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EVALUATION OF ADULT CHINOOK SALMON PASSAGE AT PRIEST RAPIDS DAM WITH ORIFICE GATES OPEN AND CLOSED

by

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Abstract

Radio-tagged adult spring and summer chinook salmon were monitored to evaluate passage condition at Priest Rapids Dam, mid-Columbia River, during 1996. Passage times were assessed during two treatment conditions: half the powerhouse orifice gates open and all orifice gates closed. Travel times from first record in the tailrace to first approach at the dam, to first entry into the fishway, first entry to the junction pool , and to pass the dam were not significantly different with respect to orifice gate closure. Of 119 radio-tagged chinook salmon monitored at Priest Rapids Dam, 115 salmon eventually crossed the dam. Salmon entered the fishway collection channel mainly at the east-shore and west-powerhouse entrances. There were more entries than exits at the east entrance, but more exits than entries at the west-powerhouse openings. Half the radio-tagged chinook salmon passed Priest Rapids Dam in less than 37.6 h. About one-third of time to pass the dam was associated with movements in and out of the junction pool area. After entering the junction pool for the first time, most (79%) fish returned to the collection channel and then exited and re-entered the fishway an average of 6.5 times before successfully crossing the dam. Six fish fell back over the dam during this study, for a fallback rate of 5.2%. Four fish re-ascended the dam in an average of 9.8 days.

Introduction

Adult chinook salmon must pass five to nine dams to reach spawning grounds or hatcheries in the mid-Columbia River (Figure 1). In 1993, a radio-telemetry study was conducted by the National Marine Fisheries Service (NMFS) to evaluate fish passage conditions at the five mid-Columbia River dams (Stuehrenberg et al. 1995). Stuehrenberg et al. (1995) recommended that passage conditions at those dams may be improved by closing collection-channel entrances that had relatively low use. It is known that some entrances at dams are used significantly more frequently than others by migrating salmon (Bjornn et al. 1995). In addition, fish will exit some openings more than others (Bjornn and Peery 1992; Bjornn et al. 1995). The strategy of closing entrances is intended to concentrate flows at entrances used most by migrating adult salmon and reduce the number of exits from the fishway.

Two other sources of delay of fish, as identified by Stuehrenberg et al. (1995), were fallback over dams and time to pass through junction pools. Fallback is when a fish ascends a dam and then returns downstream by passing through the spillway, powerhouse, fishways or navigational lock. Junction pools are the transition area between collection channels and fish ladders and some adult salmon change direction of movement temporarily in that area. Hence, junction pools may be a potential area of significant passage delay at Columbia River dams.

Passage of adult spring and summer chinook salmon with transmitters was evaluated during the spring and summer of 1996 at Priest Rapids Dam to determine the effects of closing all orifice gates. We also assessed fallback of salmon at Priest Rapids Dam and monitored passage of fish through the junction pool of the powerhouse (east-shore) fishway.

Methods

Adult chinook salmon with transmitters were monitored as they migrated past Priest Rapids Dam during periods when half the orifice gates were open (normal operation) and when all gates were closed. Orifice gates were opened and closed on an alternating schedule throughout the period of salmon migration. Fixed-site receivers were used to record routes and time of passage

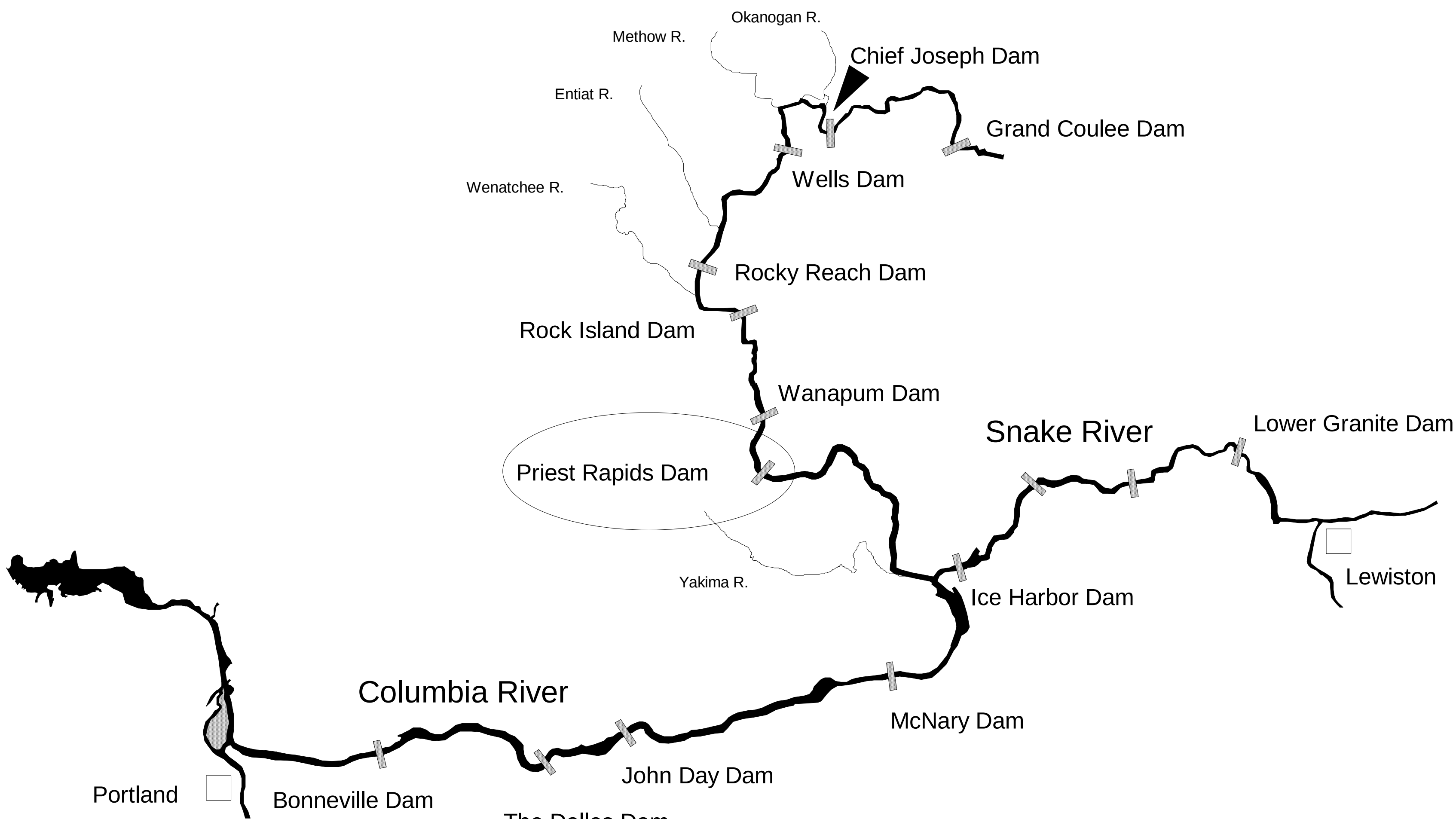

Figure 1. Location of Priest Rapids Dam.

through fishways by radio-tagged salmon. Fish used for this study were released with radio transmitters at Bonneville Dam (rkm 235.1) as part of the Lower Columbia River Adult Passage Project, funded by the U.S. Army Corps of Engineers and Bonneville Power Administration.

Study Site

Priest Rapids Dam is located at river kilometer (rkm) 638.9, between McNary (rkm 469.8) and Wanapum dams (rkm 669.0) (Figure 1). The dam consists of a 22-bay spillway adjacent to the west shore and a ten-turbine powerhouse adjacent to the east shore (Figure 2). There are two fishways, one along each shore. The west fishway, adjacent to the spillway, has a single entrance. The east fishway has two entrances at the east end of the powerhouse, (Lew4-5 and Lew6-7) but only one (Lew4-5) is typically kept open. A collection channel runs the length of the powerhouse and there are three large entrances at the western end (Lew1, 2 and 3) and 18 orifice gates (OG1 to OG18) along its downstream face. Collection channel entrances that were open during this study were Lew2 and Lew4-5 at all times and the odd-numbered orifice gates on an alternating schedule. All other gates were kept closed. The collection channel joins with the east fishway at the southeast corner of the powerhouse. The junction pool is the transition between the collection channel and the ladder, and varied in length depending on elevation of water in the tailrace (Figure 2). Priest Rapids Dam is operated by Grant County Public Utility District.

Tagging

Adult spring and summer chinook salmon were released with radio-transmitter tags near Bonneville Dam from 4 April to 27 June. Fish were collected using the trap facility located adjacent to the Washington-shore ladder. During the day, a picketed-lead weir was dropped into the ladder and adult migrants were diverted into the trap. Salmon swam from the trap into exit chutes and were diverted into an anesthetic tank (tricaine methanesulfonate) via electronically controlled guide gates. Anesthetized fish were moved to a smaller tank where lengths and presence of marks and injuries were recorded, and where fish were tagged. Each fish received a coded wire tag injected into the muscle near the dorsal fin, a numbered visual-implant (VI) tag injected under the clear tissue posterior to the eye and a radio transmitter was inserted into the

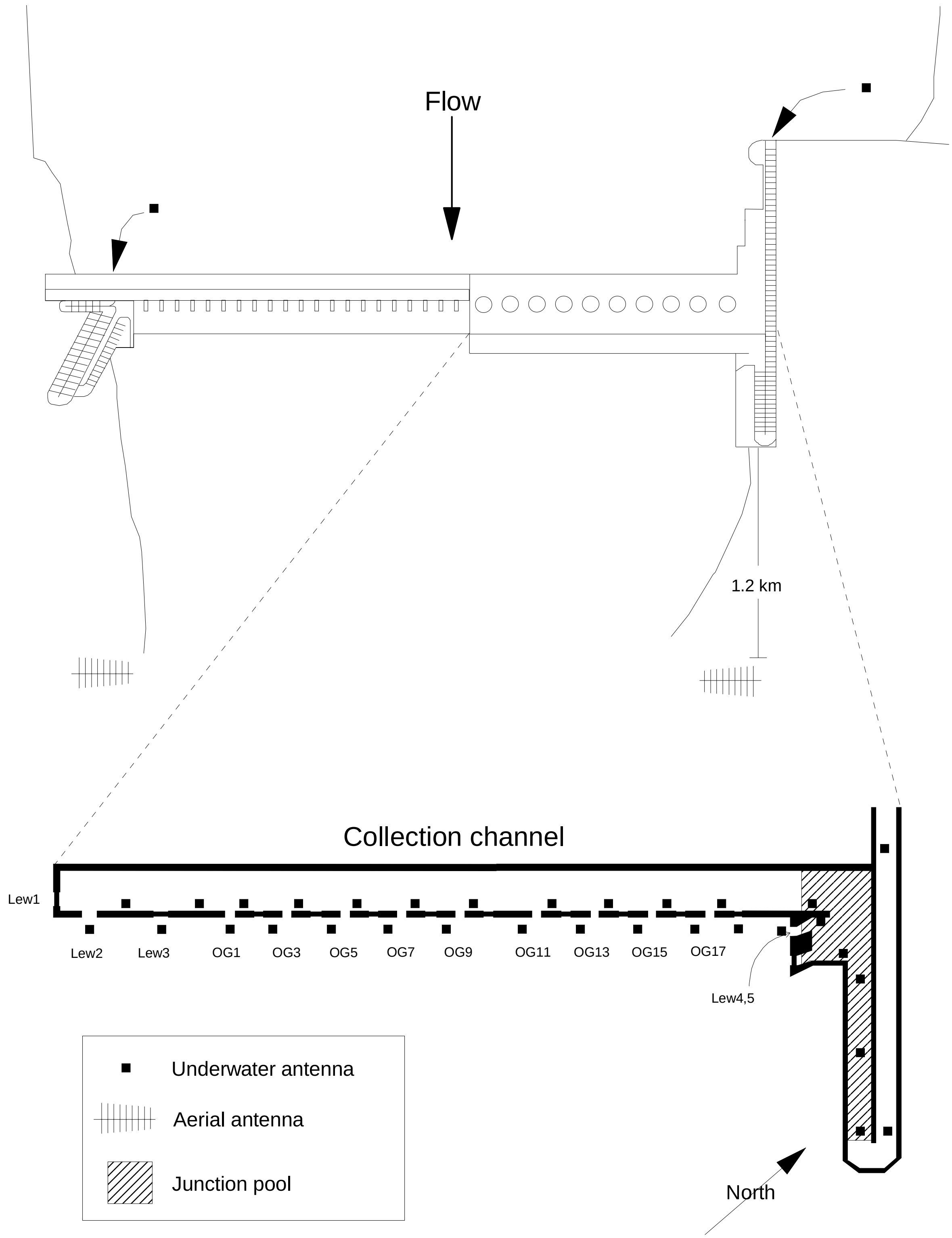

Figure 2. Study area at Priest Rapids Dam, showing placement of radio receiver antennas at the dam and collection channel. Entrances Lew2, Lew4-5 and odd numbered orifice gates were used during this study.

stomach through the mouth. Fish were then placed in an aerated tank on a trailer to recover. Fish were transported 8 km downstream from Bonneville Dam after tagging and released using an exit chute attached to the rear of the trailer. Of 853 adult chinook salmon tagged at Bonneville Dam, 703 were selected at random from the spring run and 150 from the summer run. "Jack" salmon were not tagged. Fork lengths of salmon tagged ranged from 57.5 to 125.0 cm.

Telemetry Monitoring

Radio transmitters and receivers used in this study were manufactured by Lotek Engineering Inc., of New Market, Ontario, Canada. Transmitters (80 mm long x 16 mm diameter) emitted a digitally coded signal every 5 seconds. Transmitter signals were interpreted by radio receivers as a unique numerical code on the transmitted channel (frequency). Transmitter frequencies ranged from 149.320 (channel 1) to 149.520 MHz (channel 11) in 0.02 MHz increments, excluding channels 2 and 3.

SRX-400 sequentially scanning receivers, set to scan channels for 6 seconds each, with two, 9-element Yagi antennas (one facing upstream and one facing downstream) were placed on each shore approximately 1.2 km downstream from the dam to record when fish entered the tailrace. Eight SRX receivers linked with digital-spectrum processors (DSP/SRX; can scan all channels simultaneously) were used to monitor fishway entrances and exits, and movement in the collection channel, junction pool and east ladder (Figure 2). Each DSP/SRX receiver monitored up to six coaxial-cable underwater antennas. The west-shore ladder entrance was not monitored but fish exiting the top of the west ladder were recorded. All receivers recorded and stored transmitter channel and code, relative power of signal, antenna receiving the signal, date and time. Stored information was downloaded from receivers to lap-top computers once a week.

Orifice gate treatments (half-open or all-closed) were alternated through the monitoring season, 1 May to 8 August. Orifice gates were maintained at a treatment setting until it was estimated that at least five radio-tagged fish had passed the dam, based on almost daily monitoring of fish recorded on receivers. Orifice gates were then changed to the other treatment that night, at around midnight.

Data Analysis

Downloaded data files were electronically transferred to the NMFS office in Seattle for initial processing. This involved screening each file of records and removing obvious errors and records produced from background electronic noise. Screened files were then transferred to the University of Idaho for coding. Coding involved inspection of all records for a fish and assigning a code to appropriate records that defined behavior of the fish (e.g. an entrance or exit from a fishway). Coding was facilitated by using an automated program developed with Arc View software package (Version 2 for Windows) to analyze receiver data from Priest Rapids Dam.

Coded data were used to identify movement patterns of radio-tagged fish at Priest Rapids Dam, and were also used to calculate four passage-time variables; time used by each fish to (1) first approach the dam, (2) first pass through a fishway entrance, (3) first enter the junction pool and (4) to pass over the dam. All travel times were determined from the time of the first record at a tailrace receiver site.

A block of time with one period when orifice gates were open and one period with them closed was the experimental unit during this study and mean travel times of fish in each period within a block represented a single replicate for analysis. Differences in travel times between periods when orifice gates were open and closed were tested using a split-block analysis of variance (ANOVA) model from SAS statistical package (SAS Institutes Inc. 1990). The block term was removed from the overall model if it was found to be insignificant and the analysis was rerun, testing for orifice gate status in a one-way ANOVA model. Analysis was also run after outlier records (those fish with passage times greater than 6 d) were removed from the database. The number of fish included in each period varied and depended on the orifice-gate pattern to which a fish was exposed (Figure 3). For example, if orifice-gate pattern changed between the time a fish first approached and first entered the collection channel, passage times for this fish were included in the analysis for first approaches but not for first entrances (Figure 3).

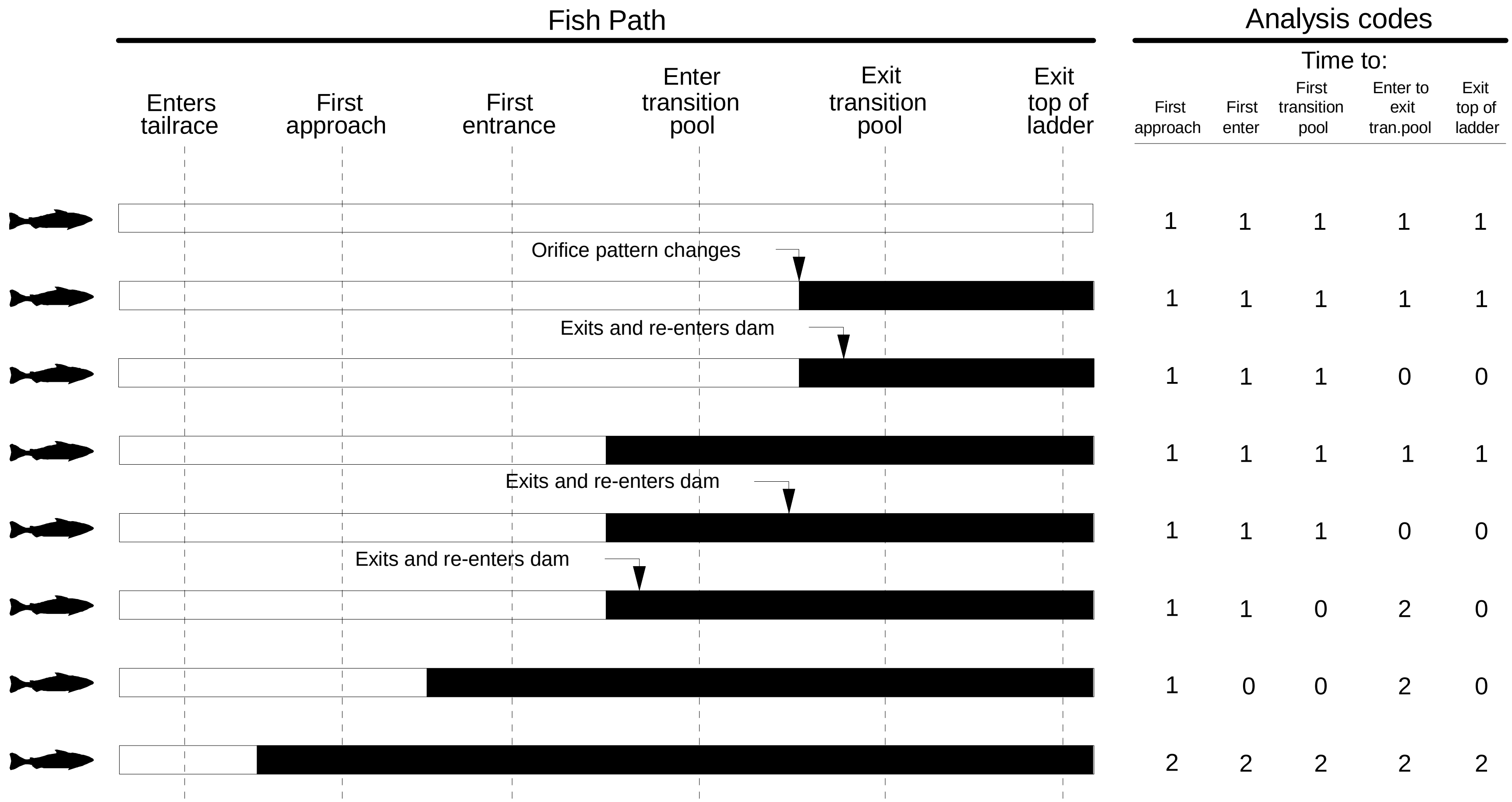

Figure 3. Illustration of process used to include or exclude travel time measurements of fish from analysis. Horizontal bars represent potential travel paths by radio-tagged chinook salmon and timing of change in orifice gate pattern (start of shaded area in bars) during a fishes passage. Codes indicate if a vairable ocurred during first (1) or second (2) orifice gate pattern or was not used in analysis (0). Changes in orifice pattern might have been from open to close setting, or vice versa.

Behavior of radio-tagged salmon in and through the junction pool was assessed by calculating the interval between first entrance to the pool and the last exit from the pool and by identifying patterns of behavior during that interval. Fallback of salmon over the dams was known to have occurred when fish that exited from top of the ladders were later recorded somewhere downstream of the dam. Delay caused from fallback events was the time required to re-ascend the dam after initial ladder exit.

Results

Radio telemetry data were collected at Priest Rapids Dam from 1 May to 8 August 1996, during which a total of 119 radio-tagged chinook salmon were recorded at Priest Rapids Dam receiver sites. The number of fish used to evaluate various passage characteristics varied according to the behavior of the fish after reaching the tailrace and timing of change in orifice gate setup. Daily river flows ranged from 110 to 282 kcfs and averaged 224.1 kcfs, and spill levels ranged from 0 to 133 kcfs and averaged 79.7 kcfs during the study period (Figure 4).

Effects of Orifice Gate Pattern

Five complete blocks of orifice gate settings were conducted during the spring of 1996 (Table 1, Figure 4), however few radio-tagged chinook salmon were recorded during the fifth block, so block five was not used in analysis. Closing all orifice gates did not significantly

Table 1. Experimental blocks of orifice gate settings and number of adult chinook salmon entering the tailrace and pass the dam during each period. Odd-numbered orifice gates were open during open setting, all orifice gates were closed during closed setting.

Block	Orifice setting	Days per treatment	Dates	Salmon passing dam
1	Open	21	1 May - 21 May	14
	Closed	15	22 May - 5 June	13
2	Open	11	6 June - 16 June	8
	Closed	13	17 June - 29 June	12
3	Open	4	30 June - 3 July	15
	Closed	1	4 July	11
4	Open	4	5 July - 8 July	17
	Closed	5	9 July - 13 July	18
5	Open	16	14 July - 29 July	6
	Closed	14	30 July - 12 August	2

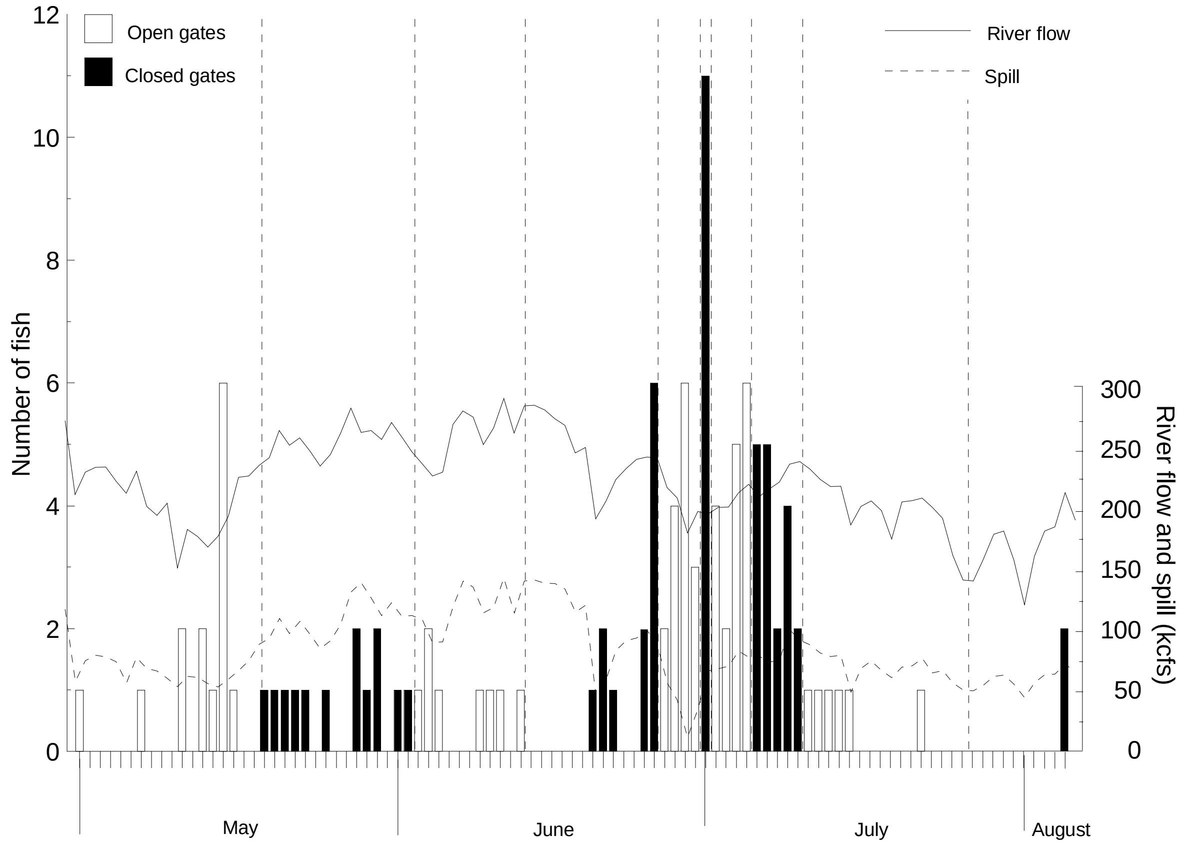

Figure 4. Distribution of the number of radio-tagged chinook salmon that passed Priest Rapids Dam during 1996 with river flows and spill levels during study period (right axis). White bars represent fish that passed the dam when orifice gates were open, black bars represent fish that passed over the dam when orifice gates were closed. Vertical dotted lines represent change in orifice gate setting.

increase the time of passage for adult salmon at Priest Rapids Dam in 1996. Lack of significance was probably related to low sample size (n =4 replicates of each treatment) which limited the power of analysis (generally < 35%) and increased the chance of making a type II error.

During the first block, mean times for salmon to approach the dam, enter the fishway, and pass over the dam were longer for fish that did so when orifice gates were closed versus times of fish that passed when orifice gates were open (Figures 5 and 6). During the second and third blocks, the reverse was observed, and during the fourth block, times were about equal. Overall

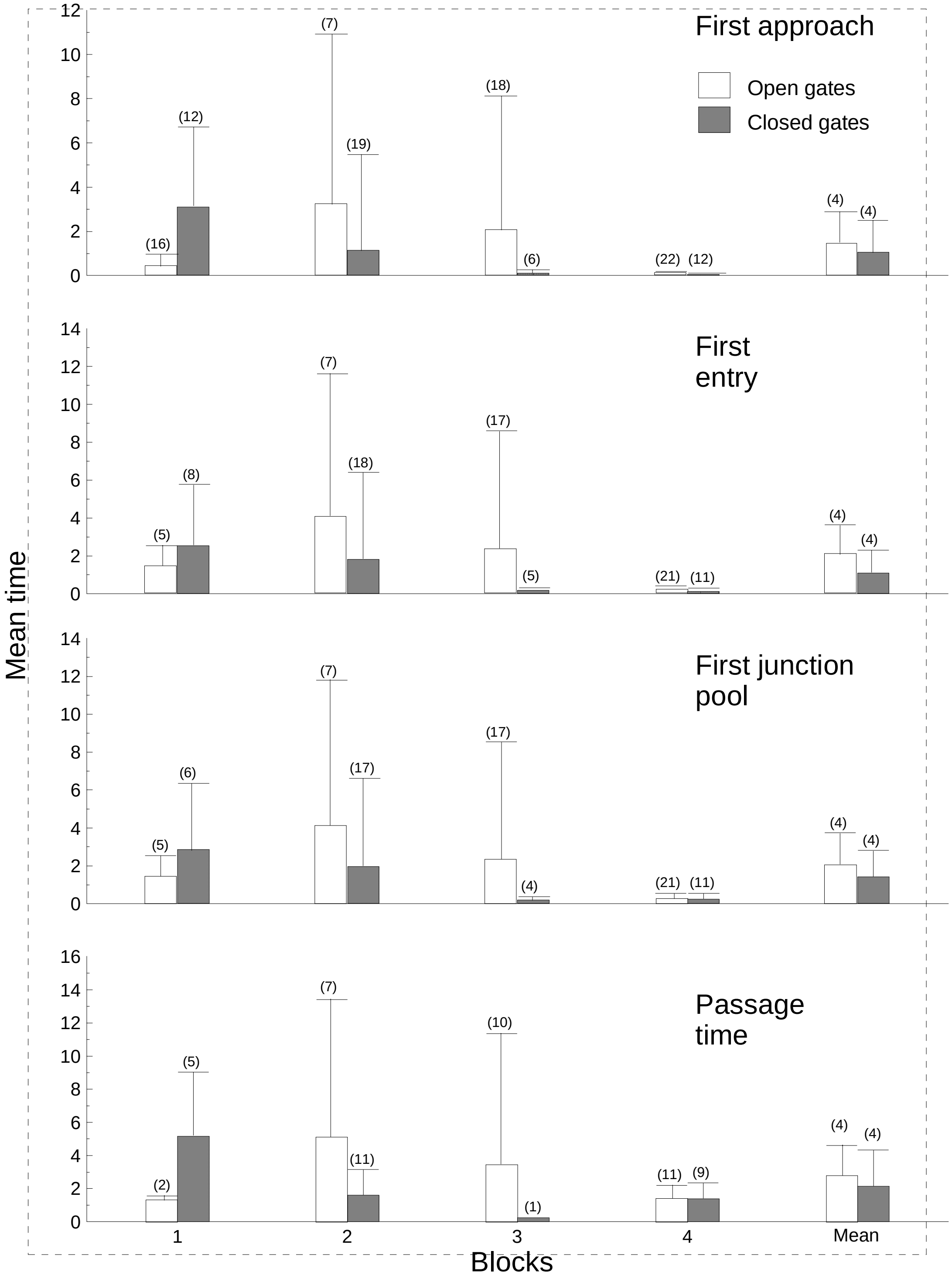

Figure 5. Mean passage times in days from tailrace to first approach, first entry, first entry to the junction pool, and total time to pass Priest Rapids Dam for radio-tagged chinook salmon with half the orifice gates open and orifice gates closed. Means are shown for the four blocks and overall treatment means. T-bars represent one standard deviation. Numbers in parenthesis represent number of fish per block.

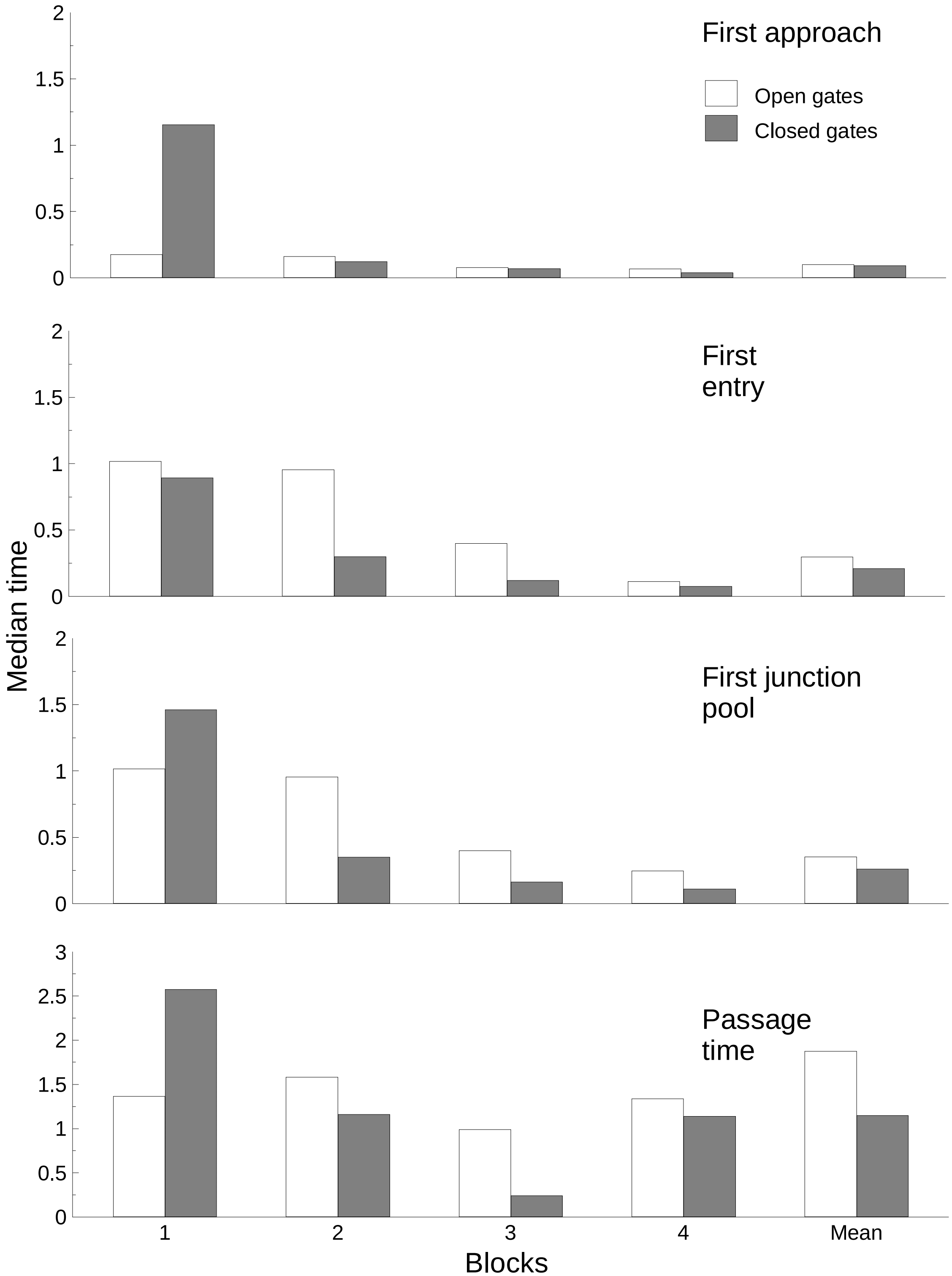

Figure 6. Median passage times in days from tailrace to first approach, first entry, first entry to the junction pool, and total time to pass Priest Rapids Dam for radio-tagged chinook salmon with half the orifice gates open and orifice gates closed. Medians are shown for the four blocks and overall treatment medians.

means of the four passage times were slightly higher when orifice gates were open versus closed, but differences between treatments were not significant (Figure 5). Since means can be skewed by outlier records, we reran the analysis after removing passage times that were longer than 6 d, which excluded three fish from open and two fish from closed orifice gate periods (Appendix A). Differences between treatments were again nonsignificant after outlier records were removed, but there was a significant block effect in the analysis for first entrances and arrival times to the junction pool. Block effects were caused from significantly lower passage times during blocks 3 and 4 than during blocks 1 and 2. Lower passage times may have been related to spill levels that were significantly lower during blocks 3 and 4 (averaged 57.5 kcfs, n = 14 d) than during blocks 1 and 2 (84.8 kcfs, n = 60 d) (Chi-square, P>0.01). River flow was not significantly different between blocks 1 and 2 (averaged 229.1 kcfs) and blocks 3 and 4 (202.5 kcfs) (Chi-square, P>0.05).

All passage variables used in analysis were calculated from the time of the first record by a fish at a tailrace receiver, as was done by Stuehrenberg et al. (1995). However, in telemetry studies conducted by Bjornn et al. (1994; 1995) on the lower Snake River, dam passage times were calculated from the last record at a tailrace receiver prior to the first approach by a fish at a dam. At Priest Rapids in 1996, the median time for radio-tagged chinook salmon between the first and last record at a tailrace receiver was 29 min and averaged 19.9 h. Using travel times calculated from the last record at tailrace receiver sites did not change the outcome of the analysis with respect to orifice gate status.

Approaches.--An approach to a fishway entrance was recorded when a fish came within range of an antenna outside fishway entrances. Fish can make multiple approaches by leaving and then returning to the dam. In this report we distinguish between the first approach and subsequent approaches. The number of radio-tagged fish recorded at tailrace receivers and then as they approached the dam for the first time within the same blocks ranged from 7 to 22 when orifice gates were open and 6 to 19 per block when orifice gates were closed (Figure 5). Mean overall times to approach the dam (time from first record at a tailrace receiver to first record at the dam) were 35.4 h when orifice gates were open and 26.4 h when orifice gates were closed, but the times were not significantly different (P>0.7277). Removing times longer than 6 d did not change the outcome of the analysis.

When orifice gates were open, first approaches by salmon were spread across the dam, with 23 (35.9%) at the west-powerhouse entrance (Lew2), 19 (29.7%) at orifice gates, 19 (29.7%) at the east-fishway entrance (Lew4-5), and 3 (4.7%) first approaches at unknown locations (Figure 7). Unknown approaches result when a fish is recorded on an antenna inside the collection channel without being previously recorded on an outside antenna. Unknown approaches (as well as unknown entrances, exits, etc.) may occur because of equipment failure (rare, see Appendix C) or, more likely, because a fish passed through the range of the underwater antenna (around 6 m) during the five second gap between transmitted signals. When orifice gates were closed, the distribution of first approaches was 16 (32.7%) at Lew2, 22 (44.9%) at Lew4-5, eight (16.3%) at orifice gates, and three (6.1%) at unknown locations.

Entrances.--A fish record was coded as an entry into the fishway when a record from an antenna inside the fishway was proceeded by a record on an antenna outside an entrance. Some fish entered and exited the fishway several times, but in this report the first entrance is the primary record of interest. Five to 21 fish were recorded as passing the tailrace receiver sites and entering the fishway the first time within a block when orifice gates were open and 5 to 18 fish per block when orifice gates were closed. Fish first entering at the west-shore fishway were not included in the analysis. Mean overall times to travel from time of the first record at the tailrace receivers to first entry averaged 48.5 h when orifice gates were open and 27.9 h when orifice gates were closed. These travel times were not significantly different between orifice gate settings (P>0.3700) (Figure 5). When passage times longer than 6 d were excluded from analysis, there again was no effect on passage time due to orifice gate setting (P>0.2543), but there was a significant block effect (P>0.0157) (Table 2). Passage times were significantly longer during blocks 1 and 2 than during blocks 3 and 4, which may have been related to higher spill levels during blocks 1 and 2 than during blocks 3 and 4.

When half the orifice gates were open, 30 radio-tagged salmon (58.8%) entered the fishway first at Lew4-5, 11 fish (21.6%) at Lew2, 3 at OG17 (5.9%) 1 at OG5 (2.0%), and 6 fish (11.8%)

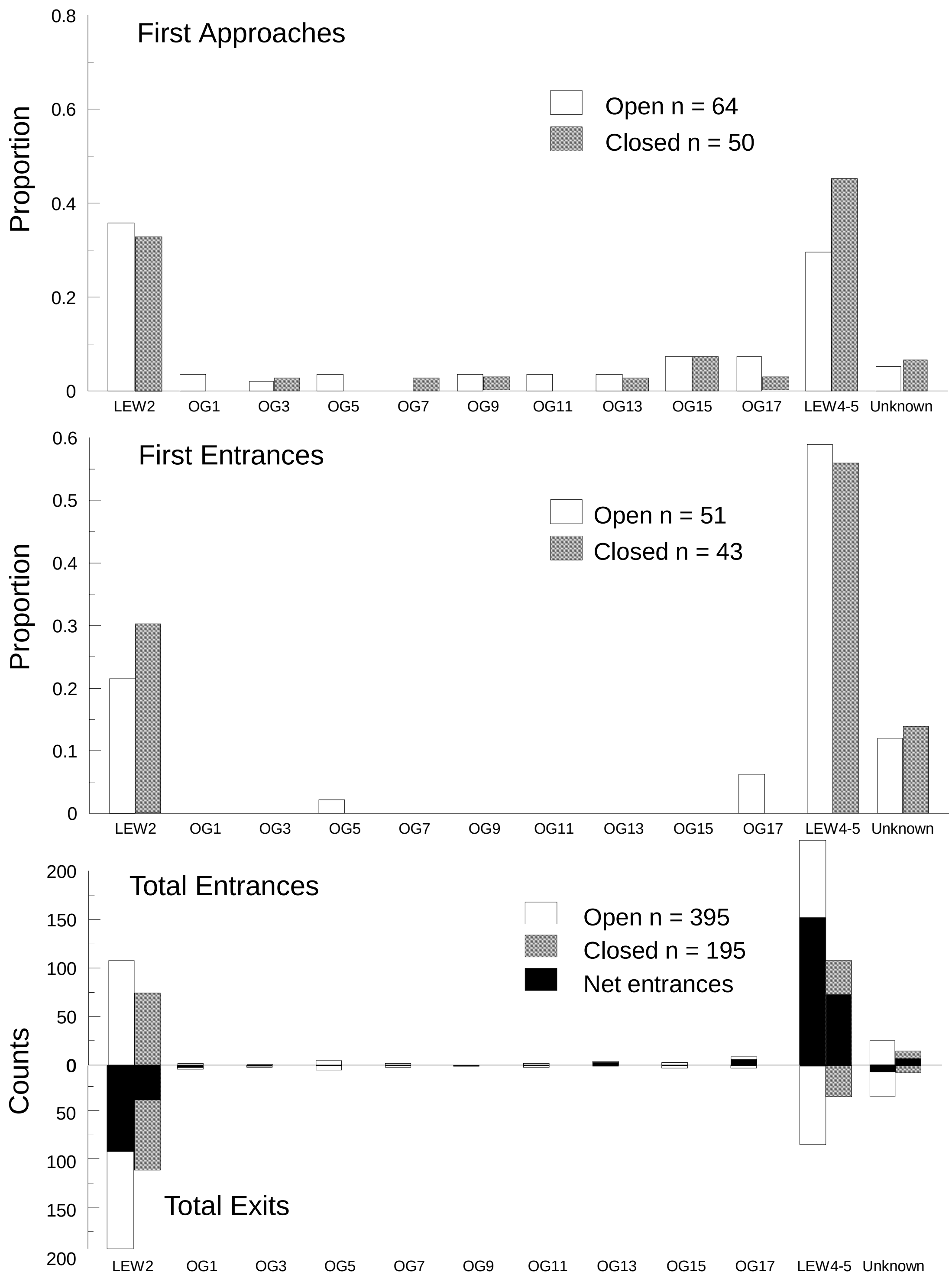

Figure 7. Distribution of first approaches (top), first entries (middle), and total entries, total exits, and net entries (bottom) for radio-tagged chinook salmon at Priest Rapids Dam with orifice gates open and closed. Lew2 is the west-powerhouse entrance, Lew4-5 is the east-fishway entrance, OG's are orifice gates.

entered at unknown locations (Figure 7). An unknown entry occurred when fish were recorded on an antenna inside the collection channel without previously being recorded on the antenna outside the nearest entrance. When orifice gates were closed, 24 radio-tagged salmon (55.8%) first entered at Lew4-5, 13 fish (30.2%) at Lew2, and 6 fish had unknown locations of first entry. The differences in entrance use for Lew4-5 or Lew2 when orifice gates were open or closed were not significant (ANOVA; P>0.2354 for Lew4-5, P>0.8950 for Lew2).

Table 2. ANOVA table for analysis of time to first entry for radio-tagged chinook salmon during blocks of open and closed orifice gate treatments, with and without passage times greater than 6 d (outliers).

Source	Degrees of freedom	Sums of squares	Mean square	F value	P > F
		With outliers			
Treatment	1	1.479	1.336	1.11	0.3700
Block	3	8.176	1.479	2.04	0.2866
Error	3	4.008	2.725		
		Without outliers			
Treatment	1	0.073	0.073	1.98	0.2543
Block	3	2.392	0.797	21.47	0.0157
Error	3	0.111	0.037		

Total entries were highest at Lew4-5 (58.7%), intermediate at Lew2 (37.6%) and relatively rare at orifice gates (7.3%) when orifice gates were open (Figure 7). When orifice gates were closed, total entrance frequencies were again higher at Lew4-5 (55.9%) than at Lew2 (37.4%). Conversely, total exits were higher at Lew2 than at Lew4-5, with open (57.8.0%, 23.3%) and closed (72.9%, 23.2%) orifice gates. Consequently, fish exiting through Lew2 more than they entered, and fish entered more than exited through Lew4-5 for both orifice-gate settings (Figure 7). Exit rates at orifice gates (8.9%) were similar to entry rates. Orifice gates on the west side of the powerhouse (near Lew2) had more exits than entries, while orifice gates on the east side of the powerhouse (near Lew4-5) had more entries than exits (Figure 7).

Entry to Junction Pool.--The junction pool in the east-shore fishway at Priest Rapids Dam is the transition area between the powerhouse collection channel and the ladder. Travel times of salmon from the tailrace receiver sites to first entry into the junction pool were calculated for 5 to 21 fish per block when orifice gates were open and 4 to 17 fish per block when orifice gates were closed. Travel time from the tailrace receiver sites to first entry into the junction pool averaged 49.4 h when orifice gates were open and 31.4 h when orifice gates were closed (Figure 7). These travel times were not significantly different between orifice gate settings ($P>0.4996$). When passage times longer than 6 d were excluded from analysis, there again was no effect on passage time due to orifice gate setting ($P>0.2782$), but there was a significant block effect ($P>0.0122$). Passage times were significantly longer during blocks 1 and 2 than during blocks 3 and 4, which may have been related to higher spill levels during blocks 1 and 2 than during blocks 3 and 4.

Exit from Top of Ladder.--Total travel time to pass the dam was the duration from first record at the tailrace receivers to the last record of a fish at the top of the east-shore ladder (fish passing at the west-shore ladder were not included in analysis). Two to 13 fish passed the dam during blocks when orifice gates were open, and 1 to 11 fish passed during blocks when orifice gates were closed and were included in the analysis for total time to pass the dam.. Overall times for salmon to pass from the tailrace to exit at top of the ladder averaged 68.7 h when orifice gates were open and 50.3 h when orifice gates were closed (Figure 7), and the times were not significantly different ($P>0.6038$). Removing fish that had passage times longer than 6 d did not change the outcome of the analysis.

General Passage Summary

Because there were no significant differences in travel times for radio-tagged chinook salmon passing while orifice gates were open or closed, data from all fish were used to summarize passage characteristics at Priest Rapids Dam. The following results are for all spring and summer chinook salmon with transmitters recorded at Priest Rapids Dam from 1 May to 8 August 1996.

Of 118 radio-tagged salmon that approached Priest Rapids Dam during the study period, 42 (35.6%) approached first at Lew2, 28 (23.7%) at orifice gates, 41 (34.7%) at Lew4-5 and 7 first approaches were at unknown locations (Figure 8). Half of 114 salmon recorded at tailrace receivers first approached the dam in less than 2.3 h (median time) versus a mean of 27.7 h, with the difference caused by the positively skewed distribution of passage times (Figure 9).

Of 103 radio-tagged chinook salmon that entered the east-shore fishway, 55 (53.3%) entered first at Lew4-5 and 30 (29.1%) entered first at Lew2 (Figure 8). Four fish entered first at orifice gates and 14 fish entered first at unknown locations. Half of 100 fish first entered the fishway in less than 6.5 h after arriving at the tailrace, versus a mean time of 36.4 h (Figure 9). There was a total of 590 entrances by 99 fish, for a mean of 6.0 entries per fish. The distribution of locations of total entries was similar to that of first entries, with 57.8% at Lew4-5, 30.8% at Lew2, 4.9% at orifice gates and 6.4% at unknown locations. There were 503 exits by 99 fish, for a mean of 5.1 exits per fish. The distribution of exits was 62.4% through Lew2, 23.3% through Lew4-5, 6.2% through orifice gates, and 8.2% at unknown locations. Consequently, exits of salmon outnumbered entries at the west end of the powerhouse and the reverse occurred at the east end of the powerhouse (Figure 8).

Half of 99 salmon moved from tailrace to the junction pool in less than 9.2 h (median time) versus a mean 41.0 h. Median time from first entry to last exit from the junction pool was 11.5 h versus a mean 19.5 h for 79 fish. Chinook salmon were classified into one of four categories based on their movements between first entry and last exit from the upstream end of the junction pool. Of 120 salmon that entered the junction pool, 21 fish (17.5%) moved through the junction pool, entered and moved up the ladder, and exited the top of the ladder, four fish (3.3%) returned to the collection channel before re-entering the junction pool, moving up the ladder and exiting the top of the ladder, 78 fish (65.0%) exited the junction pool and returned to the tailrace of the dam, then re-entered the fishway (an average of 6.5 times) before passing through the junction pool and moving up the ladder to exit at the top of the ladder, and 17 fish (14.2%) exited the fishway but did not re-enter the east-shore junction pool (ten of the last group of fish later

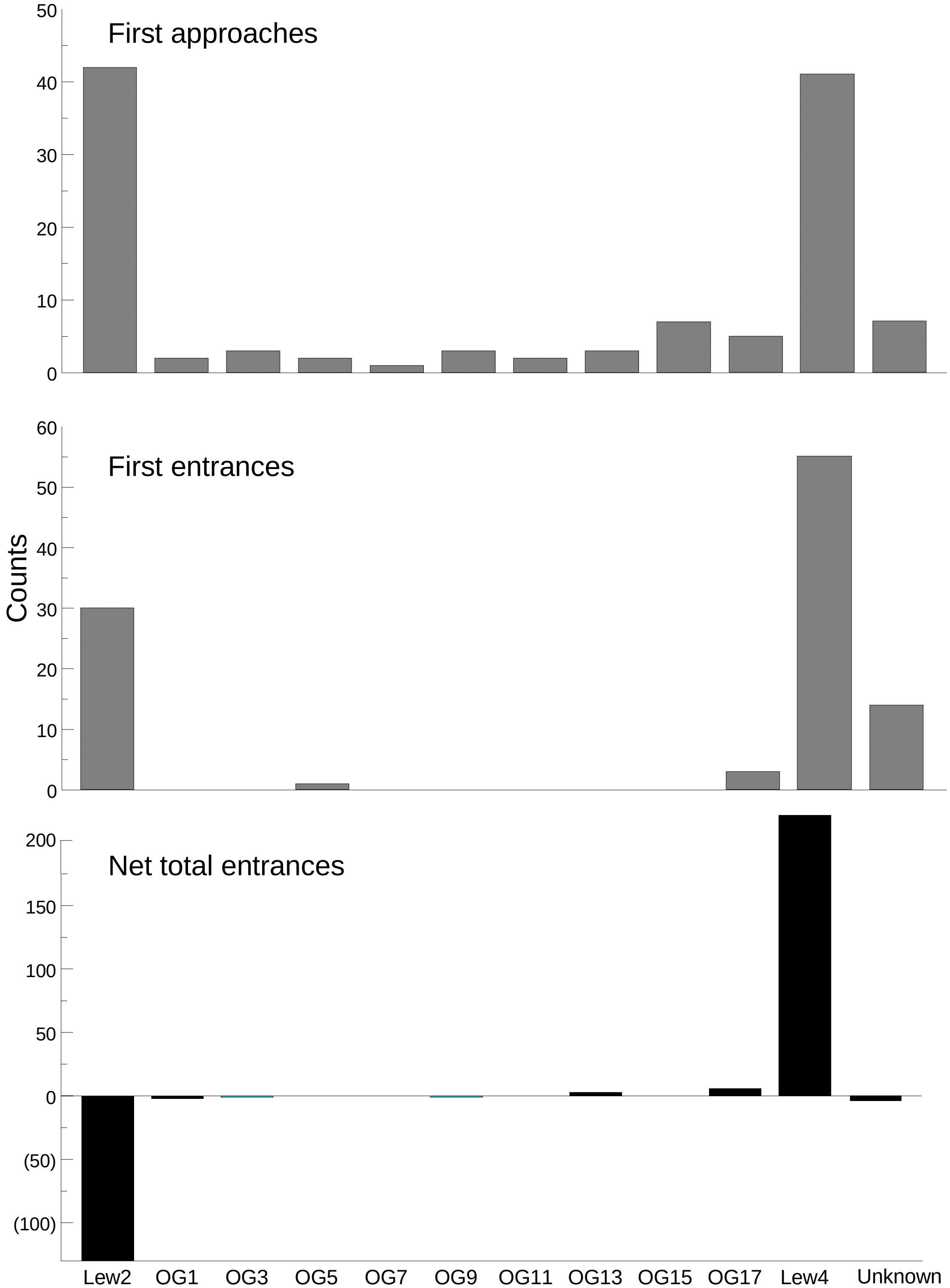

Figure 8. Distribution of first approaches (top), first entries (middle), and total net entries (bottom) for all radio-tagged chinook salmon at Priest Rapids Dam in 1996. Lew2 is the west-powerhouse entrance, Lew4-5 is the east-fishway entrance, OG's are orifice gates.

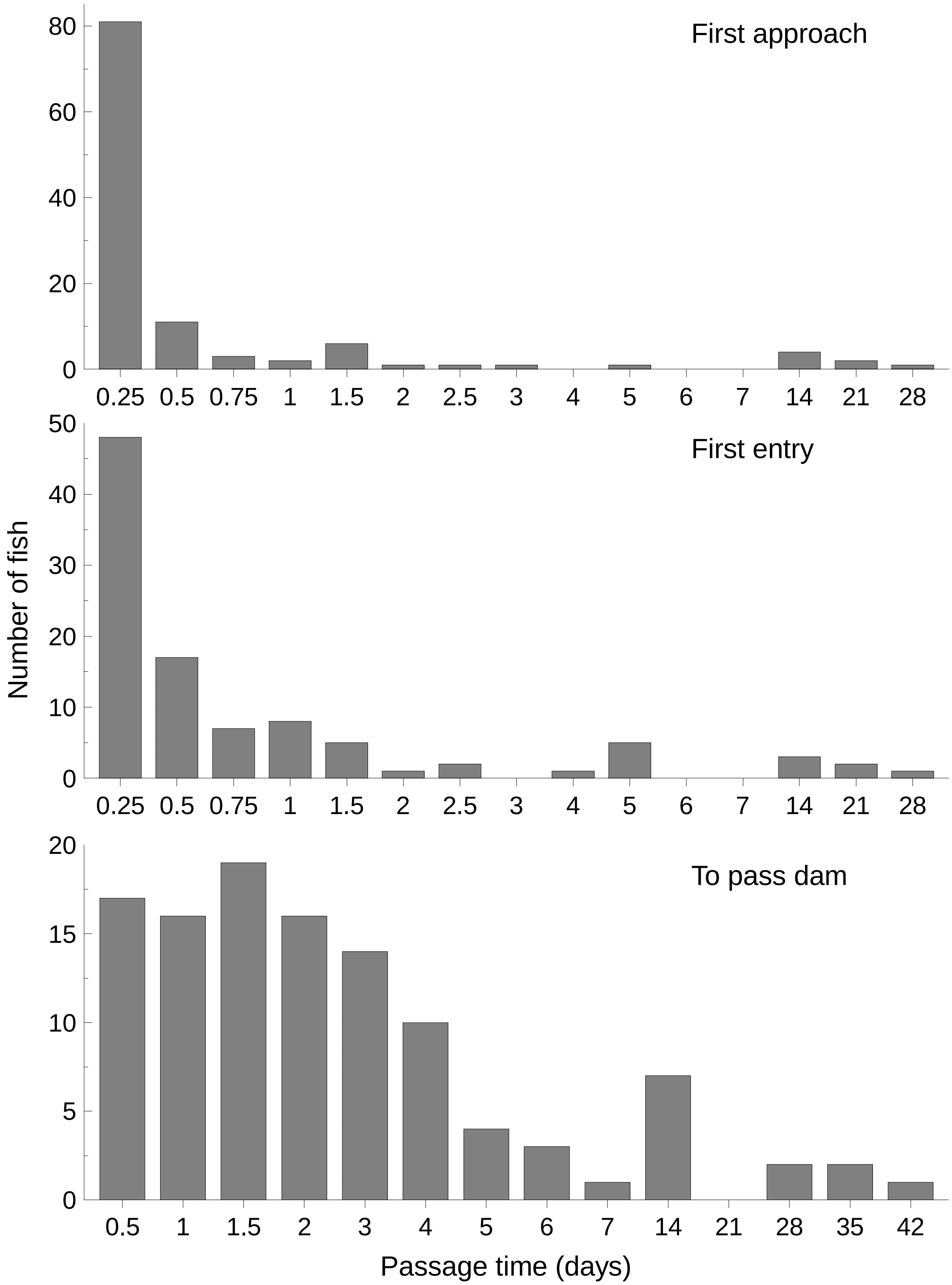

Figure 9. Frequency distributions for passage times from first record in tailrace to first approach, first entry and total time to pass Priest Rapids Dam for radio-tagged chinook salmon, in 1996.

crossed the dam via the west-shore ladder). Median durations from first to last record in the junction pool were 0.4 h for fish that moved through the junction pool, 3.6 h for fish that returned to the collection channel before moving through the junction pool, and 21.2 h for fish that returned to the tailrace before passing through the junction pool.

Of 115 radio-tagged chinook salmon that crossed Priest Rapids Dam, four fish fell back and re-crossed the dam for a total of 119 crossings. Half of 119 radio-tagged chinook salmon crossed Priest Rapids Dam in less than 37.6 h (median time, Figure 9), with 91 (76%) via the east-shore ladder in 36.3 h and 28 (24%) that crossed the dam via the west-shore ladder in 46.7 h. The median time to cross the dam for the ten fish that exited the junction pool and then crossed the dam using the west shore ladder was 32.4 h (mean = 4.73 d; one fish crossed dam after 42 days).

Fallback

Of 115 fish that passed Priest Rapids Dam during this study, 6 (5.2%) fell back over the dam. Of these 6 fish, 3 initially passed over the dam via the east-shore fishway and 3 initially passed over via the west-shore fishway. Four of the six fish eventually re-crossed Priest Rapids Dam after 1.0, 4.7, 6.1 and 27.4 d (mean = 9.8 d).

Discussion

Stuehrenberg et al. (1995) recommended that collection channel entrances with low use be closed to reduce the number of fish exiting the fishways into the tailrace. In our study to assess the effect of closing orifice gates on passage times for adult salmon at Priest Rapids Dam, we found that passage time for radio-tagged chinook salmon was not significantly longer when all orifice gates were closed. There was a trend for lower passage time to cross the dam when orifice gates were closed versus periods with open orifice gates, which may have been related to the lower proportion of fish that exited the fishway back into the tailrace when orifice gates were closed (0.79) versus open (0.85). Because some fish that were recorded at Priest Rapids Dam may actually have been destined for downstream hatcheries or the Snake River, and had long passage times, we removed fish with travel times longer than 6 d for the four test variables and reran the analysis. There again was no effect from orifice gate treatment on passage times, but there were differences between blocks in the second analysis. Passage times for first entries and first entry to the junction pool were significantly longer in blocks 1 and 2 than during blocks 3 and 4. The reason for differences in passage times between blocks is unknown but may have been related to higher spill during blocks 1 and 2 than during blocks 3 and 4. High spill levels can create turbulent conditions in the tailrace that make locating fishway entrances difficult. The ability to detect differences in parameters with respect to orifice gate configuration was less than desired because of the low number of replicate blocks in the analysis.

Median passage time for chinook salmon at Priest Rapids Dam in 1996 was 37.6 h, as compared to 44.9 h and 29.4 h for spring and summer chinook salmon in 1993 (Stuehrenberg et al. 1995). If we use mid-June as the separation date between spring and summer chinook salmon runs as Stuehrenberg et al. (1995) did for 1993, then 34 radio-tagged fish would have passed Priest Rapids Dam during the normal period for spring chinook salmon in a median 59.8 h, and 78 fish would have passed over the dam during the summer period in 32.5 h. However, timing of chinook salmon runs at Bonneville Dam appeared to have been delayed two to three weeks, as compared to the ten-year average, and so the mid-June separation date may not be valid for separating spring and summer chinook salmon runs in 1996. Using 29 June as the separation date at Priest Rapids Dam (assuming a two week delay), then 41 spring chinook would have passed over the dam in 40.1 h and 75 summer chinook salmon would have crossed the dam in 36.2 h. Median times for radio-tagged chinook salmon to pass over each of the four lower Snake River dams ranged from 16.8 to 20.4 h (from last record in the tailrace) in 1993 (Bjornn et al. 1995).

Half of the salmon with transmitters moved from the tailrace to the junction pool in less than 9.2 hours, versus median times of 2 to 5 h for chinook salmon at Snake River dams in 1993 (Bjornn et al. 1995). After first entering the junction pool, most fish (79.2%) returned to the collection channel and exited the fishway. Since most exits occurred at the western end of the powerhouse, it appeared that fish leaving the junction pool would swim the length of the collection channel and exit Lew2, which had a negative entry-exit rate during this study.

Stuehrenberg et al. (1995) reported a negative entry-exit rate at Lew2-3 for summer chinook salmon, but a positive entry-exit rate for spring chinook salmon in 1993.

In 1996, 5.2% (6/115) of the salmon with transmitters fell back over the dam versus 17.7% (35/197) of spring chinook salmon and 1.5% (4/261) of summer chinook salmon in 1993 (Stuehrenberg et al. 1995). In 1993, radio-tagged chinook salmon had fallback rates ranging from 1.9 to 3.2% at the four Snake River dams (Bjornn et al. 1995). The average delay for four fish that re-ascended the dam was 9.8 d. Fallback fish that did not re-ascend the dam, as well as fish that approached but did not pass Priest Rapids Dam, may have been destined for downstream hatcheries, fish that overshot the mouth of the Snake River, fish that lost their transmitters, or fish that died.

Recommendations

Closure of collection channel entrances with low use (orifice gates) at Priest Rapids Dam would not negatively effect adult salmon passage, based on results of the 1996 study. We recommend that the orifice-gate closure test be conducted for a second year in 1997, when increased statistical power can be obtained by better execution of the study design. Increased numbers of blocks can be obtained by downloading tailrace and ladder-top receivers daily so gate changes can be implemented quickly after an adequate number of fish have passed. Tripling replicate blocks to 12 would produce an expect power of 65% to detect a 2 d difference in mean passage times.

In this study, as in the 1993 study (Stuehrenberg et al. 1995), a large portion of the salmon exited the fishway through Lew2 after entering and then leaving the junction pool. A possible solution to this problem is to install a fish guidance fence in the west end of the collection channel (Figure 10). We do not recommend closing Lew2 to reduce exits from the collection channel because this would also eliminate the high number of entries that occur at Lew2. A fishway fence could reduce exits while still allowing fish to enter through Lew2. Fishway fences constructed of chain-link fencing material are currently being tested at Little Goose and Lower Granite dams.

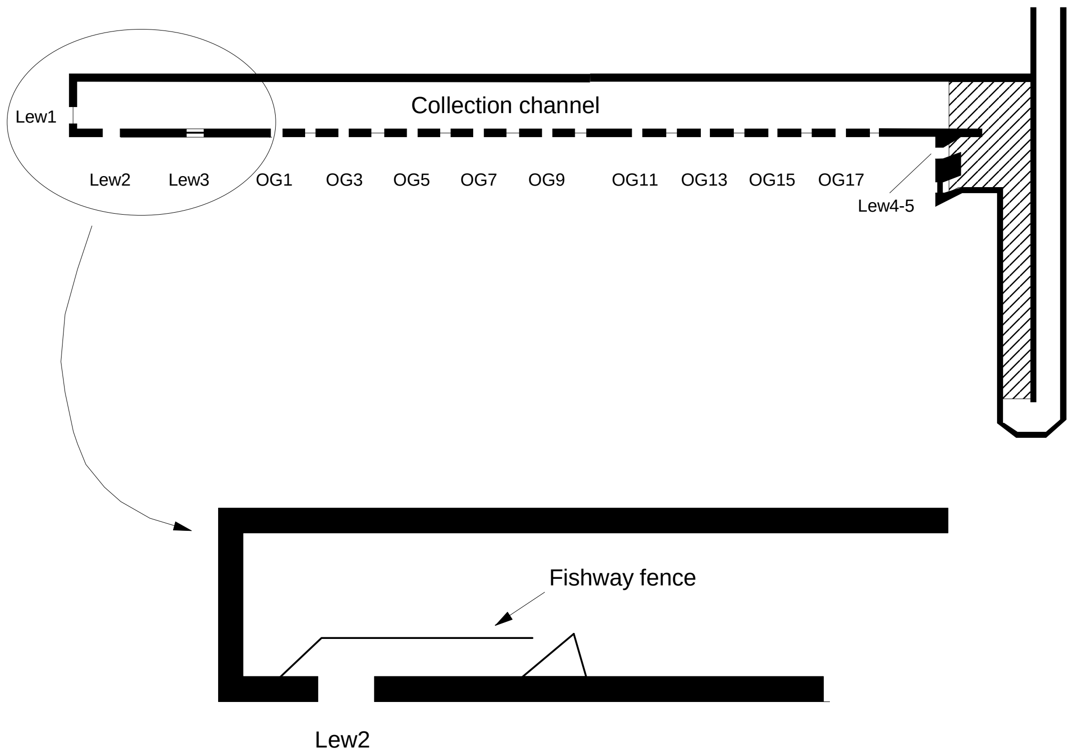

Figure 10. Potential design of fishway fence inside collection channel at Lew2. This fence is designed to reduce exits by fish moving downstream in the collection channel while still allowing fish to enter at Lew2.

Radio receivers occasionally were inoperable during this study (Appendix C), however these outages were infrequent and of short duration. Most outages occurred when a receiver's memory was filled with records and could not record any further information. A solution to these outages would be more frequent downloading of receivers and checks of the telemetry system.

References

Bjornn, T.C., and C.A. Peery. 1992. A review of literature related to movements of adult salmon and steelhead past dams and through reservoirs in the lower Snake River. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Technical Report 92-1.

Bjornn, T.C., J.P. Hunt, K.R. Tolotti, P.J. Keniry, and R.R. Ringe. 1995. Migration of adult chinook salmon and steelhead past dams and through reservoirs in the lower Snake River and into tributaries - 1993. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Technical Report 95-1.

Stuehrenberg, L.C., G.W. Swan, L.K. Timme, P.A. Ocker, M.B. Eppard, R. N. Iwamoto, B.L. Iverson, and B.P. Sandford. 1995. Migration Characteristics of adult spring, summer, and fall chinook salmon passing through reservoirs and dams of the mid-Columbia River. National Marine Fisheries Service, Seattle, WA, Final report.

SAS Institutes Inc. 1985. SAS procedures guide, Version 6, Third edition. Cary, North Carolina

Appendix A

Frequency distributions for time to first entry for radio-tagged chinook salmon at Priest Rapids Dam, 1996.

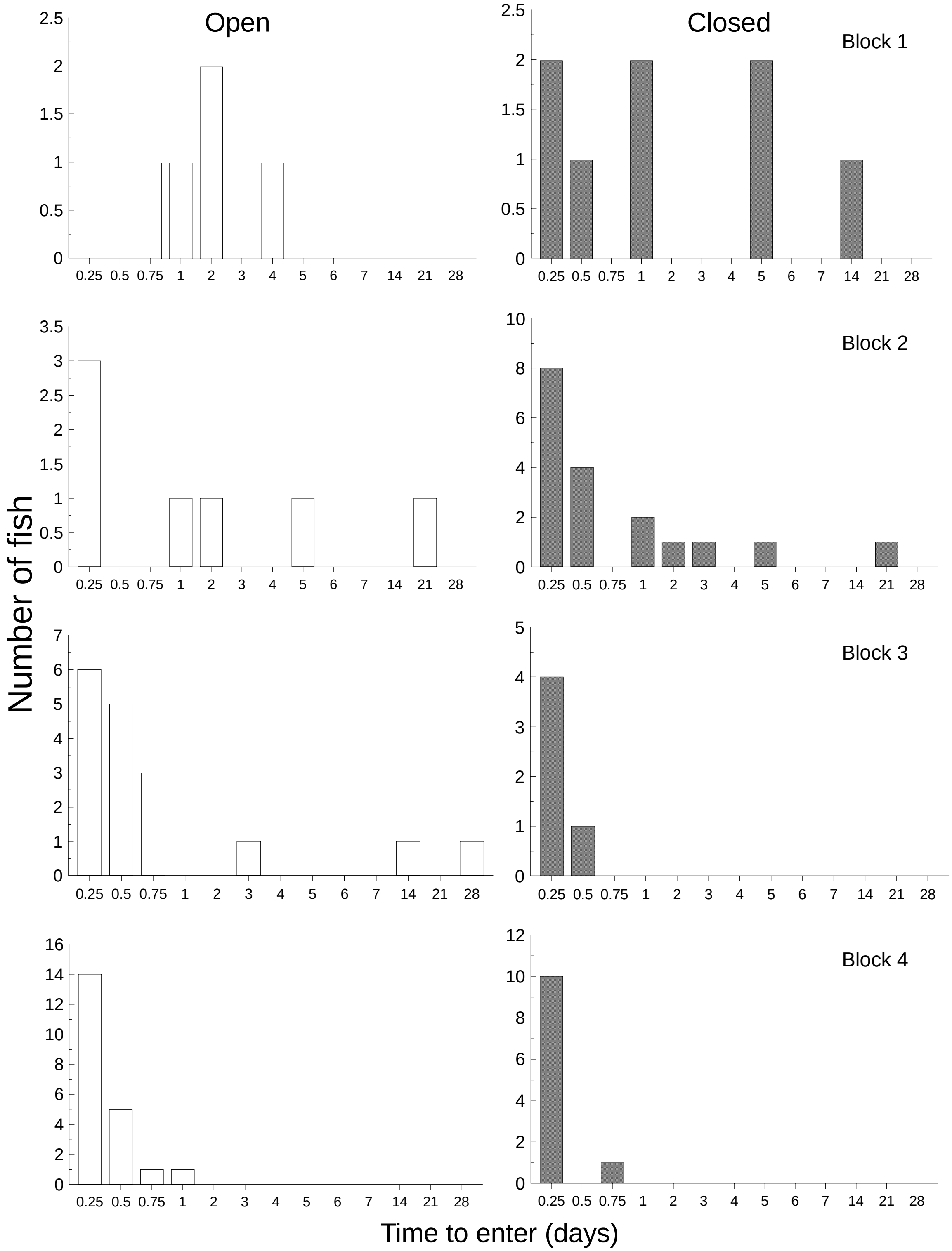

Figure A1. Frequency distributions for passage times from tailrace to first entry for radio-tagged chinook salmon at Priest Rapids Dam, 1996, when orifice gates were in open (left) and closed (right) setting.

Appendix B

Values for passage time variables used in analysis for radio-tagged chinook salmon at Priest Rapids Dam, 1996.

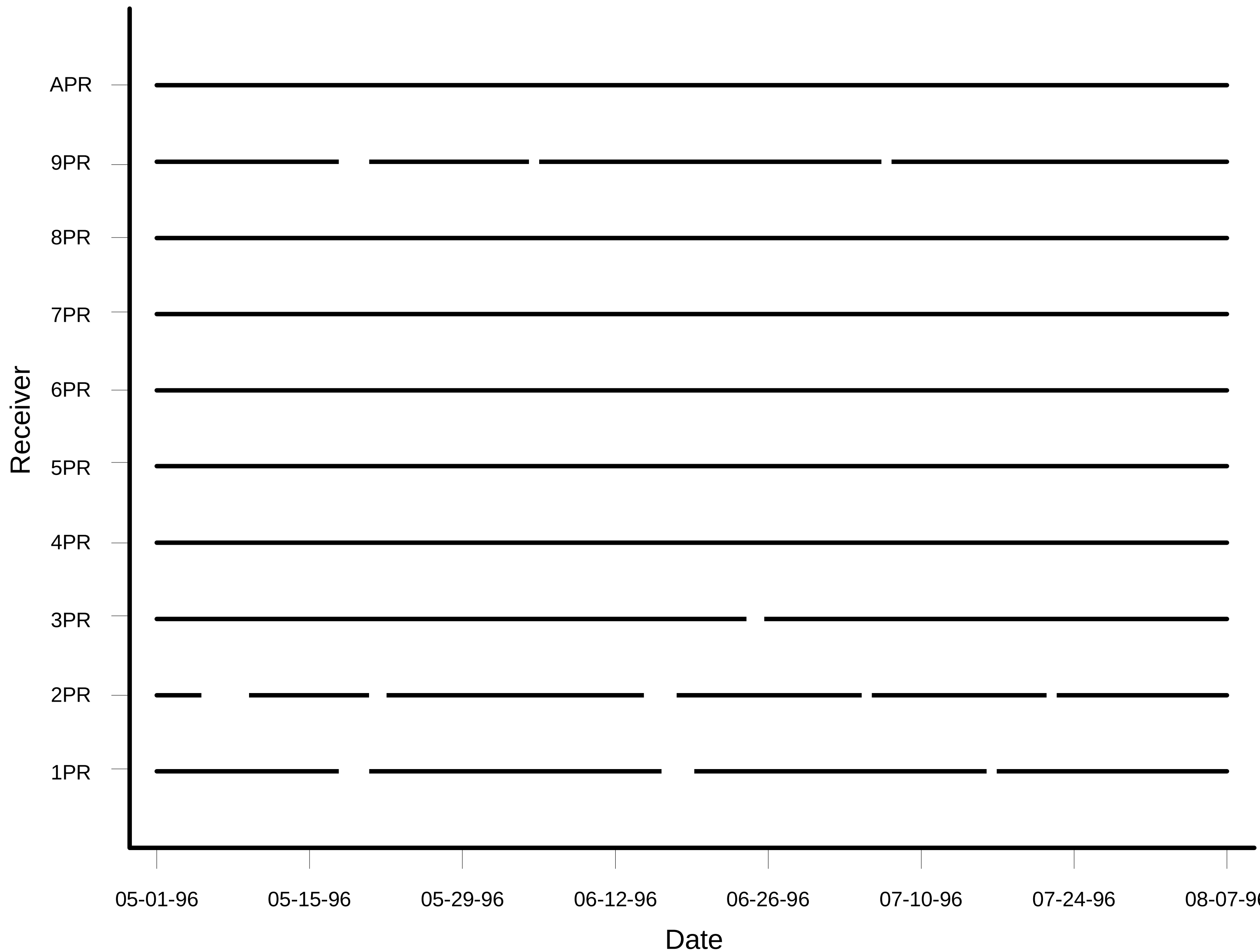

Figure B1. Time of operation of fixed-site radio receivers at Priest Rapids Dam, 1996. Breaks in time lines represent periods of time when receivers were not operational.

Appendix C

Values for passage time variables used in analysis for radio-tagged chinook salmon at Priest Rapids Dam, 1996.

Key to data spreadsheet file column headings

CHAN, CODE: Channel (frequency) and code of radio tag transmitter, identifies individual fish.

DATE: Date of activity was recorded.

TIME: Time in proportion of day (0.5 = noon) activity was recorded.

ANT: Antenna number for given receiver.

SITE: Alphanumeric designation for radio receiver.

ACTIVITY CODE: Code designating activity of fish, as follows.

- F1 = First record at tailrace receiver.
- F2 = Last record at tailrace receiver before first approaching dam.
- A1ra = First approach at dam at receiver "r" and antenna "a".
- Ara = Approach to receiver "r" and antenna "a" sometime after first approach.
- UA = Unknown approach.
- E1ra = First entrance to dam at opening associated with receiver "r" and antenna "a".
- Era = Entrance to dam at opening associated with receiver "r" and antenna "a" sometime after first entrance.
- UE = Unknown entrance.
- Xra = Exit from dam at opening associated with receiver "r" and antenna "a".
- FP = First record in junction pool.
- LP = Last record in junction pool.
- FT = First record at top of ladder.
- LT = Last record at top of ladder.
- FB = Fallback, first record downstream from dam after a LT record.

LOCATION: Location at dam associated with activity recorded.

TREATMENT: Orifice gate configuration at time of record.