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An Evaluation of Adult Chinook Salmon and Steelhead Behavior at Counting Windows of McNary Dam during 2002 & 2003 and the North Shore Counting Window at Ice Harbor Dam during 2003

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Abstract

We used radio telemetry to evaluate the behavior of adult spring–summer Chinook salmon, fall Chinook salmon, and steelhead swimming past counting windows and through adjustable overflow weirs of the Oregon and Washington shore fishways at McNary Dam during 2002 and 2003. Similarly, we evaluated their behavior at the counting window and through the vertical-slot weirs of the North shore fishway at Ice Harbor Dam during 2003.

At McNary Dam, median times to pass a counting window ranged from 5.9 to19.1 min among all run/year/fishway groups (*n*=12) and were consistently highest for run/year groups initially recorded at the Washington shore counting window. Among all year/run/fishway groups, ratios of counting window passage times to total dam passage times (first record in tailrace to last record at ladder exit) for individual fish were ≤ 4.1% based on median values and ≤13.4% based on mean values. The maximum proportion of fish swimming downstream to a transition pool after being recorded at a counting window was for fall Chinook salmon at the Washington shore counting window in 2002 (9.5%, *n*=242). The median counting window passage times for all fish that swam to a transition pool after being detected at a counting window was approximately 23 h (*n*=99).

The median counting window passage times at the North shore fishway of Ice Harbor Dam ranged between 9.9 min for spring–summer Chinook salmon (*n*=30) and 21.2 minutes for fall Chinook salmon (*n*=4). Ratios of counting window passage times to total dam passage times for individual fish were ≤ 2.4% based on median values and ≤ 4.7% based on mean values. No fish swam to a transition pool from the North shore counting window (*n*=57).

Proportions of fish recorded upstream from a counting window and then downstream from a counting window (‘up-and-back’ behavior) were typically highest for steelhead among all run/year groups with a maximum of 4.5% (*n*=156) at the Washington shore counting window at McNary Dam during 2002. Of the 3,243 unique fish recorded downstream of a counting window at McNary Dam during the two study years, 63 (1.9%) exhibited up-and-back behavior at a counting window and their median time to pass a counting window was 42.9 min. Twenty-three percent of the spring–summer Chinook salmon recorded at Ice Harbor Dam (*n*=30) exhibited up-and-back behavior but their median window passage time was slightly less than for fish that did not exhibit the behavior.

Among all run/year groups at McNary Dam, median times to pass the adjustable overflow weirs ranged from 14.2 to 21.8 min for the Oregon-shore fishway and 12.1 to 19.0 min for the Washington-shore fishway. Median times to pass the vertical-slot weirs at Ice Harbor Dam ranged from 10.3 to 13.4 min based on median values and 15.0 to 47.7 min based on means.

Among all run/year groups, ratios of median adjustable overflow weir passage times to total median dam passage times for individual fish were ≤3.0% (*mean* ≤ 5.5%) for groups initially recorded in the Oregon shore adjustable overflow weirs and ≤2.6% (*mean* ≤ 4.5%) for those first recorded at the Washington shore adjustable overflow weirs. Passing the vertical-slot weirs at Ice Harbor Dam comprised ≤ 2.2% of total dam passage times (medians) and ≤ 6.2% (means) among runs.

Overall, 0.2% of fish (*n*=3,152) swam to a McNary Dam transition pool after being detected in a set of adjustable overflow weirs and their median passage time was approximately 22 h (n=6). At Ice Harbor Dam, two fish were recorded swimming downstream to a transition pool from the vertical-slot weirs in the North shore fishway and they ultimately passed the dam via the South shore ladder.

The combined passage of counting windows and adjustable overflow weirs at termini of the McNary Dam fishways accounted for 3.1 - 8.5% of total dam passage times based on medians, and 5.1 -17.3% of total dam passage times (means) among all run/year/fishway groups. The combined passage of the counting window and vertical-slot weirs at the North shore fishway of Ice Harbor Dam accounted for 3.2 - 5.6% of total dam passage times based on medians (means = 5.4 – 14.7%).

Analyses assessing the degree of association between counting window or weir 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.

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Introduction

Radiotelemetry techniques can be used to identify potential impediments to adult salmonids as they migrate upstream past Columbia and Snake River dams, including the counting windows in dam fishways. Counting windows are narrow 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 move upstream and then downstream of 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.

As stated in the Federal Columbia River Power System Biological Opinion Action 117 (NMFS 2000), “The Corps shall evaluate adult count station facilities…to either minimize delay of adults or minimize counting difficulties that reduce count accuracy.” In response to concerns of the U.S. Army Corps of Engineers about passage at count windows, we installed receivers and deployed underwater antennas upstream and downstream from counting windows of both the Oregon and Washington shore fishways of McNary Dam in 2002-2003, and in the North-shore ladder at Ice Harbor Dam in 2003. Using telemetry data, we evaluated the behavior of radio-tagged spring–summer Chinook salmon, fall Chinook salmon, and steelhead near the counting windows and upstream weirs of the specified fishways to assess whether adult salmon passage was hindered in these sections of the ladders.

Methods

Adult spring–summer Chinook salmon and steelhead were collected in the Adult Fish Facility adjacent to the Washington shore at Bonneville Dam throughout the migration of each species during both years. 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 [22 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. Fish were released downstream from Bonneville Dam (both years) or in the forebay of Bonneville Dam (2002 only).

We used passive integrated transponder (PIT) tags as secondary tags during both years. A radio transmitter dipped in glycerin was inserted into the stomach through the mouth. 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. We also used some combination radio/data storage transmitters (RDST tags) in 2002 that recorded and stored temperature and pressure data. All transmitters were cylindrical with 43-47 cm antennas. Seven volt tags weighed 29 g in air (8.3 by 1.6 cm), RDST tags were 34 g (9.0 by 2.0 cm) and CART tags were 28 g (6.0 by 1.6 cm). Code sets allowed us to monitor up to 212 fish on each frequency. Lithium batteries powered transmitters and all but the RDST tags had a rated operating life of more than nine months. After tagging, fish were placed in an aerated transport tank where they were held until released.

At McNary Dam, we deployed underwater antennas immediately downstream and upstream from the counting windows and at the ladder exits of the Oregon and Washington shore fishways (Figure 1). The configuration of counting and visitor's fish viewing windows were different among the two fishways at McNary Dam and to this extent, the counting window passage times presented for the two fishways are not strictly comparable. We used a similar, but not identical arrangement of underwater antennas at the North shore counting window of Ice Harbor Dam in 2003 (Figure 2). McNary Dam had eight adjustable overflow weirs upstream from each counting window while the North shore ladder at Ice Harbor Dam had six vertical-slot weirs.

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 a counting window. This calculation was designed to account for the time spent by some fish swimming upstream, and then downstream from a counting window, in the total window passage time. Groupings were based on the antenna immediately downstream from a counting window where salmon and steelhead were initially detected. We calculated counting window 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 windows or weirs. 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 weir. Until a fish passed a window or weir (in either fishway) and stayed 'passed', the clock ran. This meant the time fish used swimming downstream to transition pools and (and anywhere else) after swimming to the counting window was included in the counting window or weir passage time.

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

We also deployed underwater antennas in the transition pools of McNary and Ice Harbor Dam fishways and determined the time used by fish to swim through overflow weirs to the counting windows. Specifically, we calculated the interval between the last record in the transition pool and the first record immediately downstream from a counting window for a given fish and then divided this value by the number of weirs the fish passed (min/weir). We used correlation analyses (Sokal and Rohlf, 1969) to evaluate the degree of association between counting window or vertical-slot weir passage times and total dam passage times. Finally, we used linear regression (Sokal and Rohlf, 1969) to evaluate any effects of ladder-specific fish counts on counting window and weir passage times. Specifically, we grouped radio-tagged fish with similar passage dates for each fishway using weekly blocks, weighed each block by the number of observations 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 each fishway during corresponding weeks. Ladder-specific fish count data for this analysis were obtained from the U.S. Army Corps of Engineer, Portland District – Operation Division’s web page: https://www.nwp.usace.army.mil/op/fishdata/welcome.htm.

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

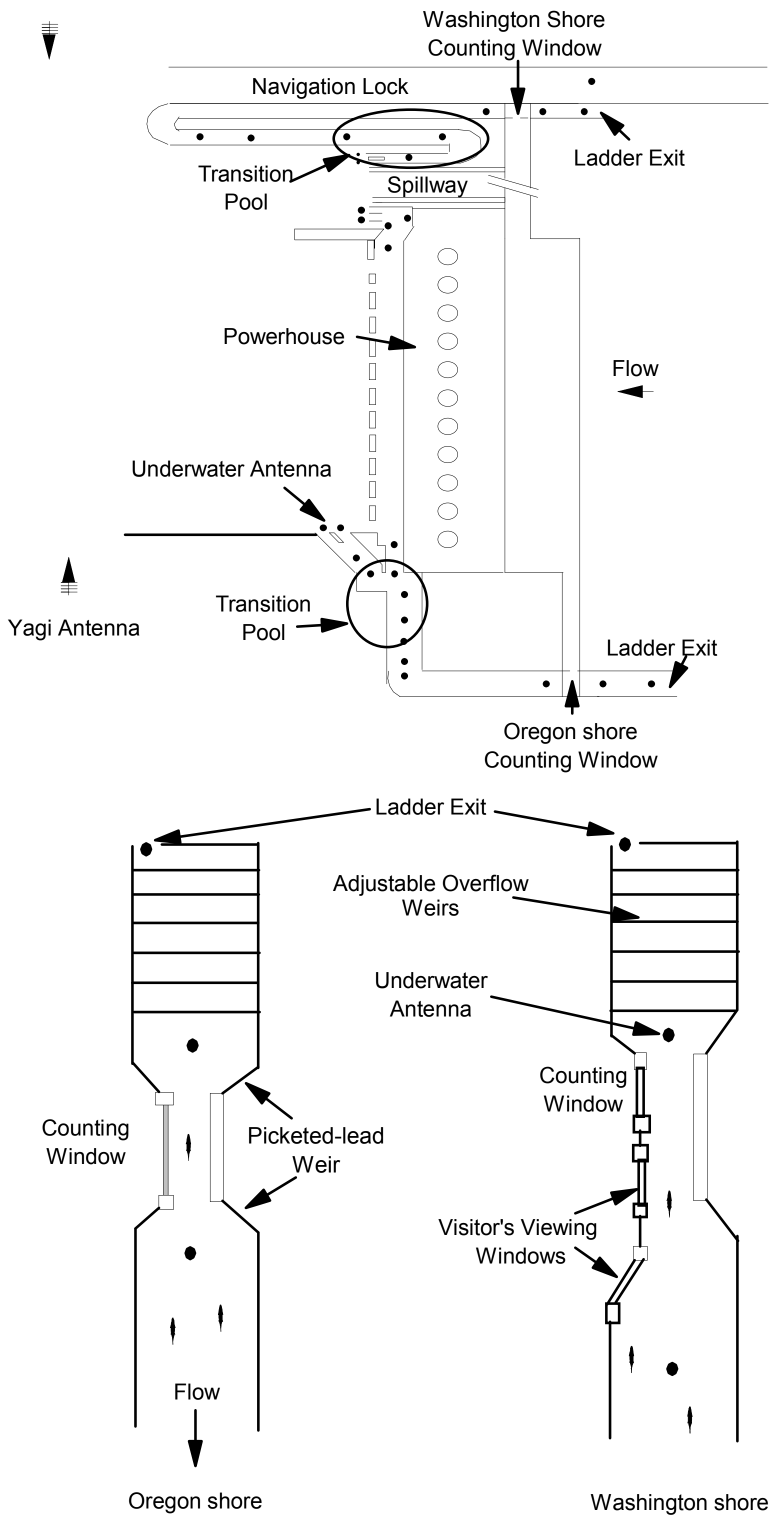

Figure 1. Aerial view of counting windows and adjustable overflow weirs in relation to transition pools (upper panel) and position of radio antennas (indicated by closed circles) deployed near counting windows and at ladder exits of Oregon and Washington shore fishways at McNary Dam in 2002 and 2003 (lower panel).

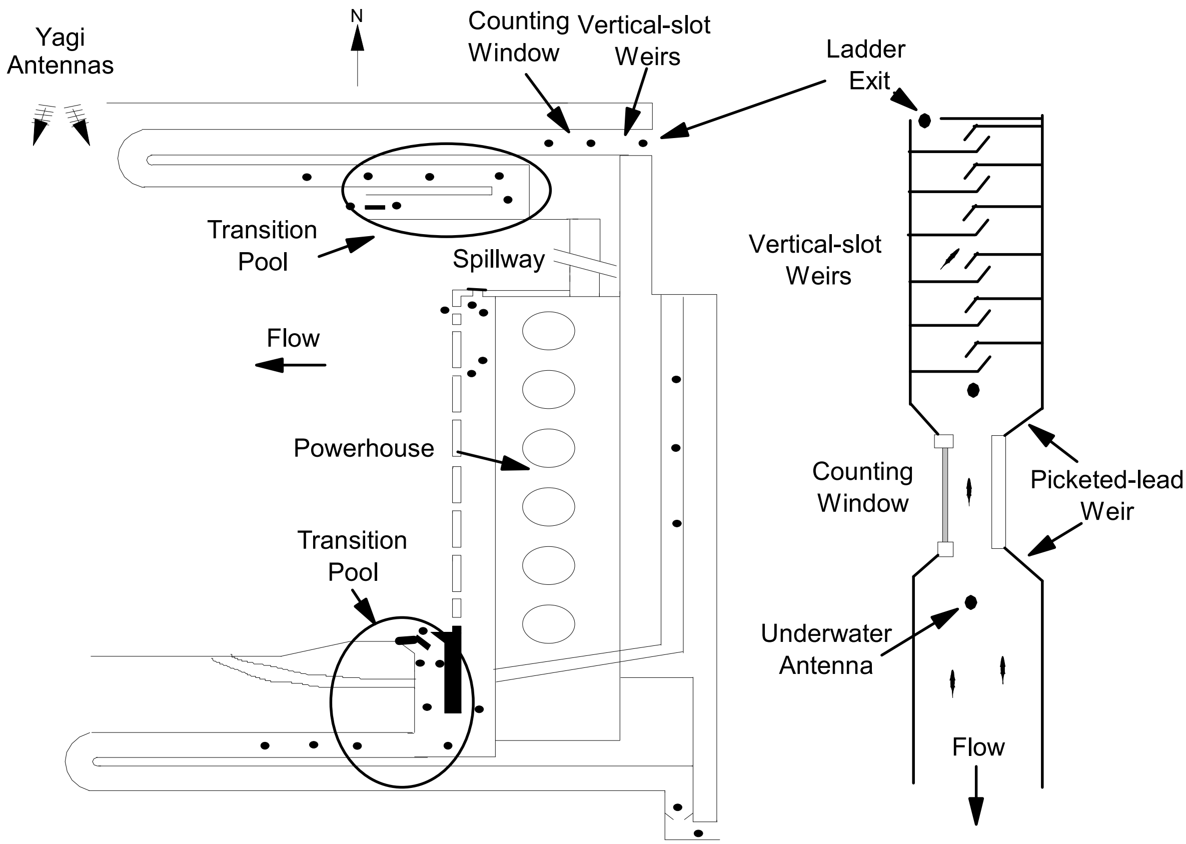

Figure 2. Aerial view of counting windows and vertical-slot weirs in relation to transition pools (panel on left) and position of radio antennas (indicated by closed dots) deployed near counting window and at ladder exit of North shore fishway at Ice Harbor Dam in 2003 (panel on right).

Results

Passage Times

McNary Dam Counting Windows

Among the three fish runs, spring–summer Chinook salmon had the highest counting window passage times for all four fishway/year combinations, with median values ranging from 14.6 to 29.9 min. (Figure 3). Steelhead consistently had the lowest median passage times and median times for fall Chinook salmon were intermediate. For all years and runs, median counting window passage times at the Washington shore fishway were higher than those at the Oregon shore counting window (Table 1). We believe this was due in part to the differences in distances between antennas upstream and downstream from the windows among fishways. Within fishways and runs, we discerned no pattern among median counting window passage times among years. The median time to pass a counting window at McNary Dam for all radio-tagged fish during both years was 15.3 min (*n* = 3,241).

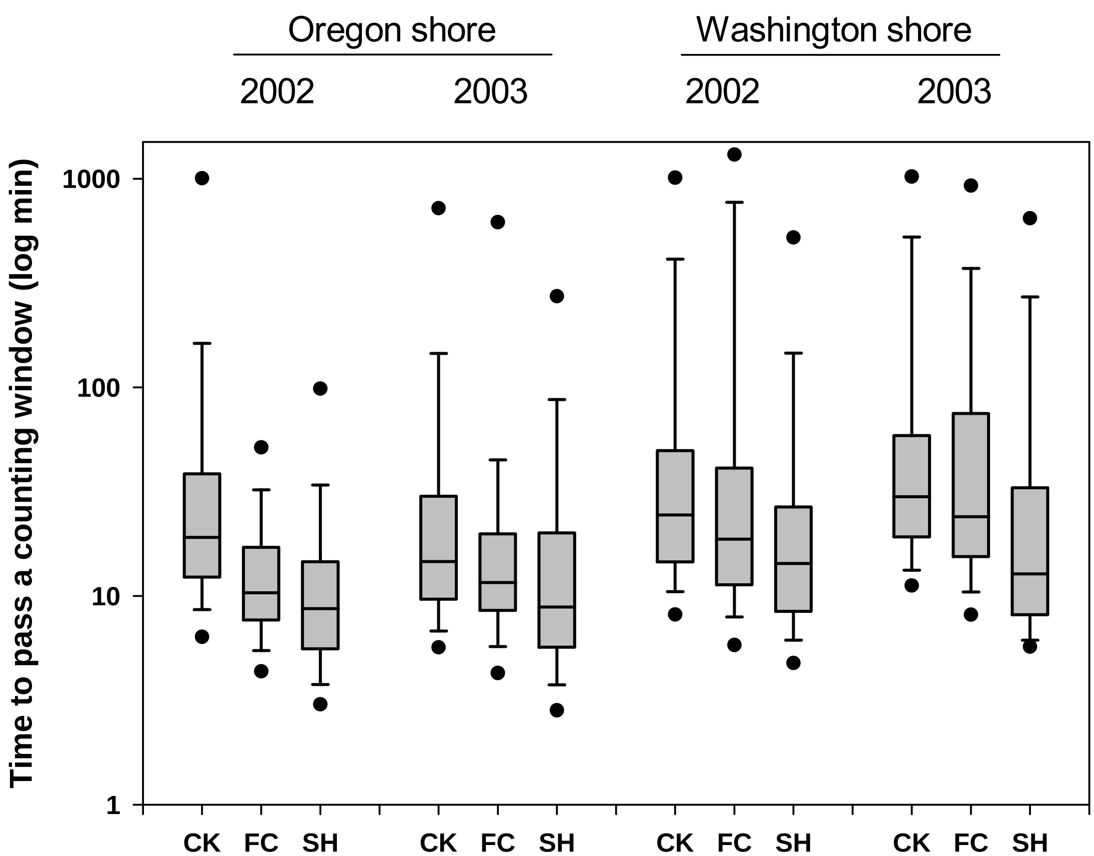

Figure 3. Median, quartile, 5th, 10th, 90th, and 95th percentile counting window passage times (min) for Oregon shore and Washington shore fishways at McNary Dam, 2002-2003. CK = spring–summer Chinook salmon, FC = fall Chinook salmon, and SH = steelhead. Sample sizes are given in Table 1.

Table 1. Median, mean, standard deviation of the mean, range, and sample sizes for counting window passage times for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at Oregon and Washington shore fishways at McNary Dam, 2002-2003.

		Oregon Shore					Washington Shore				
Year	Species (Run)	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N
2002	CK	19.1	188.1	728.6	1.3 - 7,152.2	396	24.4	160.0	492.6	4.4 – 5,485.4	352
2002	FC	10.4	36.1	197.5	2.0 - 2,770.2	229	18.7	169.9	425.1	0.8 – 2,937.8	241
2002	SH	8.7	31.9	140.8	0.8 - 2,861.9	643	14.3	125.7	809.2	1.1 – 9,973.4	156
2003	CK	14.6	110.6	375.6	3.4 – 4,133.5	300	29.9	174.8	535.0	5.0 – 5,514.2	340
2003	FC	11.6	68.5	219.4	1.1 – 1,284.0	158	24.0	166.6	515.8	3.6 – 4,496.3	126
2003	SH	8.8	47.5	137.2	1.5 – 1,151.9	258	12.8	87.6	252.9	5.4 – 1,430.9	42

Ice Harbor Dam North shore Counting Window

Sample sizes of fish passing the North shore fishway of Ice Harbor Dam were relatively small during 2003 (total *n* = 55). Median counting window passage times ranged from 9.9 min for spring–summer Chinook salmon to 21.2 minutes for fall Chinook salmon (Figure 4 and Table 2). The median counting window passage time for all radio-tagged fish initially detected downstream from the North shore counting window of Ice Harbor Dam was13.0 min.

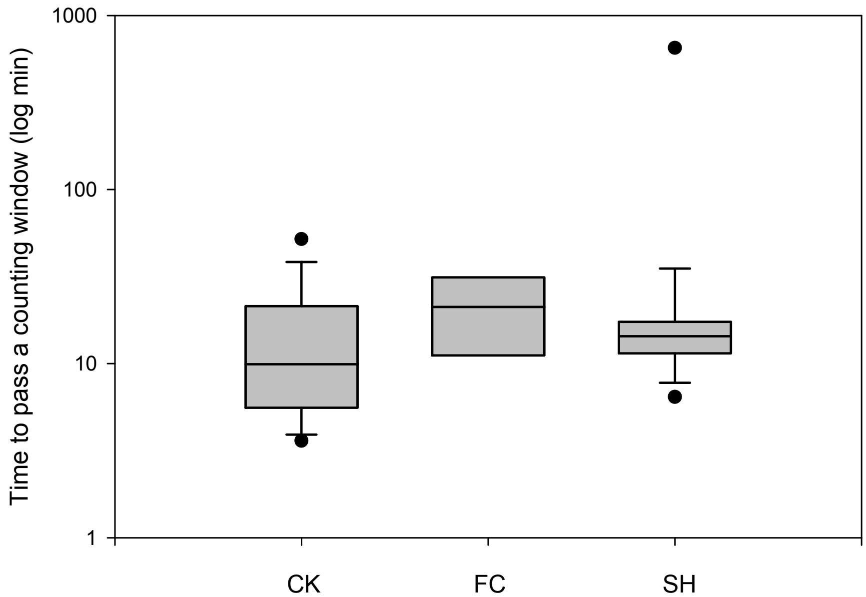

Figure 4. Median, quartile, 5th, 10th, 90th and 95th percentile counting window passage times (min) for the North shore fishway at Ice Harbor Dam, 2003. CK = spring–summer Chinook salmon, FC = fall Chinook salmon, and SH = steelhead. Sample sizes are given in Table 2.

Table 2. Median, mean, standard deviation of the mean, range, and sample sizes for counting window passage times for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at the North shore fishway at Ice Harbor Dam, 2003.

Year	Species (Run)	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N
2003	CK	9.9	15.3	13.9	3.5 - 54.0	30
2003	FC	21.2	21.2	10.8	10.2 – 32.4	4
2003	SH	14.4	48.5	153.8	6.4 – 719.4	21

<u>McNary Dam Adjustable Overflow Weirs</u>

Fall Chinook salmon had the highest median passage times through the adjustable overflow weirs of the Oregon shore fishway while spring–summer Chinook salmon had the highest median passage times in the Washington shore fishway (Figure 5). Steelhead consistently had the lowest median weir passage times in both fishways (Table 3). Within runs and fishways, differences in median weir passage times among years were small, typically less than two minutes. The median time to pass the adjustable overflow weirs at McNary Dam for all radio-tagged fish during both years was 16.2 min (*n* = 3,152).

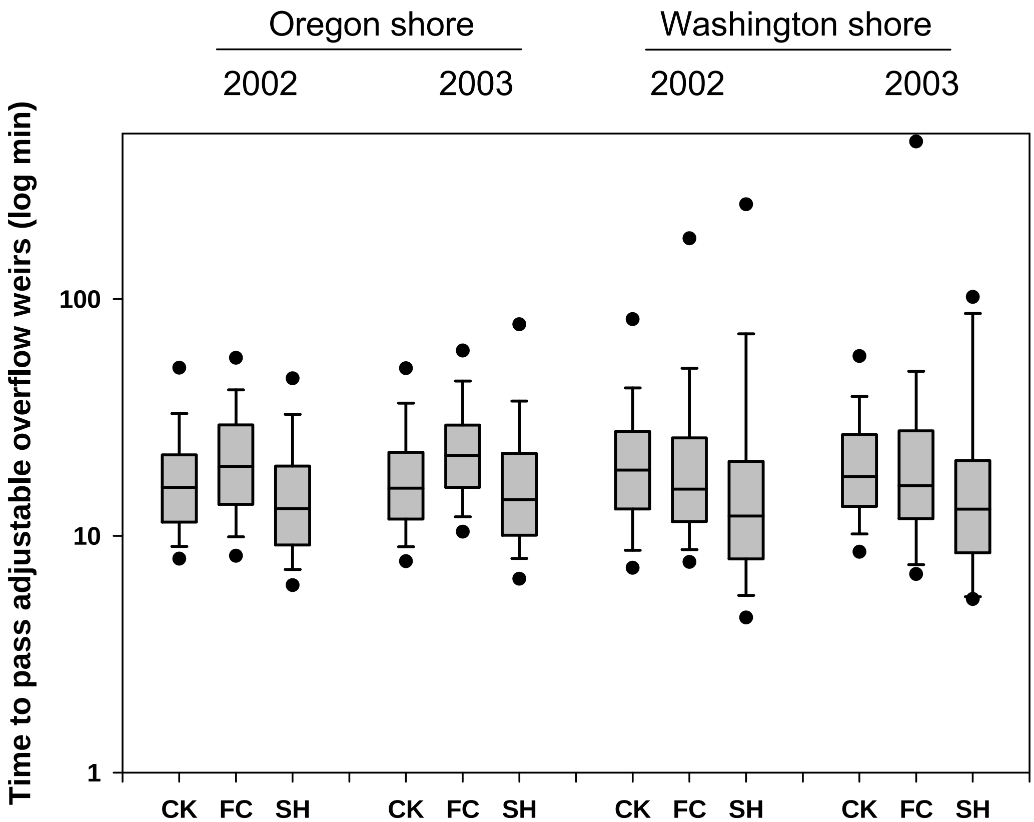

Figure 5. Median, quartile, 5th, 10th, 90th and 95th percentile adjustable overflow weir passage times (min) for Oregon and Washington shore fishways at McNary Dam, 2002-2003. (CK = spring–summer Chinook salmon, FC = fall Chinook salmon, and SH = steelhead). Sample sizes are given in Table 2.

Table 3. Median, mean, standard deviation of the mean, range, and sample sizes for adjustable overflow weir passage times for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at Oregon and Washington shore fishways at McNary Dam, 2002-2003.

		Oregon Shore					Washington Shore				
Year	Species (Run)	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N
2002	CK	16.0	27.9	65.2	5.8 – 677.9	387	19.0	41.5	121.3	4.6 – 1,314.0	342
2002	FC	19.6	77.1	634.7	6.0 – 9,412.7	238	15.8	44.2	112.6	5.5 – 931.1	222
2002	SH	13.0	23.6	58.7	3.5 – 700.4	635	12.1	92.7	635.6	3.5 – 7,628.4	147
2003	CK	15.9	32.9	152.8	5.4 – 2,471.4	297	17.8	33.9	100.5	6.1 – 1,350.5	332
2003	FC	21.8	41.7	137.8	5.9 – 1,278.6	155	16.3	54.3	137.3	4.6 – 825.8	120
2003	SH	14.2	28.0	57.9	2.9 – 513.8	236	13.0	28.0	45.7	4.2 – 265.0	41

Salmon and steelhead passage rates (min/weir) through the eight adjustable overflow weirs were consistently higher than passage rates through the respective overflow weirs downstream from the Oregon and Washington shore counting windows (Tables 4 and 5). Passage rates through the adjustable overflow weirs were 36 – 657% higher than those through the overflow weirs based on mean values and 0 – 52% higher based on median values.

Table 4. Median, mean, standard deviation of the mean, and sample sizes for overflow weir and adjustable overflow weir passage rates for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at the Oregon shore fishway at McNary Dam, 2002-2003.

		Overflow Weirs				Adjustable Overflow Weirs			
Year	Species	Med. (min/weir)	Mean (min/weir)	S.D.	N	Med. (min/weir)	Mean (min/weir)	S.D.	N
2002	CK	1.92	2.20	1.35	396	2.00	3.48	8.14	387
2002	FC	1.77	2.21	1.84	221	2.45	9.64	79.34	238
2002	SH	1.63	2.16	1.94	601	1.63	2.95	7.33	635
2003	CK	1.93	2.36	1.80	299	1.99	4.11	19.10	297
2003	FC	1.89	2.04	0.91	153	2.73	5.21	17.23	155
2003	SH	1.59	2.06	1.54	213	1.78	3.50	7.24	236

Table 5. Median, mean, standard deviation of the mean, and sample sizes for overflow and adjustable overflow weir passage rates for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at the Washington shore fishway at McNary Dam, 2002-2003.

		Overflow Weirs				Adjustable Overflow Weirs			
Year	Species	Med. (min/weir)	Mean (min/weir)	S.D.	N	Med. (min/weir)	Mean (min/weir)	S.D.	N
2002	CK	1.56	1.80	0.95	339	2.37	5.19	15.17	342
2002	FC	1.43	1.78	1.45	242	1.97	5.53	14.08	222
2002	SH	1.33	1.53	1.08	146	1.51	11.58	79.44	147
2003	CK	1.60	2.11	1.75	334	2.22	4.23	12.56	332
2003	FC	1.44	1.80	1.55	125	2.03	6.79	17.16	120
2003	SH	1.32	1.98	3.15	40	1.62	3.50	5.72	41

Ice Harbor Dam North Shore Vertical-slot Weirs

The median vertical-slot weir passage times among the three runs differed by approximately three minutes (Figure 6 and Table 4) during 2003 and the median weir passage time for all radio-tagged fish initially detected in the North shore fishway of Ice Harbor Dam was12.5 min (*n*=55).

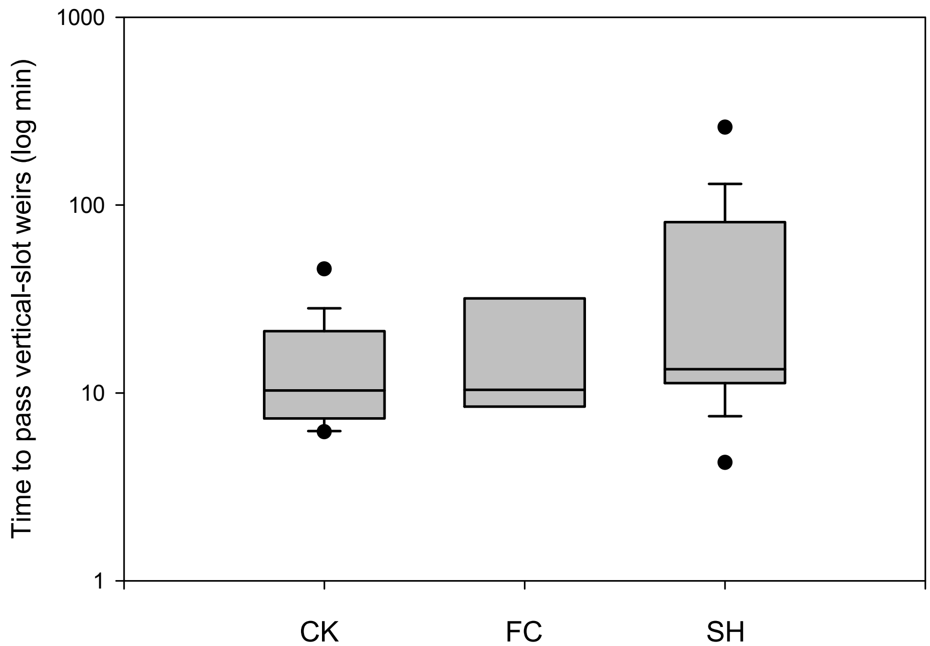

Figure 6. Median, quartile, 5th, 10th, 90th and 95th percentile vertical-slot weir passage times (min) for the North shore fishway at Ice Harbor Dam, 2003. CK = spring–summer Chinook salmon, FC = fall Chinook salmon, and SH = steelhead. Sample sizes are given in Table 6.

Table 6. Median, mean, standard deviation of the mean, range, and sample sizes for overflow and vertical-slot weir passage rates for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at the North shore fishway at Ice Harbor Dam, 2003.

Year	Species (Run)	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N
2003	CK	10.3	15.0	10.9	6.2 - 48.9	30
2003	FC	10.4	16.9	14.7	7.9 – 38.9	4
2003	SH	13.4	47.7	66.7	3.9 – 273.4	21

The passage rates through the six vertical-slot weirs were 214 – 684% higher than those through the overflow weirs based on mean values and 171 – 332% higher based on median values (Table 7).

Table 7. Median, mean, standard deviation of the mean, and sample sizes for overflow and vertical-slot weir passage rates for radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at the North shore fishway at Ice Harbor Dam, 2003.

		Overflow Weirs				Vertical-slot Weirs			
Year	Species	Med. (min/weir)	Mean (min/weir)	S.D.	N	Med. (min/weir)	Mean (min/weir)	S.D.	N
2003	CK	1.44	1.55	0.42	29	3.91	4.88	3.17	30
2003	FC	1.53	1.92	1.07	4	6.61	6.35	1.79	4
2003	SH	1.28	2.08	2.77	20	5.18	16.31	28.80	21

McNary Dam Counting Windows and Adjustable Overflow Weirs Combined

Spring–summer Chinook salmon typically had the highest median passage times in both McNary Dam fishways during both years (Figure 7 and Table 8). The lone exception was that fall Chinook salmon had a slightly higher median passage time in the Oregon shore fishway during 2003. Steelhead consistently had the lowest median passage times. The median time to pass the termini of McNary Dam fishways for all radio-tagged fish during both years was 35.1 min (n = 3,204); 30.5 min for the Oregon shore fishway (n = 1,924) and 44.1 min for the Washington shore (n = 1,225).

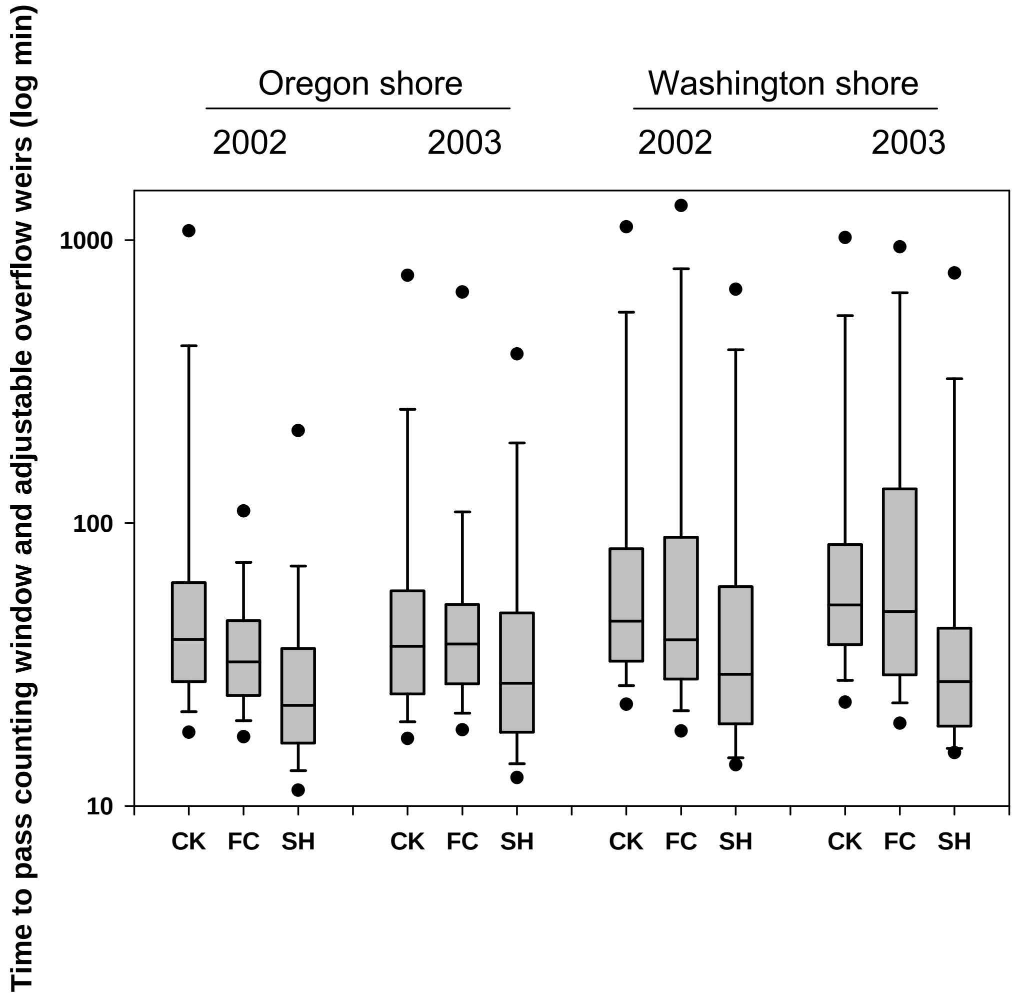

Figure 7. Median, quartile, 5th, 10th, 90th and 95th percentile counting window and adjustable overflow weir (combined) passage times (min) for spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) in the Oregon and Washington shore fishways at McNary Dam, 2002-2003. Sample sizes are given in Table 5.

Table 8. Median, mean, standard deviation of the mean, range, and sample sizes for counting window to ladder exit passage times for radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at Oregon and Washington shore fishways at McNary Dam, 2002-2003.

		Oregon shore					Washington Shore				
Year	Species (Run)	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N
2002	CK	38.8	219.0	740.0	11.2 – 7,180.0	385	45.0	198.3	512.2	15.6 – 5,498.2	344
2002	FC	32.3	104.4	657.1	11.0 – 9,437.3	225	38.6	212.3	434.7	13.9 – 2,954.0	235
2002	SH	22.7	55.4	156.6	7.8 – 2,924.4	632	29.2	216.4	1,032.5	11.3 – 9,989.0	150
2003	CK	36.6	134.6	380.8	8.8 - 4,151.1	295	51.6	195.2	531.4	13.8 – 5,523.5	334
2003	FC	37.4	95.2	221.9	12.4 – 1,308.6	152	48.7	221.1	531.0	14.9 – 4,505.5	123
2003	SH	27.1	76.4	152.3	9.6 – 1,157.3	235	27.5	101.6	259.9	13.5 – 1,448.8	39

Ice Harbor Dam North shore Counting Windows and Vertical-slot Weirs Combined

As past the counting window alone, fall Chinook salmon had the highest median time to pass the North shore counting window and vertical-slot weirs combined (Figure 8 and Table 9).

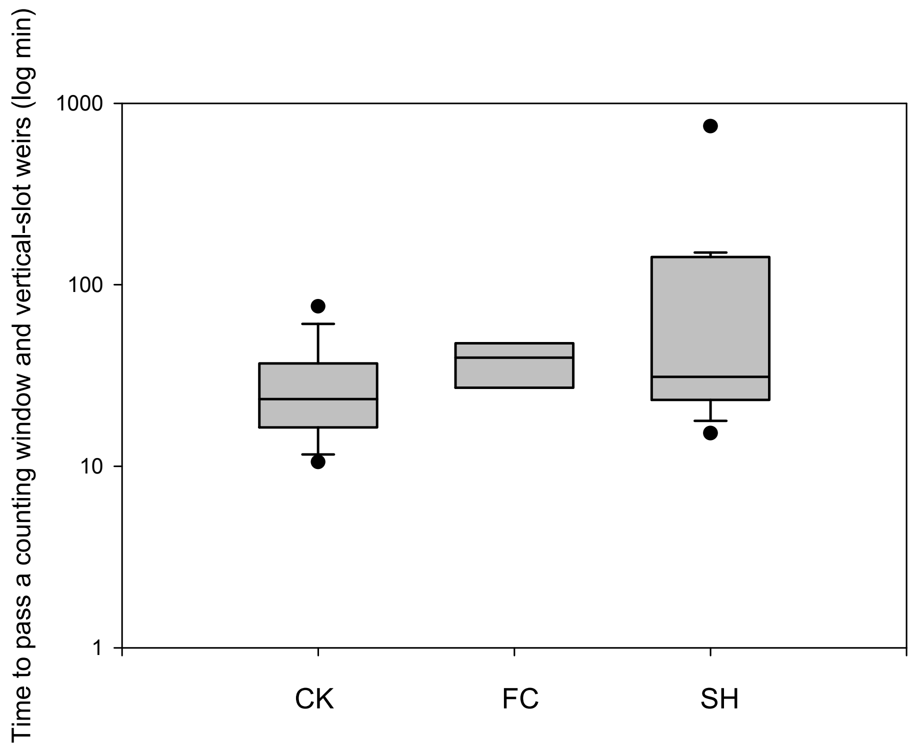

Figure 8. Median, quartile, 5th, 10th, 90th and 95th percentile counting window and vertical-slot weir (combined) passage times (min) for the North shore fishway at Ice Harbor Dam, 2003. CK = spring–summer Chinook salmon, FC = fall Chinook salmon, and SH = steelhead. Sample sizes are given in Table 6.

Table 9. Median, mean, standard deviation of the mean, range and sample sizes for counting window to ladder exit passage times for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at the North shore fishway at Ice Harbor Dam, 2003.

Year	Species (Run)	Med. (min)	Mean (min)	S.D. (min)	Range (min)	N
2003	CK	24.3	29.3	19.0	10.2 – 93.3	30
2003	FC	39.7	38.1	10.7	24.0 – 49.1	4
2003	SH	31.1	97.8	172.8	15.0 – 813.6	21

Passage Times as Proportions of Total Dam Passage Times

McNary Dam Counting Windows

Based on median values, counting window passage times accounted for ≤ 4.1% of the total dam passage times (Table 10). Using mean values, counting window passage times accounted for ≤13.4% of total dam passage times for fish initially detected at the Washington shore window and ≤ 7.5% for fish initially detected at the Oregon shore window. The highest median and mean values were for fall Chinook salmon at the Washington shore counting window during 2003. For some fish, the counting window passage time accounted for approximately 91% of their total dam passage time. The median dam passage time for all fish during both years was approximately 15 hours (*n* = 2,069).

Table 10. Median, mean, standard deviation of the mean, range and sample sizes for percentages of total passage times used by radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) to pass a counting window after initially being recorded downstream of the Oregon shore or Washington shore counting windows at McNary Dam, 2002-2003.

		Oregon shore					Washington shore				
Year	Species	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N
2002	CK	1.9	7.5	16.6	0.1 -90.6	321	2.8	8.5	16.0	0.2 – 85.1	280
2002	FC	1.5	3.5	8.8	0.1 – 67.5	137	2.9	10.8	20.3	0.1 – 83.7	139
2002	SH	1.2	3.4	8.4	0.1 – 78.4	406	1.5	6.0	14.7	0.1 – 89.7	105
2003	CK	1.8	6.3	12.9	0.1 – 66.0	216	3.7	9.7	16.2	0.1 – 80.1	230
2003	FC	1.9	5.7	11.9	0.3 – 69.3	71	4.1	13.4	21.8	0.2 – 88.1	46
2003	SH	1.7	5.3	10.1	0.1 – 71.2	106	1.8	2.2	2.1	0.3 – 7.5	12

Ice Harbor Dam North shore Counting Window

Counting window passage times comprised approximately 2% of the total dam passage times for all three runs based on median values and ≤ 4.7% based on mean values (Table 11). The median dam passage time for all fish initially detected at the North shore counting window was approximately 14 hrs (*n* = 26).

Table 11. Median, mean, standard deviation of the mean, range and sample sizes for percentages of total passage times used by radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) to pass a counting window after initially being recorded downstream of the North shore counting window at Ice Harbor Dam, 2003.

Year	Species (Run)	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N
2003	CK	2.0	2.7	3.3	0.1 – 10.8	13
2003	FC	2.4	4.7	6.1	< 0.1 – 11.7	3
2003	SH	2.3	3.3	3.2	0.1 – 10.3	10

McNary Dam Adjustable Overflow Weirs

Adjustable overflow weir passage times comprised ≤ 3% of total dam passage times based on median values and ≤ 4.5% based on mean values (Table 12).

Table 12. Median, mean, standard deviation of the mean, range and sample sizes for percentages of total passage times used by radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) to pass a vertical-slot weirs after initially being recorded downstream from the Oregon and Washington shore vertical-slot weirs at McNary Dam, 2002-2003.

		Oregon shore					Washington shore				
Year	Species	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N
2002	CK	1.4	2.2	3.4	0.1 - 30.2	320	1.7	3.6	6.5	0.1 – 57.6	281
2002	FC	2.6	4.3	8.0	0.2 – 89.4	147	2.6	4.5	7.7	0.1 – 70.8	129
2002	SH	1.8	3.2	5.9	0.1 – 73.2	408	1.1	4.4	12.8	0.1 – 88.8	103
2003	CK	1.7	2.8	5.1	0.1 – 62.8	220	1.9	3.5	6.3	0.1 – 55.5	226
2003	FC	3.0	5.5	8.4	0.5 – 56.3	71	2.3	4.2	8.2	0.2 – 55.5	46
2003	SH	2.8	4.6	7.0	0.2 – 53.4	105	1.7	3.0	3.0	0.4 – 8.5	12

Ice Harbor North shore Vertical-slot Weirs

Vertical-slot weir passage times accounted for < 1% of the total dam passage time for fall Chinook salmon and as much as 2.2% of the total dam passage time for spring–summer Chinook salmon (Table 13) based on median values. On average, vertical-slot weir passage times comprised 1.4 – 6.2% of the total dam passage times among the three runs.

Table 13. Median, mean, standard deviation of the mean, range and sample sizes for percentages of total passage times used by radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) to pass a vertical-slot weirs after initially being recorded downstream of the North shore vertical-slot weirs at Ice Harbor Dam, 2003.

Year	Species (Run)	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N
2003	CK	2.2	2.6	2.8	0.1 – 9.7	13
2003	FC	0.8	1.4	1.6	0.1 – 3.3	3
2003	SH	1.6	6.2	12.7	0.5 – 41.8	10

McNary Dam Counting Windows and Adjustable Overflow Weirs Combined

With both fishways and years included, the combined passage of counting windows and vertical-slot weirs at the termini of McNary Dam fishways accounted for 3.1 – 6.6% of total median dam passage times and 5.1 – 17.3% based on mean values (Table 14).

Table 14. Median, mean, standard deviation of the mean, range and sample sizes for percentages of total passage times used by radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) to pass counting windows and adjustable overflow weirs (combined) after initially being recorded downstream of the Oregon shore or Washington shore counting windows at McNary Dam, 2002-2003.

		Oregon shore					Washington shore				
Year	Species	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N
2002	CK	3.9	9.6	16.7	0.1 – 91.0	321	5.4	12.0	17.0	0.2 – 85.6	280
2002	FC	4.6	8.0	11.9	0.3 – 89.7	137	6.7	15.0	20.7	0.3 – 84.6	139
2002	SH	3.4	6.5	10.8	0.1 –79.0	406	3.4	9.5	17.8	0.1 - 89.9	105
2003	CK	4.2	8.9	13.0	0.1 – 68.5	216	6.7	12.5	16.1	0.2 – 80.3	230
2003	FC	6.5	9.8	12.2	1.4 – 70.7	71	8.5	17.3	22.1	1.1 – 88.3	46
2003	SH	6.6	10.0	12.0	0.3 – 72.2	105	3.1	5.1	4.2	0.7 – 11.8	12

Ice Harbor North shore Counting Window and Vertical-slot Weirs Combined

The combined passage of the counting window and vertical-slot weirs at the terminus of the North shore fishway of Ice Harbor Dam accounted for 3.2 – 5.6% of total dam passage times based on median values and 5.4 – 14.7% based on mean values (Table 15).

Table 15. Median, mean, standard deviation of the mean, range and sample sizes for percentages of total passage times used by radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) to pass the counting window and vertical-slot weirs (combined) after initially being recorded downstream of the North shore vertical-slot weirs at Ice Harbor Dam, 2003.

Year	Species (Run)	Med. (%)	Mean (%)	S.D. (%)	Range (%)	N
2003	CK	4.6	5.4	4.7	0.2 – 12.3	13
2003	FC	3.2	6.1	7.8	0.1 – 14.9	3
2003	SH	5.6	14.7	23.5	0.9 – 78.0	10

Correlation Analyses

Because counting window passage time is a component of total dam passage time, we know the two parameters are not independent. The same is true for adjustable overflow and vertical-slot weir passage times. However, if the counting windows or weirs at McNary Dam or the North shore fishway of Ice Harbor Dam were impediments to adult salmon and steelhead passage during 2002-2003, we should have consistently observed high counting window or weir passage times associated with high total dam passage times. Conversely, if fish with high total dam passage times had low counting window or vertical-slot weir passage times, the strength of the relationship between counting window passage time and total dam passage time would be diminished.

When we combined data from all runs and both years at McNary Dam, we found significant, positive correlations between total dam passage times and counting window or adjustable overflow weir passage times for the two fishways, but the r^2 values were ≤ 0.10 (Figure 9). This suggests that while fish with high counting window or weir passage times tended to have high total dam passage times at McNary Dam, the relationship was weak.

The slopes for the linear correlation equations from the North shore window or weirs of Ice Harbor Dam were not significantly different from zero and the r^2 values were ≤ 0.14 (Figure 10). The non-significant slopes for the Ice Harbor data suggest there was no association between counting window or vertical-slot weir passage times and total dam passage times.

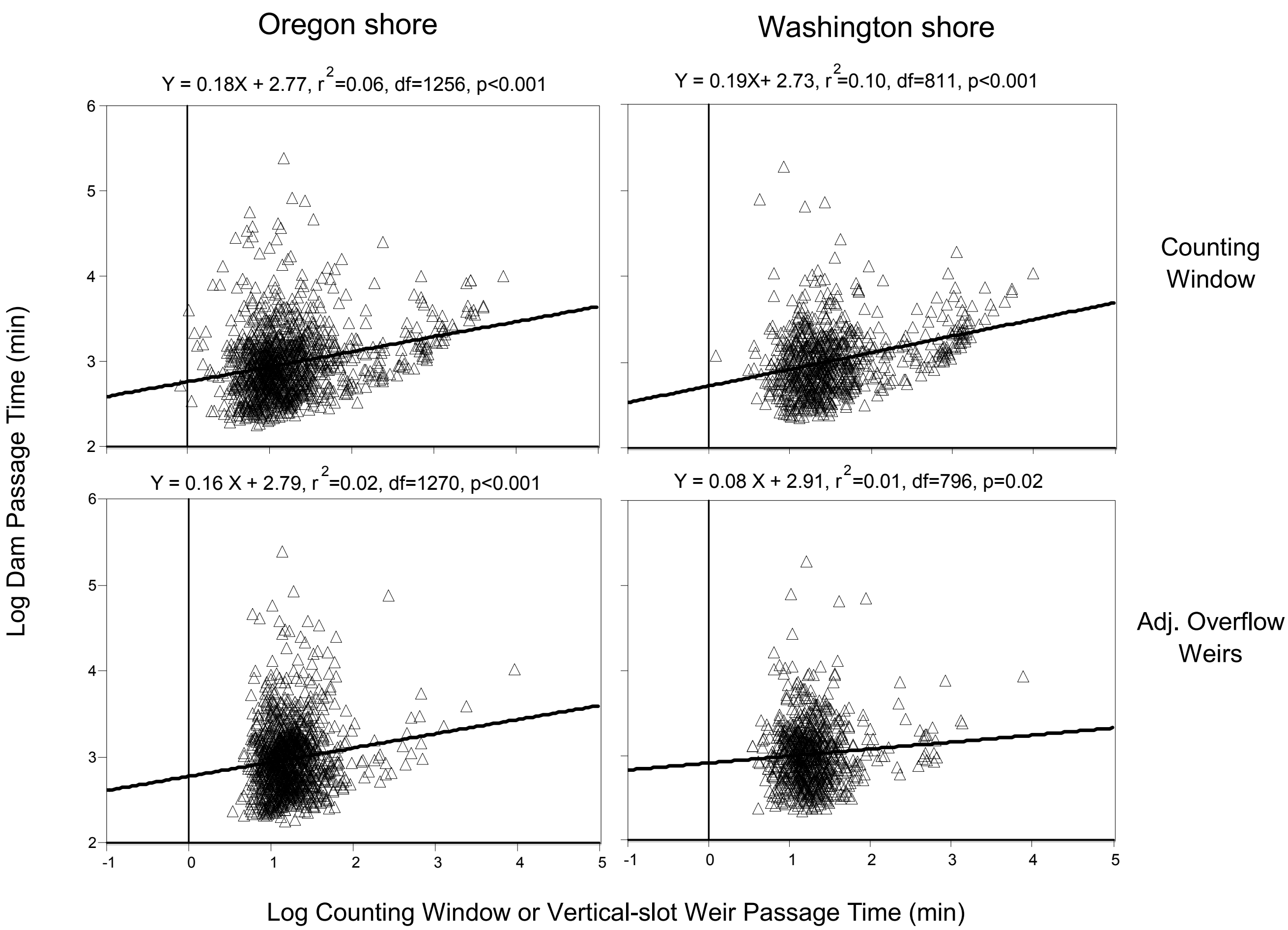

Figure 9. Linear regression models of log-transformed counting window or adjustable overflow weir passage times with log-transformed total dam passage times for spring–summer and fall Chinook salmon and steelhead in the Oregon and Washington shore fishways at McNary Dam, 2002-2003.

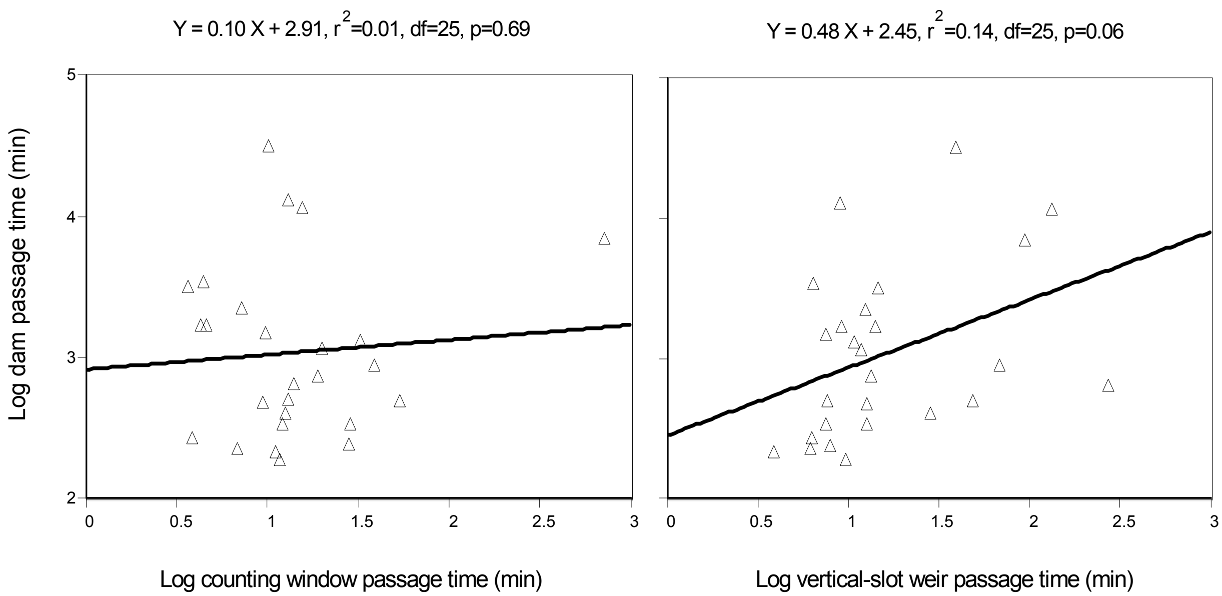

Figure 10. Linear correlation models of log-transformed counting window or vertical-slot weir passage times with log-transformed total dam passage times for spring−summer and fall Chinook salmon, and steelhead in the North shore fishway at Ice Harbor Dam, 2003.

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

Among the twelve run/year/fishway combinations at McNary Dam, no regression models for counting window passage times and fish counts produced a slope significantly different from zero (Table 16). Generally, little variation in weekly median counting window passage times was explained by the fish count data. Nine of the twelve models had r^2 values less than 0.06. The results for North shore counting window at Ice Harbor Dam were similar to those for McNary Dam in that no regression model for counting window passage times and fish counts produced a slope significantly different from zero (Table 17).

Table 16. Regression coefficients and significance levels for weighted regression models where median weekly counting window passage times at McNary 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.

		Oregon shore					Washington Shore				
Year	Species (Run)	r^2	*P*	*Slope*	*Intercept*	*df*	r^2	*P*	*Slope*	*Intercept*	*df*
2002	CK	0.01	0.64	-0.00010	20.04	17	0.21	0.07	-0.00141	31.51	16
2002	FC	0.06	0.41	-0.00035	12.81	12	0.13	0.21	-0.10070	256.96	13
2002	SH	0.01	0.70	0.00017	8.74	23	0.02	0.54	-0.00631	46.17	23
2003	CK	0.01	0.69	-0.00157	50.89	20	0.06	0.28	-0.00035	32.40	22
2003	FC	0.17	0.21	-0.00151	26.95	10	0.01	0.71	-0.00332	40.70	12
2003	SH	0.02	0.58	-0.00095	20.99	20	< 0.01	0.89	-0.00244	65.42	14

Table 17. Regression coefficients and significance levels for weighted regression models where median weekly counting window passage times at the North shore ladder of Ice Harbor 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.

		North shore				
Year	Species (Run)	r^2	*P*	*Slope*	*Intercept*	*df*
2003	CK	0.02	0.67	-0.00819	17.08	12
2003	FC	0.27	0.48	0.03810	7.90	3
2003	SH	0.08	0.44	0.00471	12.82	9

One of the twelve models associated with adjustable overflow weir passage times at McNary Dam produced a slope significantly different from zero: spring–summer Chinook salmon in the Washington shore weirs during 2002 (Table 18). As with counting window regression models, little variation in weir passage times was explained by the fish count data. Eleven of the twelve models had r^2 values less than 0.16. There were no regression models for Ice Harbor vertical-slot weir passage times and fish counts that produced a slope significantly different from zero (Table 19).

Table 18. Regression coefficients and significance levels for weighted regression models where median weekly adjustable overflow weir passage times at McNary 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.

		Oregon shore					Washington Shore				
Year	Species (Run)	r^2	*P*	*Slope*	*Intercept*	*df*	r^2	*P*	*Slope*	*Intercept*	*df*
2002	CK	0.14	0.12	0.00030	15.17	17	0.28	0.03	0.00068	16.26	16
2002	FC	0.02	0.62	-0.00028	21.65	12	0.04	0.48	-0.00084	18.34	13
2002	SH	0.02	0.51	0.00027	12.85	23	0.02	0.47	-0.00409	28.90	23
2003	CK	< 0.01	0.94	-0.00025	27.89	20	< 0.01	0.86	-0.00003	18.90	22
2003	FC	0.16	0.23	0.00043	18.71	10	0.01	0.73	0.00158	17.77	12
2003	SH	0.05	0.33	0.00018	13.83	20	< 0.01	0.84	-0.00022	17.70	13

Table 19. Regression coefficients and significance levels for weighted regression models where median weekly vertical-slot weir passage times at the North shore ladder of Ice Harbor 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.

		North shore				
Year	Species (Run)	r^2	*P*	*Slope*	*Intercept*	*df*
2003	CK	0.10	0.29	-0.01201	16.82	12
2003	FC	0.08	0.08	-0.09225	49.15	3
2003	SH	0.08	0.43	-0.11716	68.69	9

Over half of the models produced negative slopes (although not significantly different from zero), which on their face, suggest that high fish counts catalyze the movements of radio-tagged fish past the windows and weirs. Based on these analyses, we believe any effects of high fish counts on counting window or vertical-slot weir passage times were negligible.

Salmon and Steelhead Swimming to Transition Pools after Being Recorded at Counting Windows or in Weirs

The maximum proportion of any group recorded swimming to a transition pool after being recorded downstream of a counting window was 9.5% for fall Chinook salmon in the Washington shore fishway in 2002 (Table 20). With both years combined, spring–summer Chinook salmon had the highest proportion of fish swimming downstream to a transition pool (4.7%, n = 1,388) among the three runs. Within runs and years, the proportion of fish recorded swimming to a transition pool was consistently higher in the Washington shore fishway as compared to the Oregon shore fishway. Overall, slightly more than 3% (n = 3,242) of the radio-tagged fish initially recorded downstream from a counting window swam downstream to a transition pool. The median time to pass a counting window for all fish recorded swimming to a transition pool from a counting window was 1,354 minutes, or approximately 23 h (n = 99). One fall Chinook salmon swam past the Oregon shore counting window, swam downstream to a transition pool and did not pass the dam.

Table 20. Frequency, percentage, median passage time, and sample size of radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) recorded swimming to a transition pool after being recorded downstream from a counting window in the Oregon or Washington shore fishways at McNary Dam, 2002-2003.

		Oregon shore			Washington shore		
Year	Species	Freq.	Percent	N	Freq.	Percent	N
2002	CK	19	4.8	396	21	6.0	352
2002	FC	0	0.0	229	23	9.5	242
2002	SH	0	0.0	643	3	1.9	156
2003	CK	10	3.3	300	15	4.4	340
2003	FC	1	0.6	158	5	4.0	126
2003	SH	1	0.4	258	2	4.8	42

No fish were recorded swimming to a transition pool from the counting window in the North shore ladder of Ice Harbor Dam during 2003.

In contrast to counting windows, very few fish were recorded swimming to a transition pool after being recorded in the adjustable overflow weirs at McNary Dam. The maximum proportion of any group recorded swimming to a transition pool after being recorded in the adjustable overflow weirs was 1.3% for fall Chinook salmon in the Oregon shore fishway during 2002 (Table 21). Overall, 0.2% (*n* = 3,152) of the radio-tagged fish recorded in the adjustable overflow weirs of McNary Dam during both study years swam downstream to a transition pool. The median adjustable overflow weir passage time for these fish was 1,315 min, or about 22 h (*n* = 6).

Table 21. Frequency, percentage, median vertical-slot weir passage time, and sample sizes of radio-tagged spring−summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) recorded swimming to a transition pool after being recorded in the adjustable overflow weirs of the Oregon or Washington shore fishways at McNary Dam, 2002-2003.

		Oregon shore			Washington shore		
Year	Species	Freq.	Percent	N	Freq.	Percent	N
2002	CK	0	0.0	387	0	0.0	342
2002	FC	1	0.4	238	1	0.4	222
2002	SH	0	0.0	635	0	0.0	147
2003	CK	1	0.3	297	1	0.3	332
2003	FC	2	1.3	155	0	0.0	120
2003	SH	0	0.0	236	0	0.0	41

Some fish that approached or even passed a counting window swam downstream to a transition pool and did not pass the dam. Two fall Chinook salmon during 2002, and one fall Chinook salmon during 2003 did not pass the dam after being recorded on antennas upstream of a counting window. Of the 3,243 total radio-tagged fish recorded downstream of a counting window during both years, 3,240 (99.9%) ultimately passed the dam.

At Ice Harbor Dam, two fish were recorded swimming downstream to a transition pool from the vertical-slot weirs in the North shore fishway and they ultimately passed the dam via the South shore ladder (Table 22). All fish recorded immediately downstream of the North shore counting window ultimately passed the dam.

Table 22. Frequency, percentage, median passage time, and sample size of radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) recorded swimming to a transition pool after being recorded in the vertical-slot weirs in the North shore fishway at Ice Harbor Dam, 2003.

		North shore		
Year	Species	Freq.	Percent	N
2003	CK	1	3.2	30
2003	FC	0	0	4
2003	SH	1	4.6	22

Up-and-back Behavior

Some fish were recorded upstream of a counting window and then downstream of a counting window, an event we termed up-and-back behavior. Of the 3,243 unique fish recorded downstream of a counting window at McNary Dam during the two study years, 63 (1.9%) exhibited up-and-back behavior at a counting window.

All runs consistently exhibited greater proportions of up-and-back behavior after being detected at the Washington shore counting window as compared to the Oregon shore counting window (Table 24). With years combined, fall Chinook salmon exhibited the highest proportion of up-and-back behavior (2.6%, n = 756), followed by steelhead (1.8%, n = 1,099) and spring–summer Chinook salmon (1.7%, n = 1,388)

Table 24. Frequency, percentage, and sample sizes of radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) recorded upstream and then downstream of a counting window in the Oregon or Washington shore fishways at McNary Dam, 2002-2003.

		Oregon shore			Washington shore		
Year	Species	Freq.	Percent	N	Freq.	Percent	N
2002	CK	3	0.8	396	6	1.7	352
2002	FC	5	2.2	229	7	2.9	242
2002	SH	10	1.6	643	7	4.5	156
2003	CK	5	1.7	300	9	2.7	340
2003	FC	2	1.3	158	6	4.7	127
2003	SH	0	0.0	258	3	7.1	42

Of the total 63 fish that exhibited up-and-back behavior at McNary Dam, five (8%) swam downstream to a transition pool. By subtraction, 58 (92%) of the fish exhibiting up-and-back behavior swam upstream and passed the dam via the same counting window/fishway where they were initially recorded. One fall Chinook salmon swam downstream to a transition pool from the Washington shore adjustable overflow weirs in 2003 and did not pass the dam. Another fall Chinook salmon exhibited up-and-back behavior at the Washington shore counting window, swam to a transition pool, and passed the dam via the Oregon shore fishway. The median time to pass a counting window for the 62 up-and-back fish that passed the dam was 42.9 min, approximately 28 min higher than the median counting window passage time for all fish during both years (15.3 min, n = 3,241). The median counting window passage time for fish that exhibited up-and-back behavior, swam to a transition pool, and passed the dam was 1,926 min, or approximately 32 hours (n = 4).

Spring–summer Chinook salmon were the only run of fish to exhibit up-and-back behavior at the North shore counting window of Ice Harbor Dam during 2003 (Table 25). The median counting window passage time for the seven spring–summer Chinook salmon that exhibited up-and-back behavior was 10.4 min, slightly less than the median counting window passage time for all fish (13.0 min, n = 55) but slightly higher than the median counting window passage time for spring–summer Chinook salmon (9.9 min, n = 30)

Table 25. Frequency, percentage, and sample sizes of radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) recorded upstream and then downstream of a counting window in the North shore fishway at Ice Harbor Dam, 2003.

		North shore		
Year	Species	Freq.	Percent	N
2003	CK	7	23.3	30
2003	FC	0	0	4
2003	SH	0	0	22

Diel Effects on Counting Window Passage Times

We compared the counting window passage times of salmon and steelhead that were first detected downstream of a counting window during the day (0500 to 2100) and night. Relatively few salmon and steelhead were initially recorded downstream of a counting window at McNary Dam during the night but those that were had substantially higher median and mean counting window passage times (Table 26).

Table 26. Median, mean, and sample sizes for counting window passage times based on day or night arrivals for radio-tagged spring–summer Chinook salmon (CK), fall Chinook salmon (FC), and steelhead (SH) at Oregon (OR) and Washington shore (WA) counting windows at McNary Dam, 2002-2003.

			Night			Day		
Year	Fishway	Species (Run)	Med.(min)	Mean(min)	N	Med. (min)	Mean (min)	N
2002	OR	CK	605.3	590.8	11	18.8	176.6	385
2002	OR	FC	725.0	725.0	2	10.3	30.1	227
2002	OR	SH	703.5	713.3	7	8.6	24.4	636
2003	OR	CK	580.8	634.8	10	14.0	92.5	290
2003	OR	FC	870.0	805.7	5	10.9	44.4	153
2003	OR	SH	571.7	587.1	9	8.7	28.0	249
2002	WA	CK	676.8	665.6	10	23.6	145.2	342
2002	WA	FC	818.4	851.5	8	17.7	146.5	233
2002	WA	SH	672.2	716.5	3	13.9	114.1	153
2003	WA	CK	646.8	657.1	12	28.9	157.1	328
2003	WA	FC	732.2	726.2	6	23.5	138.6	120
2003	WA	SH	609.4	609.4	2	12.6	61.5	40

There was one steelhead initially recorded downstream from the North shore counting window at Ice Harbor Dam during the night and it passed the counting window in approximately ten minutes.

Discussion

For the majority of radio-tagged adult salmon and steelhead, the counting windows and adjustable overflow weirs were not impediments to passing McNary Dam during 2002 or 2003. A similar argument can be made for the North shore counting window and vertical-slot weirs at Ice Harbor Dam during 2003. These assertions are based on the high passage efficiency of salmon and steelhead recorded downstream of a counting window (99.9% - McNary Dam, 100% - North shore of Ice Harbor Dam). In contrast, Ocker et al. (2001) state counting windows at Bonneville Dam consistently obstructed the passage of (adult) radio-tagged lamprey in1998 and 1999 and cited counting window passage efficiencies of 78% (*n*=49) and 63% (*n*=59), respectively.

While window and weir passage times at McNary Dam comprised higher proportions of total dam passage times (window: ≤ 4.1% *median*, <13.4% *mean*; weir: <5% *median*, ≤ 9% *mean*) than those observed at Bonneville Dam (window: ≤ 1.0% *median,* ≤ 6.7% *mean*; weir: ≤3.8% *median*, ≤7.3% *mean)* during 2001 and 2002 (Jepson et al., 2004), we believe this was due in part to the lower median dam passage time observed at McNary Dam (~15 hrs) during 2002 and 2003 as compared to Bonneville during 2001 and 2002 (~23 hrs). In absolute terms, 75% of all fish recorded passing a counting window at McNary Dam (independent of fishway) did so in less than 32 min. The upper quartile counting window passage time at the North shore counting window at Ice Harbor Dam was <19 min.

As past the counting windows at Bonneville Dam during 2001 and 2002, spring–summer Chinook salmon had the highest window passage times at McNary Dam during 2002 and 2003. Water temperatures are typically cooler during the migration of spring–summer Chinook salmon and this may explain the higher median counting window and vertical-slot weir passage times as compared to fall Chinook salmon and steelhead. In contrast to the data from Bonneville and McNary dams, spring–summer Chinook salmon had the lowest median counting window passage times among the three runs at the North shore window of Ice Harbor Dam, although sample sizes were relatively low. Fall Chinook salmon had the lowest median counting window passage times at Bonneville Dam during 2001 and 2002 but steelhead had the lowest median counting window passage times at McNary Dam during 2002 and 2003.

The median counting window passage times for the Washington shore fishway at McNary Dam were as much as two times those for the Oregon shore fishway (steelhead and fall Chinook salmon during 2003). While direct comparisons of passage times are compromised by differences in distances between antennas, the magnitude of these differences, while on the order of minutes, suggest that the configuration of the Washington shore counting window contributes to higher window passage times in general. We speculate that if a single counting window may impede adult fish passage, the presence of the two additional windows for visitor's viewing in the Washington shore fishway may compound their potential for inhibiting fish movements.

Generally, there was little difference among fishways with respect to adjustable overflow weir passage times at McNary Dam. Specifically, the upper quartile weir passage time for all runs and years combined was 23.1 and 26.1 min for the Oregon and Washington shore fishways, respectively. Steelhead, which consistently had the lowest passage rates at overflow weirs downstream from the counting windows, also had the lowest median passage times through the adjustable overflow weirs. Annual differences among counting window and vertical-slot weir passage times in the two fishways were small.

The relationship between counting window or vertical-slot weir passage times and total passage times was weak, suggesting high dam passage times at McNary Dam during 2002 and 2003 were not directly related to the attributes of the counting windows or weirs. For the North shore fishway at Ice Harbor Dam during 2003, there was no significant correlation between counting window or vertical-slot weir passage times and dam passage times. Our findings that fish counts were poor predictors of window or weir passage times at McNary and Ice Harbor dams were consistent with similar analyses conducted with Bonneville Dam data collected during 2001 and 2002 (Jepson et al. 2004).

Fish that swam downstream to transition pools at McNary Dam consistently had the highest counting window and weir passage times but fish that did so comprised a relatively small proportion of all fish recorded at a counting window (~ 3%, *n* = 3,242). The proportion of fish swimming to a transition pool after being recorded at a counting window at McNary Dam however, was approximately six times higher than the proportion recorded doing so at Bonneville Dam during 2001 and 2002 (~0.5%, *n* = 4,277).

Fish that exhibited up-and-back behavior at McNary Dam had high median counting window passage times; especially if they also swam to a transition pool. Most fish (92%) exhibiting up-and-back behavior at McNary Dam did not swim to a transition pool, however. In contrast, spring–summer Chinook salmon at the North shore fishway of Ice Harbor Dam exhibited a relatively high proportion of up-and-back behavior (~23%) but their median counting window passage time was slightly less than the median counting window passage time for all fish not exhibiting the behavior.

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