Dam.

The median time to pass the counting window for all radio-tagged fish was 14.3 min (*n* = 325) but the median passage times for runs released from Ice Harbor Dam were consistently higher than for runs released from Bonneville Dam. The median time to pass the pool upstream from the window for all radio-tagged fish was 3.8 min (*n*=321). The median time to pass the counting window and upstream pool combined was 18.9 min (*n*=324). On median, passing the counting window and upstream pool combined accounted for 3.5% of total dam passage times for fish with complete sets of detections (tailrace, downstream from window, upstream from pool, and ladder exit) and the median dam passage time for these fish was 10 h (*n*= 298).

Slightly more than four percent of radio-tagged fish were recorded swimming downstream to a transition pool after being detected immediately downstream from the window (*n*=349). The median time to pass the north-shore window for these fish (with complete sets of detections) was 1,181 minutes, or approximately 19.7 h (*n* = 10). Approximately four percent of all radio-tagged fish exhibited up-and-back behavior at the counting window (*n*=349). Spring–summer Chinook salmon exhibited the highest percentage of up-and-back behavior among the runs (8.7%, *n*=150). The maximum window passage time for any spring–summer Chinook salmon which exhibited up-and-back behavior was 40.3 min. Four steelhead exhibited up-and-back but we do not believe their downstream movements were directly attributable to the window or pool.

Radio-tagged salmon and steelhead initially recorded downstream from the counting window at night had higher median counting window passage times than fish initially recorded there during the day. Analyses assessing the degree of association between counting window passage times and total dam passage times suggested the correlations were positive, but weak. Linear regression models using median weekly passage times as dependent variables and mean daily fish counts (during corresponding weeks) as predictors suggested that effects of high fish abundance on counting window or weir passage times were small.

We conclude that one can expect a relatively small percentage of adult migrants to swim downstream after being detected at a counting window or in its upstream pool (and thereby have relatively higher total dam passage times) but it is unclear as to what steps might be taken to minimize these events since no window or pool modifications were experimentally evaluated for this study.

Introduction

Radiotelemetry techniques can be used to identify potential impediments to adult salmonids as they migrate upstream past Snake River dams, including the counting windows in dam fishways. Counting windows are passage points that may create a discontinuity in fishway conditions such that upstream movements of fish are inhibited. Fish have been observed by counters to occasionally swim upstream and then downstream from counting windows (‘up-and-back’ behavior) and to hold for extended periods at counting windows. Moreover, the crowding of fish near counting windows, particularly during periods of high fish abundance, may elicit an avoidance response in some fish.

The Federal Columbia River Power System Biological Opinion Action 117 (NMFS 2000) states “The Corps shall evaluate adult count station facilities…to either minimize delay of adults or minimize counting difficulties that reduce count accuracy.” USACE (2003) states that delay of adult fish is believed to be a problem at the north-shore count station at Lower Monumental Dam although delay is not clearly defined in the report. USACE speculates this may be due to: 1) an eddy in the pool immediately upstream from the count window, 2) adult shad tend to stack up in the pool, 3) there is a right-angle bend in the ladder from that pool to the next upstream pool - all other ladders at Walla Walla District dams are "straight" near the count station, 4) the first pool upstream from the count station is mostly open to sunlight whereas the next upstream pool is shaded - no other ladders have such a light-to-shade transition near the count window.

In response to concerns of the U.S. Army Corps of Engineers, we installed a receiver and deployed underwater antennas upstream and downstream from the counting window of the north-shore fishway of Lower Monumental Dam during 2004. We evaluated the behavior of radio-tagged spring–summer Chinook salmon, fall Chinook salmon, and steelhead detected downstream from the counting window and its upstream pool to assess whether adult salmon passage was hindered in this section of the fish ladder.

Methods

We collected adult steelhead and spring, summer, and fall Chinook salmon in the Adult Fish Facility adjacent to the Washington-shore at Bonneville Dam throughout the migration of each species during 2004. During the day, a picketed lead weir was dropped into the ladder and adult migrants were unselectively diverted into the trap. Fish swam from the trap into exit chutes and were diverted into an anesthetic tank [20 mg/l clove oil] (Peake 1998) via electronically-controlled guide gates. Anesthetized fish were moved to a smaller tank where lengths, marks and injuries were recorded, and where fish were tagged.

We additionally trapped and tagged 100 adult Chinook salmon and 100 steelhead at Ice Harbor Dam as part of a separate study designed to evaluate the relationship between river temperatures during salmonid migrations, gametogenesis, and spawning success. We lowered picket screens into the fishway near the top of the south-shore ladder which guided fish through to the main trap. Pneumatically-controlled gates, operated by an individual in a floating booth adjacent to the trap, were used to capture fish. Trapped fish were diverted to a separate holding cage and the cage was lifted over an aerated transport tank on the forebay deck which received trapped fish via a canvas sleeve in the bottom of the holding pen. The holding pen contained a solid bottom that retained water, ensuring that trapped fish were submerged at all times during the transfer. The trailer was driven to the juvenile fish facility where fish were transferred via rubber nets to an anesthetic tank containing 20 ppm clove oil (Peake 1998). Once sedated, fish were transferred to a smaller tank where lengths, marks and injuries were recorded and where fish were tagged.

A radio transmitter dipped in glycerin was inserted into the stomach through the mouth of each fish tagged at either Bonneville or Ice Harbor Dam. We used 3- and 7-volt transmitters developed and supplied by Lotek Wireless (Newmarket, Ont.), that emitted a digitally-coded signal (containing the frequency and code of the transmitter) every 5 s. Some fish trapped at Ice Harbor Dam were outfitted with Data Storage Tags (DSTs), which additionally recorded temperature and pressure (converted to depth) during the fish's migration. All fish tagged at Ice Harbor Dam had a temperature recorder sutured to the base of their dorsal fin. All transmitters were cylindrical with 43-47 cm antennas. Seven volt tags weighed 29 g in air (8.3 by 1.6 cm), three volt tags weighed 11 g in air (4.3 by 1.4 cm), and DSTs (9.0 by 2.0 cm) weighed 34 g in air. Code sets allowed us to monitor up to 212 fish on each frequency. Lithium batteries powered the transmitters which had a rated operating life of more than nine months. We used passive integrated transponder (PIT) tags as secondary tags. After tagging, fish were placed in an aerated transport tank where they were held until release. Fish tagged at Bonneville Dam were released approximately nine kilometers downstream from the dam on either side of the river or back into the Washington-shore fish ladder. Fish tagged at Ice Harbor Dam were released into the juvenile bypass flume which routed them to the dam tailrace.

We deployed underwater antennas immediately downstream and upstream from the counting window, and upstream from the first pool above the counting window (Figure 1). We calculated the window passage time of individual fish as the difference in time between the first record on the antenna immediately downstream from a counting window and the first record on the antenna upstream from a counting window, provided the fish eventually passed the dam after passing the north-shore counting window. This calculation was designed to account for the time spent by some fish swimming upstream and then downstream from the counting window as part of the total window passage time. We similarly determined the time fish used to swim from the antenna immediately upstream from the counting window past the upstream pool. Specifically, we calculated the difference in time between the first detection on the antenna upstream from the window to the last detection on the antenna upstream from the pool. All uses of the term 'pool' in this report refer to the pool upstream from the north-shore counting window and any reference to transition pools are qualified as such. We calculated counting window and pool passage times as proportions of total dam passage times (first record in tailrace to last record at ladder exit) by dividing passage times of individual fish by the total dam passage times for those same fish.

Passage times for some fish did not accurately represent the amount of time used strictly to pass either the window or pool. Because of the way we defined passage times, the 'clock' started when a fish was first detected on the antenna downstream from either a window or the pool. Until a fish passed the window or pool and stayed 'passed', the clock ran. This meant the time fish used swimming downstream to transition pools (or anywhere else) after swimming to the counting window was included in the counting window or pool passage time. Because

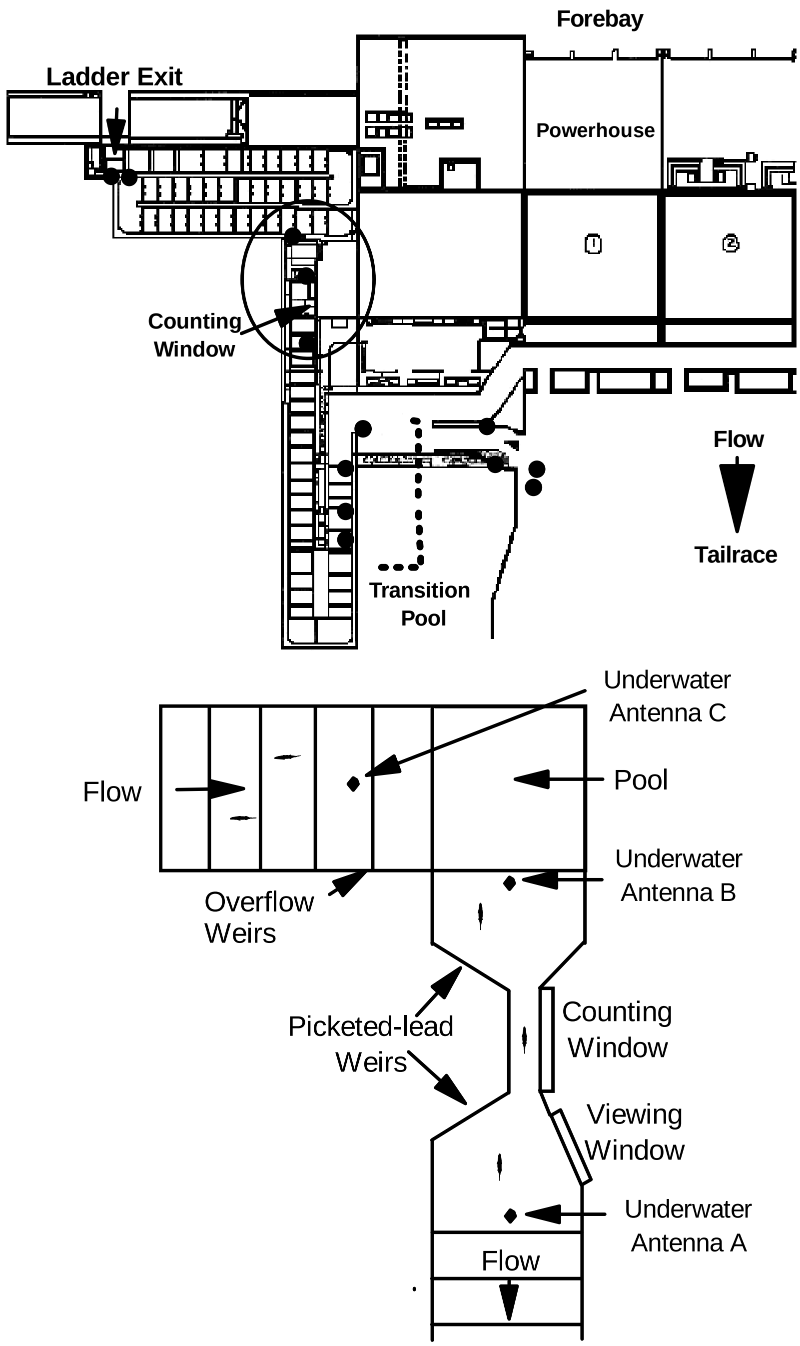

Figure 1. Aerial view of counting window and upstream pool in relation to transition pool (upper panel) and position of underwater radio antennas (indicated by closed circles and labeled A, B, and C) deployed near the counting window and upstream pool of the north-shore fishway at Lower Monumental Dam during 2004 (lower panel).

passage times were based on first detections at antennas downstream from either the counting window or upstream pool, fish exhibiting up-and-back behavior could have passage time 'clocks' running for both segments (count window and pool) simultaneously. We adopted this approach because we believed it allowed for maximal estimates of both counting window and pool passage times. To this extent, we believe it was the most conservative approach for assessing any negative effects associated with either the window or pool. In all cases, we excluded counting window passage times associated with fish reascending the dams after they had fallen back.

We used correlation analyses (Zar, 1999) to evaluate the degree of association between counting window or pool passage times and total dam passage times. Finally, we used linear regression (Zar, 1999) to evaluate any effects of ladder-specific fish counts on counting window and pool passage times. Specifically, we grouped radio-tagged fish with similar passage dates for the north-shore fishway using weekly blocks, weighed each block by the number of radio-tagged fish within that block, and used weekly median passage times as the dependent variable. The independent variable was the daily mean fish count (all species counted) for the north-shore fishway during corresponding weeks. Ladder-specific fish count data for this analysis were obtained from Larry Beck, U.S. Army Corps of Engineers.

In all analyses, we used dates accepted by the USACE to separate between spring, summer, and fall-run fish at Bonneville or Ice Harbor dams and combined spring and summer Chinook salmon for these analyses. Fish kept their run designation from Bonneville or Ice Harbor Dam regardless of the date of passage at Lower Monumental Dam.

Results

Outages

There were three outages at the receiver deployed to monitor radio-tagged salmon and steelhead behavior near the north-shore counting window of Lower Monumental Dam during 2004. The three outages combined for a total of 16.8 days without monitoring (Table 1). Inferred from detections at upstream antennas, counting window and pool passage data were not collected for at least 31 spring–summer Chinook salmon as a result of these outages.

Table 1. Dates, times, durations, and causes of receiver outages while monitoring the north-shore counting window at Lower Monumental Dam during 2004.

Outage Start	Outage End	Duration (d)	Cause
21 May – 11:03	26 May – 15:45	5.2	Power strip breaker tripped
28 May – 04:00	2 June – 12:00	5.3	Power strip breaker tripped
1 July – 10:00	7 July – 15:23	6.2	Receiver unplugged

Passage Times

Counting Window

The median time to pass the north-shore counting window at Lower Monumental Dam for all radio-tagged fish during 2004 was 14.3 min (Table 2, Figure 2). The median counting window passage times for the runs released from Ice Harbor Dam were consistently higher than for runs released from Bonneville Dam. Among fish released from Bonneville Dam, fall Chinook salmon had the highest median window passage time while spring–summer Chinook salmon had the highest median counting window passage time among the runs released from Ice Harbor Dam. Fall Chinook salmon had the highest median counting window passage time among the runs when we combined fish released from both Bonneville and Ice Harbor dams.

Table 2. Median, quartiles, range, and sample sizes of counting window passage times (min) at the north-shore fishway of Lower Monumental Dam for spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville Dam (BO) or Ice Harbor Dam (IH) during 2004.

Species (Run)	Release Site	Lower Quartile (min)	Med. (min)	Upper Quartile (min)	Range (min)	n
CK	BO	8.4	11.8	17.1	2.8 – 1,206.7	132
FC	BO	11.8	17.5	28.5	5.5 – 1,155.7	21
SH	BO	9.7	14.3	21.8	4.2 – 33,055.4	75
CK	IH	15.8	26.8	45.8	6.2 – 575.6	12
FC	IH	14.8	23.7	37.7	5.1 – 70.4	19
SH	IH	11.4	16.7	23.0	4.0 – 9,695.7	66
CK	All	8.7	12.3	17.7	2.8 – 1,206.7	144
FC	All	12.3	20.3	35.4	5.1 – 1,155.7	40
SH	All	10.4	15.7	22.2	4.0 – 33,055.4	141
All	All	9.7	14.3	22.0	2.8 – 33,055.4	325

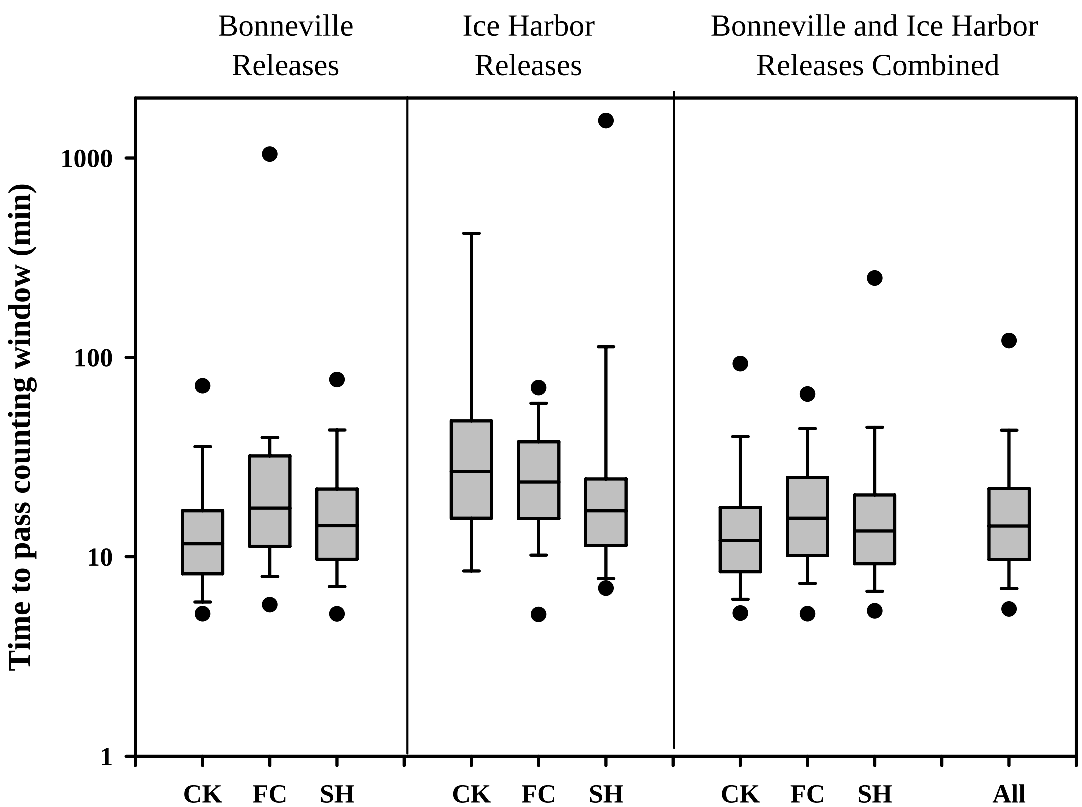

Figure 2. Median (line), quartile (box), 5th and 95th (points), and10th and 90th (whiskers) percentile of counting window passage times (min) for spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville and Ice Harbor dams at the north-shore fishway at Lower Monumental Dam Dam, 2004. Sample sizes are provided in Table 2.

Pool Upstream from Counting Window

The median time to pass the pool upstream from the north-shore counting window at Lower Monumental Dam for all radio-tagged fish during 2004 was 3.8 min (Table 3, Figure 3). Fall Chinook salmon had slightly higher median pool passage times than spring–summer Chinook and steelhead when we combined fish released from Bonneville and Ice Harbor dams. Among the runs released from Bonneville Dam, there was little difference (12 seconds) in median pool passage times. Spring–summer Chinook salmon had the highest median pool passage time among the runs released from Ice Harbor Dam.

Counting Window and Upstream Pool Combined

For all radio-tagged fish passing the north-shore fishway of Lower Monumental Dam during 2004, the median time to pass the counting window and upstream pool combined was 18.9 min (Table 4, Figure 4). Fall Chinook salmon had the highest median passage time among the runs

Table 3. Median, quartiles, range, and sample sizes of upstream pool passage times (min) at the north-shore fishway of Lower Monumental Dam for spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville Dam (BO) or Ice Harbor Dam (IH) during 2004.

Species (Run)	Release Site	Lower Quartile (min)	Med. (min)	Upper Quartile (min)	Range (min)	n
CK	BO	2.8	3.8	6.5	0.5 – 42.0	133
FC	BO	2.5	4.0	5.6	0.6 – 62.3	21
SH	BO	2.7	3.9	5.8	0.4 – 33,054.3	74
CK	IH	3.1	5.2	7.8	1.4 – 13.8	10
FC	IH	2.2	4.0	6.0	1.1 – 8.6	18
SH	IH	1.7	3.2	4.8	0.6 – 7,046.4	65
CK	All	2.9	3.8	6.5	0.5 – 42.0	143
FC	All	2.2	4.0	6.0	0.6 – 62.3	39
SH	All	2.2	3.6	5.1	0.4 – 33,054.3	139
All	All	2.5	3.8	5.9	0.4 – 33,054.3	321

when we combined fish released from Bonneville and Ice Harbor dams. Among the runs released from Bonneville Dam, fall Chinook salmon had the highest median passage time. Spring–summer Chinook salmon had the highest median passage time among the runs released from Ice Harbor Dam.

Passage Times as Proportions of Total Dam Passage Times

Counting Window

With all runs and release sites combined, counting window passage times accounted for 2.5% of the total dam passage times based on median values (Table 5). The median total dam passage time for all radio-tagged fish with calculable north-shore counting window passage times was 621 min, or 10.3 h (n = 300). Counting window passage times for Fall Chinook salmon accounted for 3.1% of dam passage times when we combined fish released from Bonneville and Ice Harbor dams. Among the runs released from Bonneville Dam, steelhead had the highest percentage of dam passage times accounted for by window passage times. Fall Chinook salmon had the highest median percentages of dam passage times accounted for by window passage times among the runs released from Ice Harbor Dam.

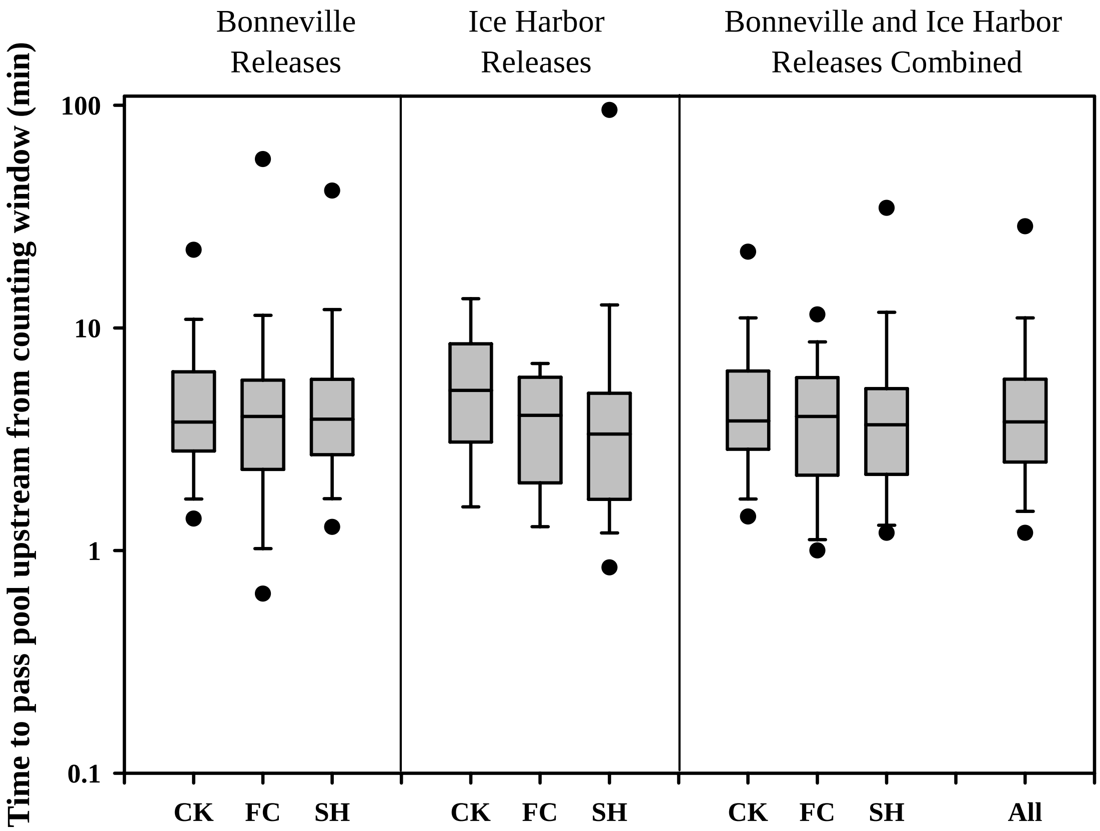

Figure 3. Median (line), quartile (box), 5th and 95th (points), and10th and 90th (whiskers) percentile of pool passage times (min) at the north-shore fishway at Lower Monumental Dam for spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville and Ice Harbor dams during 2004. Sample sizes are given in Table 3.

Pool Upstream from Counting Window

Generally, pool passage times accounted for very low percentages of total dam passage times. With all runs and release sites combined, pool passage times accounted for 0.6 % of the total dam passage times based on median values (Table 6). With fish released from Bonneville and Ice Harbor dams combined, pool passage times accounted for 0.7 % or less of dam passage times on median. Among the runs released from Bonneville Dam, steelhead had the highest percentage of dam passage times accounted for by window passage times. Spring–summer Chinook salmon had the highest median percentages of dam passage times accounted for by window passage times among the runs released from Ice Harbor Dam.

Counting Window and Upstream Pool Combined

With all runs and release sites combined, the combined passage of the counting window and upstream pool accounted for 3.5% of the total dam passage times based on median values (Table 7). Window and pool passage times combined for Fall Chinook salmon accounted for 4.0 % of

Table 4. Median, quartiles, range, and sample sizes of counting window and upstream pool passage times (min) at the north-shore fishway of Lower Monumental Dam for spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville Dam (BO) or Ice Harbor Dam (IH) during 2004.

Species (Run)	Release Site	Lower Quartile (min)	Med. (min)	Upper Quartile (min)	Range (min)	n
CK	BO	12.6	17.1	23.7	6.2 – 1,208.2	133
FC	BO	14.1	21.5	33.8	10.4 – 1,156.7	21
SH	BO	13.0	18.8	28.6	8.0 – 33,060.0	75
CK	IH	19.8	32.7	55.6	7.6 – 578.6	10
FC	IH	21.2	27.9	43.9	6.5 – 71.9	18
SH	IH	15.4	20.1	34.0	9.1 – 9,699.7	67
CK	All	12.7	17.5	25.4	6.2 – 1,208.2	143
FC	All	15.3	23.9	39.2	6.5 – 1,156.7	39
SH	All	13.8	19.6	28.6	8.0 – 33,060.0	142
All	All	13.7	18.9	28.5	6.2 – 33,060.0	324

dam passage times when we combined fish released from Bonneville and Ice Harbor dams. Among the three runs released from Bonneville Dam, steelhead had the highest percentage of dam passage times accounted for by combined window and pool passage times. Spring–summer Chinook salmon had the highest median percentages of dam passage times accounted for by window passage times among the three runs released from Ice Harbor Dam.

Correlation Analyses

Because counting window passage time is a component of total dam passage time, the two parameters are not independent. The same is true for pool passage times. However, if the counting window or pool in the north-shore fishway at Lower Monumental Dam were impediments to adult salmon and steelhead passage during 2004, we should have consistently observed high counting window or pool passage times associated with high total dam passage times. Conversely, if fish with high total dam passage times had low counting window passage times, the strength of the relationship between counting window or pool passage times and total dam passage time would be diminished.

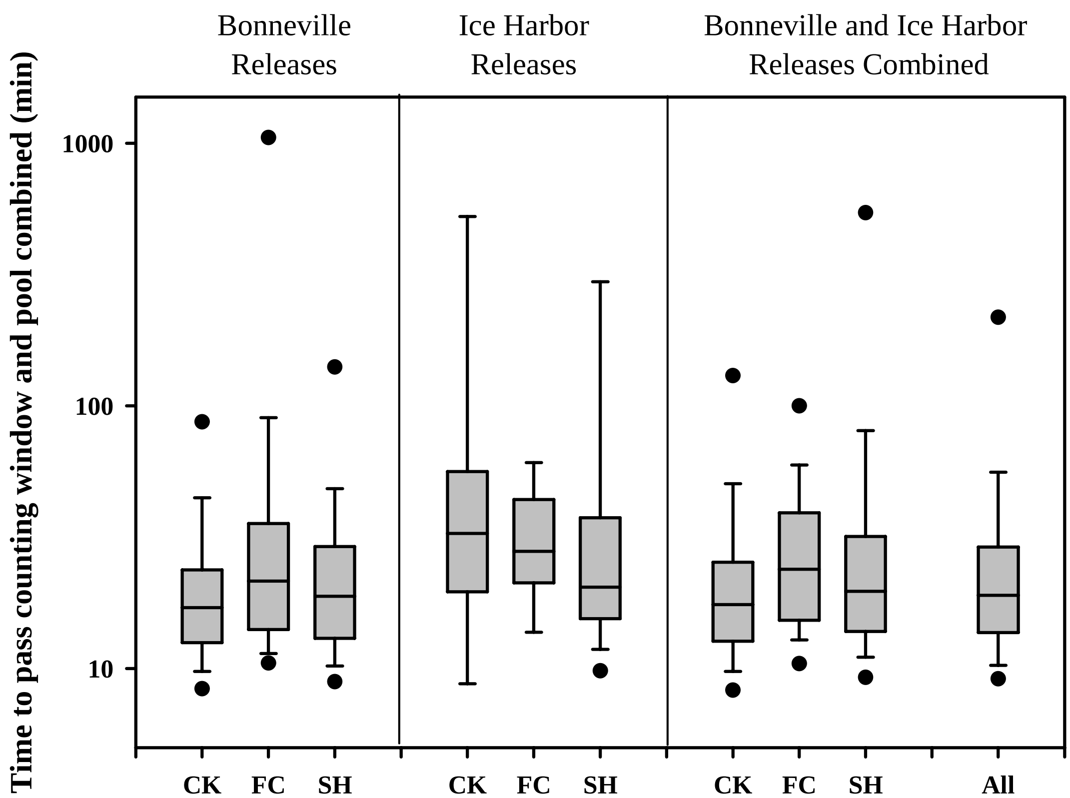

Figure 4. Median (line), quartile (box), 5th and 95th (points), and10th and 90th (whiskers) percentile of counting window and pool passage times (min) at the north-shore fishway at Lower Monumental Dam for spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville and Ice Harbor dams during 2004. Sample sizes are given in Table 4. Sample sizes were too small to estimate 5th and 95th percentiles for Ice Harbor-released spring–summer and fall Chinook salmon.

When we combined data from all runs and release sites, we found highly significant ($P < 0.0001$) , positive correlations between total dam passage times and counting window or pool passage times, but the maximum r^2 value was 0.25 (Figure 5). This suggests that while fish with high counting window or pool passage times tended to have high total dam passage times at Lower Monumental Dam, the relationship was weak.

Regression Analyses – Effects of Fish Counts on Window and Pool Passage Times

We found no signification relationship between weekly median counting window or pool passage times and fish counts (Table 8). Eight of the nine models produced negative slopes which suggested that high fish counts actually catalyze the movements of radio-tagged fish past the window and/or pool. Generally, little variation in weekly median counting window passage times was explained by the fish count data. Based on these analyses, we believe any effects of high fish counts on counting window and pool passage times were either negligible or slightly beneficial.

Table 5. Median dam passage times and median, quartiles, range and sample sizes for percentages of total dam passage times used by radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville (BO) and Ice Harbor (IH) dams to pass the counting window at the north-shore fishway of Lower Monumental Dam during 2004.

Species (Run)	Release Site	Med. Dam Passage Time (min)	Lower Quartile (%)	Med. (%)	Upper Quartile (%)	Range (%)	n
CK	BO	554	1.5	2.1	3.6	0.3 – 71.6	132
FC	BO	748	1.3	2.6	3.7	0.9 – 49.5	17
SH	BO	501	1.5	2.9	4.5	0.5 – 97.7	70
CK	IH	1,023	1.3	2.7	6.6	0.2 – 61.7	10
FC	IH	783	1.9	3.9	5.7	0.4 – 8.1	15
SH	IH	770	1.4	2.7	4.9	0.4 – 92.2	56
CK	All	585	1.4	2.1	3.6	0.2 – 71.6	142
FC	All	763	1.6	3.1	4.5	0.4 – 49.5	32
SH	All	626	1.4	2.9	4.6	0.4 – 97.7	126
All	All	621	1.4	2.5	4.3	0.2 – 97.7	300

Salmon and Steelhead Swimming to Transition Pools after Being Recorded at the Counting Window or Pool

Approximately four percent of all radio-tagged fish recorded downstream from the north-shore counting window of Lower Monumental Dam during 2004 (Antenna A in Figure 1) were recorded swimming to a transition pool (Table 9). With both release sites combined, spring–summer Chinook salmon had the highest proportion of fish swimming downstream to a transition pool among the runs. Five radio-tagged fish passed the dam via the south shore fishway after swimming downstream to a transition pool from the north-shore counting window. The median time to pass the north-shore counting window for all fish recorded swimming to a transition pool was 1,181 minutes, or approximately 19.7 h (n = 10).

Five steelhead were recorded swimming downstream to a transition pool after being detected on Antenna A. Four of these five steelhead returned to pass the dam via the north-shore fishway and one passed via the south-shore fishway. An additional four steelhead (not listed in Table 9) were recorded swimming downstream to a transition pool (nine steelhead total) but they had completely passed the pool upstream from the window (based on a minimum interval of 2 h between detections on Antenna C or detections at the ladder exit antenna) before subsequently

Table 6. Median dam passage times and median, quartiles, range and sample size for percentages of total dam passage times used by radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville (BO) and Ice Harbor (IH) dams to pass the pool upstream from the counting window at the north-shore fishway of Lower Monumental Dam during 2004.

Species (Run)	Release Site	Med. Dam Passage Time (min)	Lower Quartile (%)	Med. (%)	Upper Quartile (%)	Range (%)	N
CK	BO	554	0.4	0.7	1.2	0.1 – 11.0	133
FC	BO	750	0.3	0.6	0.9	< 0.1 – 3.6	17
SH	BO	492	0.4	0.9	1.5	0.1 – 97.7	69
CK	IH	795	0.4	0.6	1.1	0.1 – 2.9	8
FC	IH	783	0.1	0.5	0.8	< 0.1 – 2.0	15
SH	IH	770	0.2	0.4	0.9	< 0.1 – 4.0	54
CK	All	555	0.4	0.7	1.2	0.1 – 11.0	141
FC	All	763	0.2	0.5	0.8	< 0.1 – 3.6	32
SH	All	626	0.2	0.6	1.4	< 0.1 – 97.7	123
All	All	599	0.3	0.6	1.3	< 0.1 – 97.7	296

swimming downstream past the counting window. We do not believe the downstream movements of these four steelhead were directly attributable to the window or pool.

Up-and-back Behavior

Some fish were recorded upstream from the counting window (on Antennas B, C, or at the ladder exit antenna) and then downstream from the window, an event we termed up-and-back behavior. Of the 349 unique fish recorded downstream from the north-shore counting window at Lower Monumental Dam during 2004, 17 (4.9%) exhibited up-and-back behavior at the counting window (Table 10). Radio-tagged spring–summer Chinook salmon exhibited the highest percentage of up-and-back behavior among the runs. The maximum window passage time for any spring–summer Chinook salmon that exhibited up-and-back behavior was 40.3 min and the median window passage time for all thirteen spring–summer Chinook salmon that exhibited the behavior was 12.4 min. The four steelhead that exhibited up-and-back behavior were also recorded swimming downstream to a transition pool. Three of these steelhead returned to pass via the dam via north-shore fishway and one did not pass the dam after swimming downstream past the counting window.

Table 7. Median dam passage times and median, quartiles, range and sample size for percentages of total dam passage times used by radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville (BO) and Ice Harbor (IH) dams to pass the counting window and upstream pool combined at the north-shore fishway of Lower Monumental Dam during 2004.

Species (Run)	Release Site	Med. Dam Passage Time (min)	Lower Quartile (%)	Med. (%)	Upper Quartile (%)	Range (%)	n
CK	BO	554	2.0	3.0	4.8	0.5 – 71.7	133
FC	BO	750	2.4	3.9	4.5	1.0 – 49.5	17
SH	BO	475	2.3	4.0	6.5	0.8 – 97.7	70
CK	IH	795	2.4	4.5	7.7	0.3 – 62.0	8
FC	IH	783	2.7	4.0	5.9	0.4 – 10.0	15
SH	IH	780	1.8	3.2	6.0	0.5 – 92.3	55
CK	All	555	2.0	3.1	5.3	0.3 – 71.7	141
FC	All	763	2.5	4.0	5.9	0.4 – 49.5	32
SH	All	626	2.0	3.7	6.0	0.5 – 97.7	125
All	All	599	2.0	3.5	5.8	0.3 – 97.7	298

Table 8. Regression coefficients and significance levels for weighted regression models where median weekly counting window passage times, pool times, and window and pool times combined at the north-shore fishway of Lower Monumental Dam were dependent and mean daily fish count within weeks/blocks (all species summed) were predictors. All models were weighted by the number of radio-tagged fish in each week/block.

Species (Run)	Parameter	r^2	*P*	*Slope*	*Intercept*	*df*
CK	Window	0.21	0.06	-0.004	19.6	16
FC	Window	< 0.01	0.89	<-0.001	19.7	7
SH	Window	0.06	0.28	-0.030	121.8	20
CK	Pool	< 0.01	0.80	<-0.001	5.0	15
FC	Pool	0.02	0.73	<-0.001	4.3	7
SH	Pool	0.02	0.55	-0.027	99.0	20
CK	Window + Pool	0.21	0.08	-0.003	23.7	15
FC	Window + Pool	< 0.01	0.98	0.000	22.8	7
SH	Window + Pool	0.04	0.36	-0.052	204.8	20

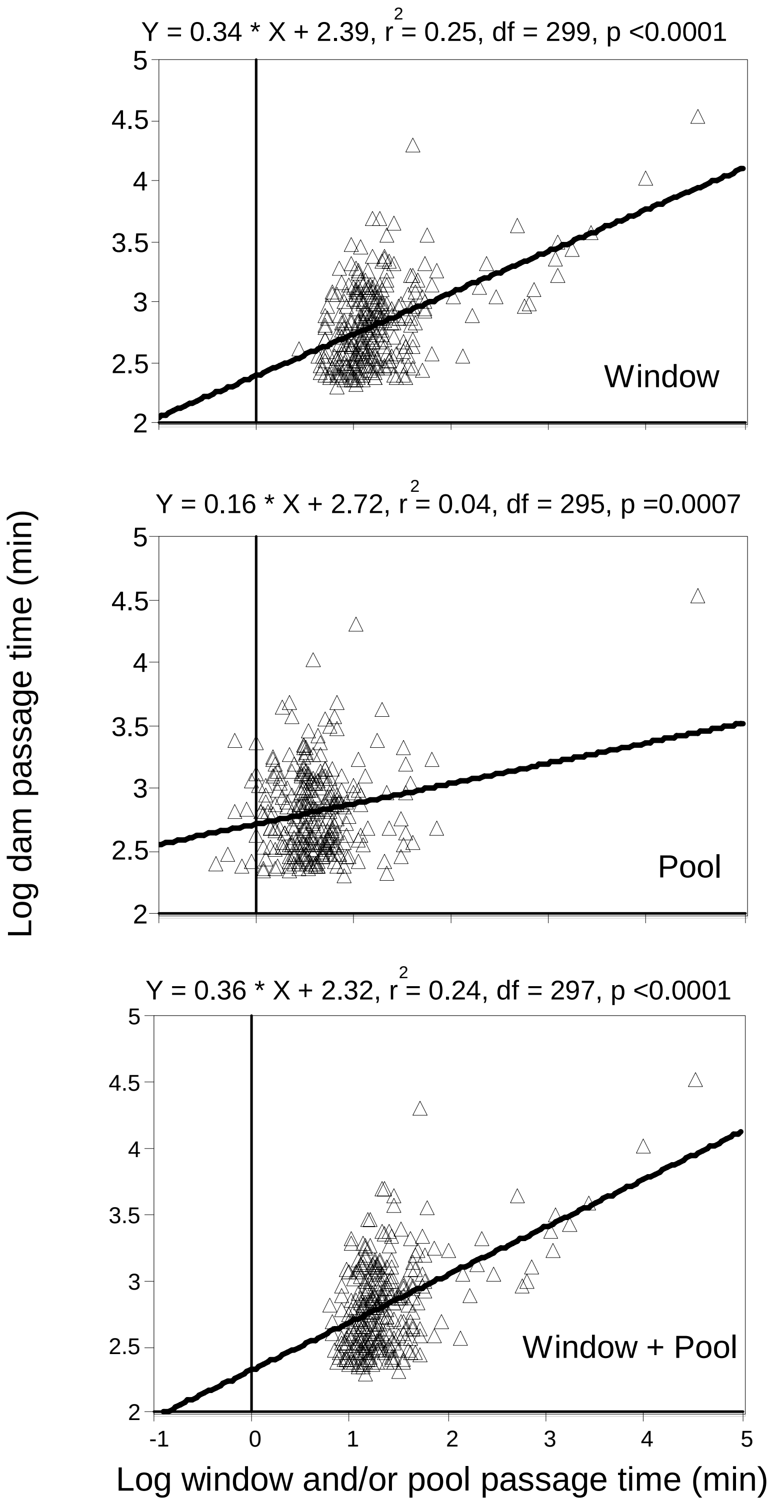

Figure 5. Linear correlation models of log-transformed counting window (upper panel), pool (middle panel), and window and pool passage times combined (lower panel) with log-transformed total dam passage times for spring–summer and fall Chinook salmon, and steelhead in the north-shore fishway at Lower Monumental Dam during 2004.

Table 9. Frequency, percentage, and sample size of radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville (BO) and Ice Harbor (IH) dams recorded swimming to a transition pool after being recorded downstream from the counting window in the north-shore fishway at Lower Monumental Dam during 2004.

Species (Run)	Release Site	Freq.	Percent	n
CK	BO	6	4.4	130
FC	BO	2	9.1	22
SH	BO	0	0.0	79
CK	IH	2	14.3	14
FC	IH	0	0.0	21
SH	IH	5	6.5	77
CK	All	8	5.3	150
FC	All	2	4.6	43
SH	All	5	3.2	156
All	All	15	4.3	349

Diel Effects on Counting Window Passage Times

We compared the median counting window passage times of salmon and steelhead (with complete sets of detections) that were first recorded immediately downstream from the counting window during the day (0500 to 2100 hrs) and night. Few salmon and steelhead were initially recorded downstream from the counting window during the night (3.7%, n = 325) but those that were typically had higher median counting window passage times (Table 11).

Discussion

For the majority of radio-tagged adult salmon and steelhead, the counting window and upstream pool in the north-shore ladder were not impediments to passing Lower Monumental Dam during 2004. This assertion is based on the high passage efficiency of salmon and steelhead recorded downstream from the north-shore counting window that ultimately passed the dam via the north-shore fishway (98.6%). In contrast, Ocker et al. (2001) concluded that counting windows at Bonneville Dam consistently obstructed the passage of adult radio-tagged lamprey in1998 and 1999 after finding counting window passage efficiencies of 78% (n=49) and 63% (n=59), respectively.

Table 10. Frequency, percentage, and sample sizes of radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville (BO) and Ice Harbor (IH) dams recorded upstream and then downstream of a counting window in the north-shore fishway at Lower Monumental Dam during 2004.

Species (Run)	Release Site	Freq.	Percent	n
CK	BO	11	8.1	136
FC	BO	0	0.0	22
SH	BO	1	1.3	79
CK	IH	2	14.3	14
FC	IH	0	0.0	21
SH	IH	3	3.9	77
CK	All	13	8.7	150
FC	All	0	0.0	43
SH	All	4	2.2	156
All	All	17	4.9	349

While differences in counting window and radio antenna configurations prohibited strict statistical comparisons among dams, the median counting window passage time for all radio-tagged fish recorded at the north-shore fishway of Lower Monumental Dam during 2004 (14.3 min, n = 325) was higher than the value at Bonneville Dam during 2001-2002 (8.5 min, n = 4,271) (Jepson et al. 2004) or 2003-2004 (7.2 min, n = 3,336) (Jepson et al. 2006a). It was higher than the median counting window passage time in the north-shore fishway of Ice Harbor Dam during 2004 (13.0 min, n = 55) but it was less than the value observed at McNary Dam during 2002-2003 (15.3 min, n = 3,240) (Jepson et al. 2006b).

Window passage times in the north-shore fishway of Lower Monumental Dam during 2004 comprised higher proportions of total dam passage times (1.4 % *median*, n = 300) than they did at Bonneville Dam during 2003-2004 (0.4 % *median*, n = 2,766). Still, we believe this was due in part to the lower median dam passage time observed at Lower Monumental Dam during 2004 (~10.3 hrs, n = 300) as compared to Bonneville Dam during 2003-2004 (~23 hrs, n = 2,791). While the proportion of total dam passage time is a relative measure, we believe it offers modest insights into how much time fish use to pass these segments of the dam

Table 11. Median passage time and sample size based on day or night arrivals of radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) released from Bonneville (BO) and Ice Harbor (IH) dams at the counting window in the north-shore fishway of Lower Monumental Dam, 2004.

		Day		Night	
Species (Run)	Release Site	Median	n	Median	n
CK	BO	11.7	130	72.2	2
FC	BO	17.5	21	-	0
SH	BO	13.1	70	15.9	5
CK	IH	25.9	11	50.6	1
FC	IH	23.7	19	-	0
SH	IH	16.6	62	16.4	4
CK	All	12.0	141	50.6	3
FC	All	20.3	40	-	0
SH	All	15.7	132	16.0	9
All	All	14.0	313	18.4	12

Median count-window passage times for the runs released from Ice Harbor Dam were consistently higher than for runs released from Bonneville Dam. Since Lower Monumental Dam is approximately 50 river kilometers upstream from Ice Harbor, it is possible there were some latent effects of the anesthesia/handling responsible for slower passage times by this group. Alternately, the smaller number of Ice Harbor Dam releases compared to those from Bonneville Dam, particularly for spring–summer Chinook salmon, may have been responsible for this observation.

With release sites combined, Fall Chinook salmon had the highest median window passage time among runs in the north-shore ladder of Lower Monumental Dam during 2004. Fall Chinook salmon also had the lowest median counting window passage times at Bonneville Dam during 2001 and 2002 (Jepson et al., 2004) but steelhead had the lowest median counting window passage times at McNary Dam during 2002 and 2003 (Jepson et al., 2006a). These results discredit the idea that all runs pass counting windows with consistent relative speed and suggests that site-specific features at counting windows (e.g. hydrology) may be mediating differences among runs.

The degree of the association between counting window or pool passage times and total dam passage times was low, suggesting high dam passage times at Lower Monumental Dam during

2004 were not directly related to the attributes of the counting window or its upstream pool. Our finding that fish counts were poor predictors of window passage times at the north-shore fishway of Lower Monumental Dam was consistent with similar analyses conducted with data collected at McNary Dam during 2002-2003 (Jepson et al., 2006b), the north-shore fishway of Ice Harbor Dam during 2003 (Jepson et al., 2006b), and Bonneville Dam during 2001-2004 (Jepson et al. 2004 and 2006a).

Fish that swam downstream to a transition pool from the north-shore counting window at Lower Monumental Dam consistently had the highest counting window passage times. Fish that did so however, comprised a relatively small proportion of all fish recorded at the counting window (4.3%, n =349). Still, the proportion of radio-tagged fish swimming to a transition pool after being recorded at the north-shore window was over eight times higher than the proportion doing so at Bonneville Dam during 2001 and 2002 (~0.5%, n = 4,277) (Jepson et al. 2004).

Fish that exhibited up-and-back behavior at the north-shore counting window of Lower Monumental Dam during 2004 actually had lower median counting window passage times (12.5 min) than fish that did not (14.5 min). Similarly, spring–summer Chinook salmon at the north-shore fishway of Ice Harbor Dam exhibited a relatively high proportion of up-and-back behavior (~23%, n = 30) but their median counting window passage time was slightly less than the median counting window passage time for fish not exhibiting the behavior. We believe this may have been an artifact of the low sample size.

While fish initially detected downstream from the counting window during the night had higher window passage times than those initially detected there during the day, they comprised a small percentage of all fish initially detected downstream from the north-shore counting window at Lower Monumental Dam during 2004.

The underlying premise of this evaluation involved there being some causal mechanism or mechanisms for high window or pool passage times. That is, if an adult salmon or steelhead began to swim downstream at a given point in its upstream migration, some stimulus, absence of stimulus, or combination of stimuli caused the fish to swim downstream. Identifying the stimulus or stimuli that may have caused downstream movements of adult migrants was challenging since most radio-tagged fish were seemingly unimpeded by the counting window and pool evaluated in this study.

In summary, we've presented descriptive statistics for passage times and behaviors at the north-shore counting window and its upstream pool at Lower Monumental Dam during 2004. We conclude that one can expect a relatively small percentage of adult migrants to swim downstream after being detected at this counting window or in its upstream pool (and thereby have relatively higher total dam passage times). It is unclear as to what steps might be taken to minimize these events however, since no window or pool modifications were experimentally evaluated during 2004.

Epilogue

The north-shore count station was reconstructed during the winter of 2004-05 (Rex Baxter, USACE Walla Walla District, pers. comm.). The hydraulics in the vicinity of the window have changed somewhat due to having different picketed leads and other new in-water structures. Moreover, there is still an eddy in the pool immediately upstream from the count station but it is unclear if it significantly different from the eddy which existed prior to the modifications. There is more head differential across the count slot area, at least at times, and this has increased water velocity through the count slot. It is unknown at this time if these modifications have significantly altered passage times or behavior of adult salmonids in the vicinity of the counting stations at Lower Monumental Dam.

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