Technical Report 2000-2

ADULT CHINOOK AND SOCKEYE SALMON, AND STEELHEAD FALLBACK RATES AT THE DALLES DAM - 1996, 1997, AND 1998

A report for Project MPE-P-95-1

by

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Bonneville Power Administration
Portland, Oregon

2000

Preface

Recent studies of adult salmon and steelhead migrations past dams, through reservoirs, and into tributaries with radio telemetry began in 1990 with planning, purchase and installation of equipment for studies at the Snake River dams. Adult spring and summer chinook salmon and steelhead were outfitted with transmitters at Ice Harbor Dam in 1991, 1992, 1994, and at John Day Dam in 1993 and reports of those studies are available (Bjornn et al. 1992; 1994; 1995; 1998a; 1998b). The focus of adult salmon passage studies was shifted to the lower Columbia River dams in 1995 when telemetry equipment was set up at the dams and tributaries and spring and summer chinook salmon were outfitted with transmitters at Bonneville Dam in 1996, 1997, and 1998. Steelhead, sockeye salmon, and fall chinook salmon were also outfitted with transmitters during some years. In this report we present information on fallback behavior by spring and summer chinook salmon, sockeye salmon, steelhead, and fall chinook salmon at The Dalles Dam for the years 1996 to 1998. Additional reports will be issued on detailed analysis of passage at dams that had a full complement of receivers and antennas to monitor use of fishway entrances and passage through transition pools. General migration patterns, minimum survivals, and distributions will also be presented in reports for all groups tagged.

Acknowledgments

Many people assisted in the field work and data compilation for this project and the successful completion was made possible by John Ferguson, Bob Dach, Teri Barila, and Rebecca Kalamacz of the Corps of Engineers. Michelle Feeley, Brian Hastings, Steve Lee, and Jay Nance assisted with data processing and analysis.

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Abstract

We outfitted 853 spring and summer chinook salmon *Onchorhynchus tshawytscha* with radio transmitters at Bonneville Dam in 1996, 1,016 in 1997, and 957 in 1998. We outfitted 577 sockeye salmon *O. nerka* in 1997, 770 steelhead *O. mykiss* in 1996, 975 steelhead in 1997, and 1,032 fall chinook salmon in 1998. Of these, 1,894 spring and summer chinook salmon, 616 fall chinook salmon, 485 sockeye salmon, and 1,219 steelhead retained transmitters and were recorded passing The Dalles Dam via fishways. An additional 1% to 3% were known to pass the dam, either via the navigation lock or during antenna outages. We monitored passage and fallbacks at The Dalles Dam using antennas/receivers in the tailrace and fishways in all years and supplemented that data with recapture records, telemetry records from receivers at upriver dams and the mouths of tributaries, and locations of fish by mobile trackers.

We calculated the percentage of steelhead, and chinook and sockeye salmon that fell back, fallback rates that included multiple fallback events by individual fish, and escapement adjustment factors to adjust counts of fish passing through fishways. We also calculated fallback percentages and rates separately for fish that passed the Oregon- and Washington-shore fishways. We summarized fallback timing for all fish, and whether fish had been upriver prior to fallback events. We also examined the effects of environmental conditions (flow, spill, Secchi disk visibility, dissolved gas pressure, and water temperature) on fallback rates with a variety of techniques.

Overall known fallback percentages for spring and summer chinook salmon that passed the dam ranged from 11.0% to 14.2% and were highest in 1997. Fallback percentages were 4.9% for sockeye salmon, 6% for steelhead tagged in 1996, 6.7% for steelhead tagged in 1997, and 10.4% for fall chinook salmon in 1998. Fallback rates for spring and summer chinook salmon ranged from 13.8% to 18.4% and were also highest in 1997. Fallback rates were 5.1% for sockeye salmon, 6.8% to 7.7% for steelhead, and 11.8% for fall chinook salmon. Percentages and rates were less than 4.5% for steelhead when we only included data through 31 October of the year they were tagged, the date when almost all steelhead had passed the dam. Standard 95% confidence intervals on fallback rates and percentages for all species were +/- 1% to 4% for radio-tagged fish. Confidence intervals were slightly wider when weighted by total passage at the dam for some species.

Between 55% and 68% of spring and summer chinook salmon that fell back eventually reascended the dam and were last recorded at upstream sites. About 75% of steelhead and sockeye salmon eventually reascended; 23% of fall chinook salmon reascended after fallback.

With the exception of sockeye salmon (72%), less than one third of the fish that fell back did so within 24 h of passing the dam. About 60% of spring and summer chinook salmon, 24% of sockeye salmon, 67% of steelhead, and 85% of fall chinook salmon were recorded at upstream sites before falling back. We did not observe a significant pattern of higher fallbacks associated with either ladder for spring and summer chinook

salmon or fall chinook salmon, although rates tended to be higher for the Oregon-shore ladder. Sockeye salmon that passed over the Washington-shore ladder fell back at significantly higher rates than those that passed the Oregon-shore ladder. Most steelhead that fell back within 24 h of passage had passed the dam via the Oregon-shore fishway.

Ladder count adjustment factors based on pooled data for spring and summer chinook salmon were 0.840 in 1996, 0.839 in 1997, and 0.875 in 1998. Using pooled correction factors, positive biases due to fallbacks in counts of spring and summer chinook salmon passing ladders at The Dalles Dam were about 5,900 fish in 1996, 14,400 fish in 1997, and 5,100 fish in 1998. The adjustment factor for sockeye salmon in 1997 using pooled data was 0.951, and the positive bias was about 1,600 fish. For steelhead tagged in 1996, the pooled correction factor was 0.937 and the positive bias was about 10,200 fish. The pooled correction factor was 0.926 for steelhead tagged in 1997, with a positive bias of about 12,200 fish. The pooled correction factor was 0.888 for fall chinook salmon, with a positive bias of about 10,400 fish. Weighted correction factors were similar to pooled values for spring and summer chinook salmon and sockeye salmon, and were slightly higher for steelhead and fall chinook salmon. Escapement adjustments based on values weighted by total counts of fish passing via ladders were generally similar to adjustments based on pooled data and were not consistently higher or lower than adjustments based on pooled data.

Limited antenna coverage at The Dalles Dam in all years made it difficult to monitor specific fallback routes, but we believe that most radio-tagged spring and summer chinook salmon and sockeye salmon fell back via the spillway. Between 94% and 100% of fallbacks by spring and summer chinook salmon and sockeye salmon occurred on days with forced spill. About 43% of fallbacks by steelhead tagged in 1996 and 29% of fallback by steelhead tagged in 1997 fell back on days with spill. Radio-tagged fall chinook salmon did not begin passing the dam until after the period of no-spill began on 1 September. A small number of fish may have fallen back through the navigation lock and via the ice and trash sluiceway in all years, but we did not monitor those routes. It was not clear how many fish fell back through powerhouses, as routes through turbine intakes also were not monitored, but we believe few fell back via that route.

The percentage of spring and summer chinook salmon that fell back and fallback rates were highest in 1997, the year with highest flow and spill. Rates and percentages were nearly as high in 1996, which was also a relatively high flow year and also had a period of high turbidity. Fallback percentages and rates were intermediate for 1998 spring and summer chinook salmon, when flow and spill were lower than the previous two years. Fallback percentages and rates were relatively low for 1997 sockeye salmon and steelhead tagged in both 1996 and 1997.

We used a variety of methods to test relationships between fallback within 24 h of dam passage and environmental conditions at the dam. Fallback ratios based on moving averages, consecutive 5-d blocks and variable-day bins tended to increase with increased flow, spill, and dissolved gas, and decrease with increased turbidity for spring and summer chinook salmon in 1996 and 1997 and sockeye salmon in 1997. Some linear and logistic regression models were significant, but most r^2 values were < 0.25. Few steelhead or fall chinook salmon fell back within 24 h during zero spill conditions in any year.

T-tests and logistic regressions using binary datasets (fallback or no fallback within 24 h of passage) showed few significant differences in environmental conditions for fallback fish. Flow and spill at the time of passage were higher for spring and summer chinook salmon in 1996 and 1997, sockeye salmon in 1997, and fall chinook salmon in 1998 that fell back within 24 h, but differences were not significant at ($P < 0.05$). Spill was significantly higher for steelhead that fell back within 24 h in 1997 ($P < 0.05$) and Secchi visibility was significantly lower for spring and summer chinook salmon that fell back in 1996 ($P < 0.005$). We found few indications that water temperature affected fallback by salmon or steelhead, except that fallback ratios for 1997 spring and summer chinook salmon and sockeye salmon spiked higher at approximately 18º C.

Stepwise multiple regression models produced results similar to univariate models. The addition of multiple variables did not improve model predictions for fallback ratios for spring and summer chinook or sockeye salmon. We did not run multivariate models for steelhead or fall chinook salmon.

We used complete general migration information to determine the final distribution of fish that fell back at The Dalles Dam. Approximately 62% to 76% of spring and summer chinook salmon, 57% (1996) and 47% (1997) of steelhead, 67% of sockeye salmon, and 62% of fall chinook salmon that fell back at The Dalles Dam were subsequently recorded at tributary locations or the uppermost monitoring sites and potentially spawned, or were transported from adult traps to hatcheries. Of those that fell back, from 15% to 26% of spring and summer chinook salmon, 11% of steelhead tagged in 1996, 0% of steelhead tagged in 1997, 13% of sockeye salmon, and 46% of fall chinook salmon entered tributaries downriver from The Dalles Dam, indicating some fallbacks were likely caused by wandering, overshoot behavior, or other migration factors. From 24% to 35% of spring and summer chinook salmon and 18% to 20% of steelhead that fell back were recorded in tributaries upriver from Lower Granite Dam or were transported from the adult trap at Lower Granite Dam to hatcheries. About 54% of the sockeye salmon that fell back at The Dalles Dam were last recorded in tributaries to the upper Columbia River, mostly in the Wenatchee and Okanogan rivers. Fish not recorded in tributaries or the uppermost monitoring sites (24% to 38% of spring and summer chinook salmon, sockeye salmon, and fall chinook salmon, 43% to 53% of steelhead) were last detected primarily at dam sites or in reservoirs throughout the lower-Columbia River/Snake River hydrosystem.

Introduction

Significant numbers of adult salmon and steelhead fall back at The Dalles Dam in most years, particularly from stocks that pass over the dam during spring and summer when flows are high and there is forced or deliberate spill (Bjornn and Peery 1992). Prior to this study and recent developments in radio telemetry that allowed us to put transmitters in large numbers of fish and precisely monitor their movements, fallback at The Dalles Dam had been identified (Monan and Liscom 1979; Gibson et al. 1979; Young et al. 1978; Liscom et al. 1979), but not fully evaluated. In the studies that began in 1996, we have been able to assess the proportion of fish passing the dam that fell back over the dam and the effect of falling back on passage rates at the dam, fate of the fallback fish, and survival to upstream destinations. Fish that fall back and subsequently reascend The Dalles Dam cause a positive bias in fish counts at the dam, and overcounts may have serious management implications, particularly for years with low returns.

In this report, we present our best estimates of the proportion of spring, summer and fall chinook salmon, sockeye salmon, and steelhead with transmitters that fell back at The Dalles Dam in the years 1996-1998. A more complete analysis of fallbacks throughout the Columbia River basin is presented in reports that cover the entire migration of each stock (the first of such reports are for the 1996 run of spring/summer chinook salmon and the 1996 run of steelhead, Bjornn et al. 2000a; 2001), and in reports detailing fallback behavior at Bonneville and John Day dams (Bjornn et al., 2000b; 2000c).

We assessed three years (1996 to 1998) of radio-telemetry data for spring and summer chinook salmon, one year (1997) for sockeye salmon, two years (1996 and 1997) for steelhead, and one year (1998) for fall chinook salmon to characterize and evaluate fallback behavior at The Dalles Dam. Data for all years are of high quality because all of the records at all dams and tributary sites have been coded (fish movements interpreted) and analyzed along with mobile-track and recapture data.

In all years, we attempted to select a sample of fish for tagging in proportion to the daily counts of fish throughout the migration season at Bonneville Dam (Figures 1 and 2). We selected fish for tagging in the Adult Fish Facility at Bonneville Dam after they had been diverted from the Washington-shore fishway. Trapping of spring and summer chinook salmon began in early April each year and continued to mid July with fish tagged and released 10 d out of every 14 d period. We tagged steelhead from mid June through mid October, sockeye from early June to early August, and fall chinook salmon starting September 1. For all species, the only selection criteria was size; we did not put transmitters in “jack salmon” that had only spent one year in the ocean. Tagging was interrupted in some years due to high water temperatures at Bonneville Dam, and the last part of the summer chinook runs were under represented. Counts of radio-tagged fish at upstream dams as a proportion of tagged fish counts at Bonneville Dam were similar to proportions of total fish counts passing the ladders, particularly for radio- tagged spring and summer chinook salmon and steelhead; differences in proportions passing upstream dams were more divergent for fall chinook salmon and sockeye salmon (Figure 3). Reported ladder counts for sockeye salmon increased at each dam from The Dalles Dam to Priest Rapids Dam (USACE 1997), suggesting the large difference between radio-tagged and total fish counts at Priest Rapids Dam may have been due to counting errors. Relatively high proportions of radio-tagged sockeye salmon (9% at Bonneville and 14% at McNary Dam) pass via navigation locks, suggesting that USACE ladder counts were likely underestimates of escapement at some dams. The higher proportions of radio-tagged fall chinook salmon at upstream dams was likely because we did not tag fall chinook at Bonneville Dam during August, when many lower Columbia River stocks may have passed the dam.

In all years, we unselectively outfitted with transmitters what we believe was a near-random sample of adult fish. The sample was not truly random because only fish passing via the Washington-shore ladder at Bonneville Dam were sampled, the proportion sampled each day varied, more fish were sampled in the morning than afternoon, and no fish were sampled at night. However, fish were tagged as they were trapped, and we tagged almost all fish regardless of minor injury or fin clip; a minimal number (<1%) of fish with more serious injuries were rejected.

Spring and summer chinook salmon with transmitters that passed The Dalles Dam made up 1.3% of those counted at the dam in 1996, 0.9% in 1997, and 2.0% in 1998. Radio-tagged sockeye salmon made up 1.6% of those counted at the dam in 1997, tagged steelhead made up 0.36% of the 1996 count and 0.41% of the 1997 count. Radio-tagged fall chinook salmon made up 0.69% of the count at the dam in 1998.

We evaluated our sampling effort by calculating proportions of radio-tagged fish to total counts passing ladders for 5-d blocks. Proportions varied from 0.0 when no tagged fish passed the dam during a 5-d block to about 0.08 (8% of fish) when tagged fish were passing but relatively few fish were counted. Over- and undersampling were equally represented by standardizing each block to the total chinook salmon sampling effort and using a log (~base 2) scale. We tended to undersample spring and summer chinook salmon and sockeye salmon early and late in the migrations (Figures 4 and 5). We also proportionately oversampled the early summer chinook salmon run in 1997, and undersampled late summer chinook salmon in all years due to high water temperatures. We tended to oversample early and late in the steelhead runs and undersample steelhead during peak counts (Figures 6 and 7). We did not sample the early fall chinook run, and oversampled the late fall chinook run (Figures 6 and 7). For most of each run, however, proportions of tagged fish did not deviate far from the overall sampling

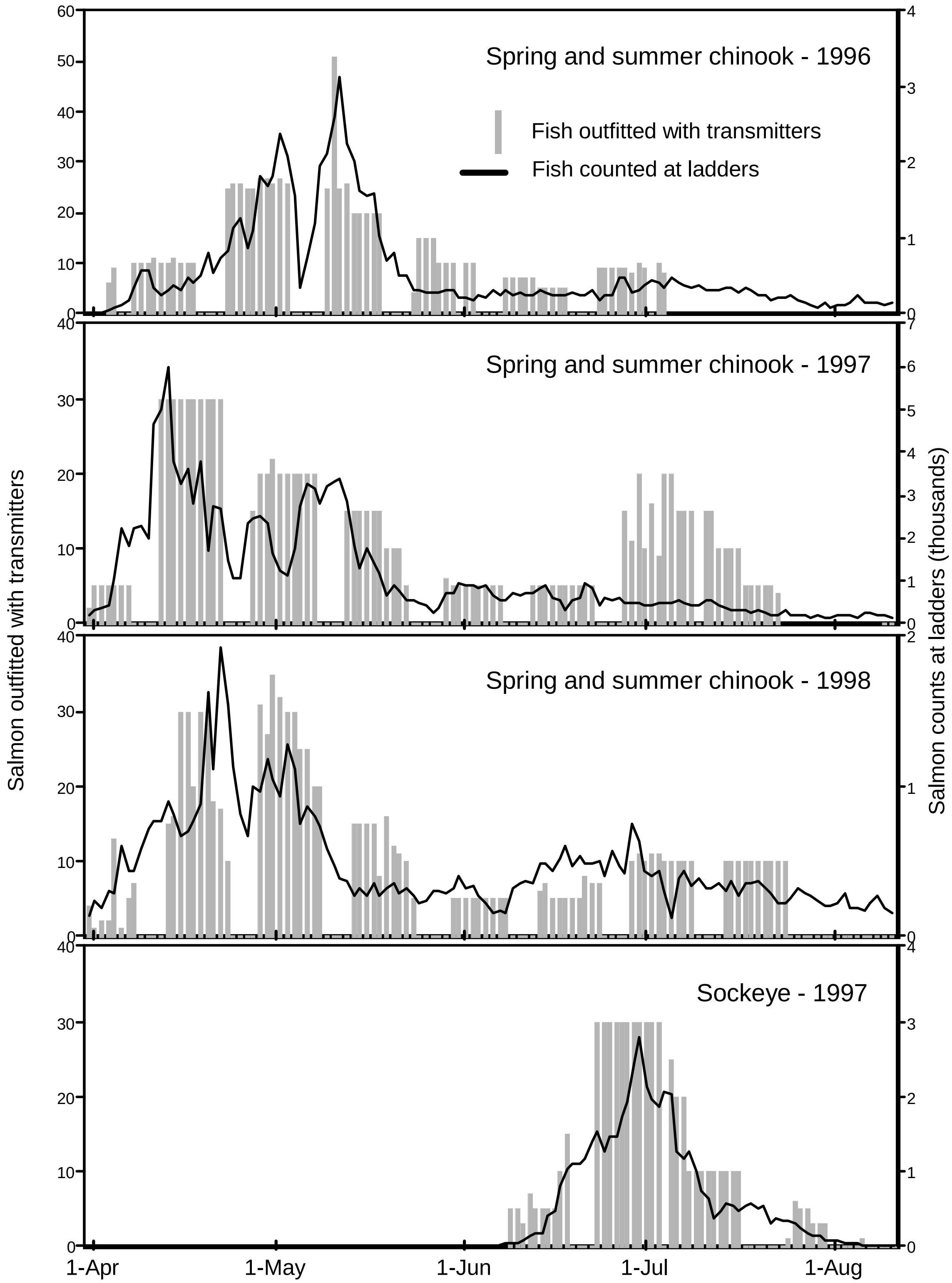

Figure 1. Daily spring and summer chinook salmon and sockeye counts at Bonneville Dam and the number of salmon outfitted with transmitters in 1996, 1997, and 1998.

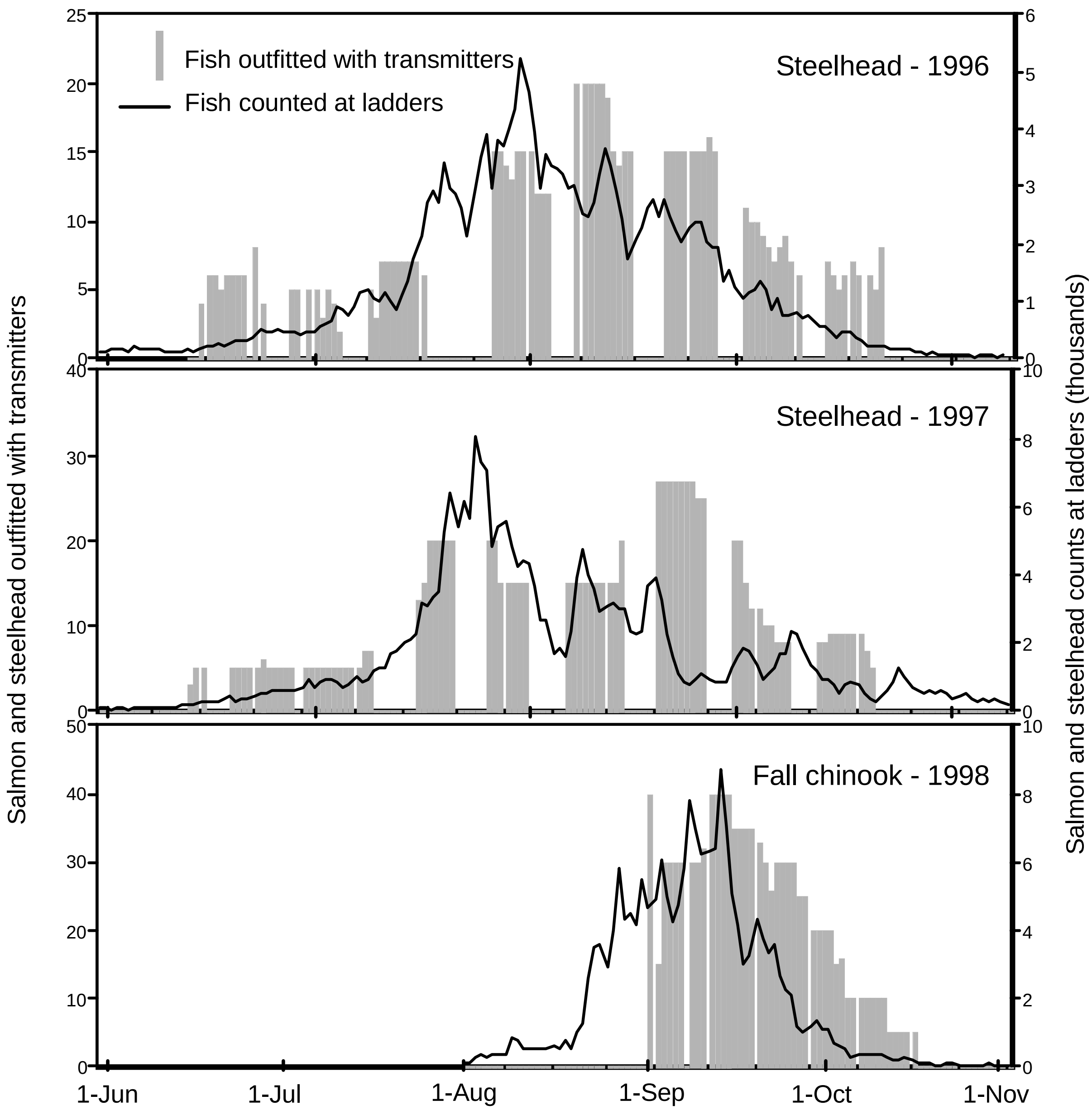

Figure 2. Daily steelhead and fall chinook salmon counts at Bonneville Dam and the number of steelhead and salmon outfitted with transmitters in 1996, 1997, and 1998.

proportion for the run. Some variability was unavoidable because we set tagging schedules in advance of each season based on past counts of fish and could not adjust easily to unexpected deviations in numbers of fish passing the dam.

During the 1997 spring and summer chinook salmon run, a 4-d period of no tagging in early April coincided with a large number of spring chinook salmon passing Bonneville Dam (Figure 1). The gap in tagging during the spike in ladder counts was reflected in passage at The Dalles

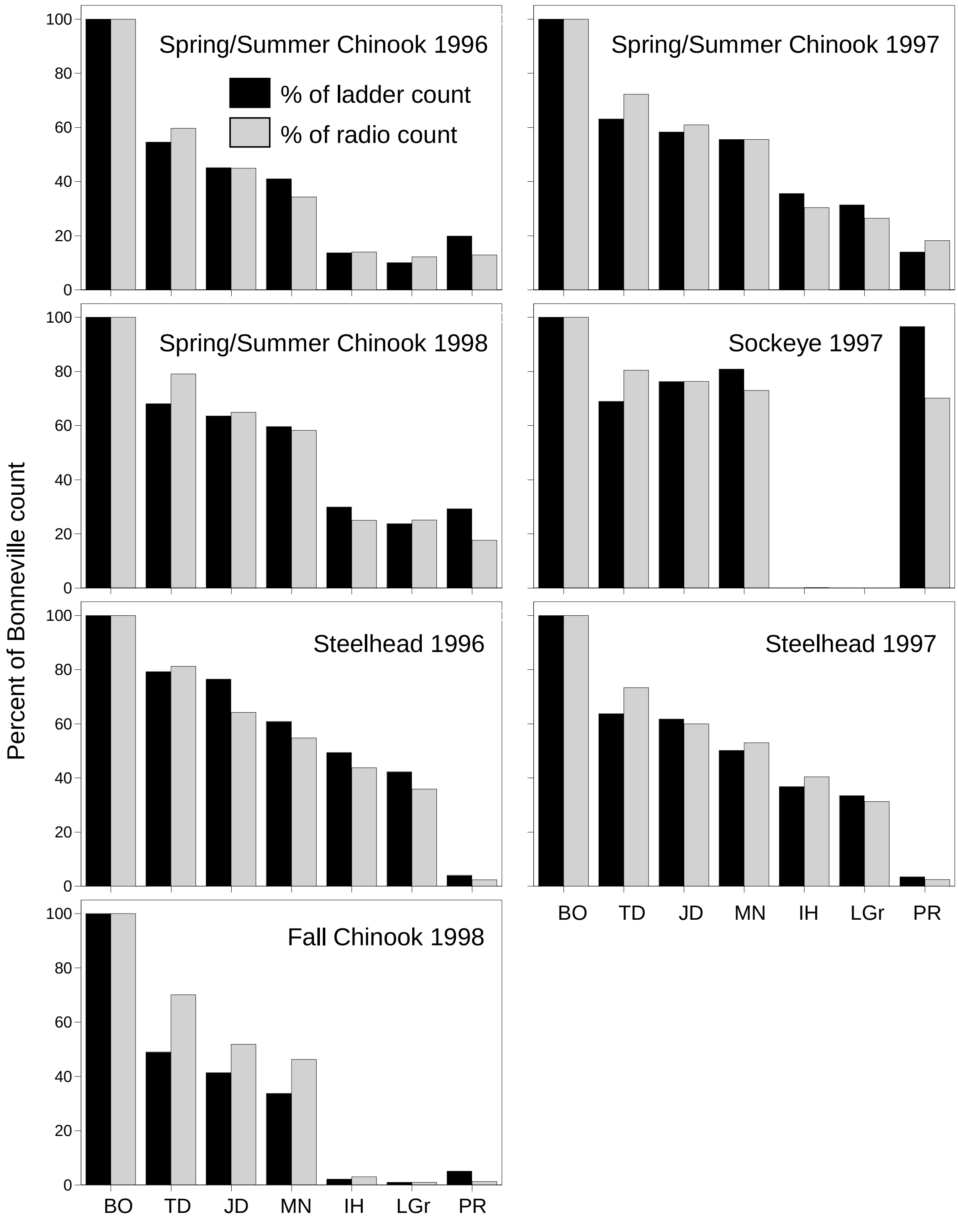

Figure 3. Percent of chinook and sockeye salmon and steelhead counted at Bonneville Dam and radio-tagged salmon and steelhead recorded at Bonneville Dam that were recorded upstream at other Columbia and Snake River dams in 1996, 1997, and 1998. Counts not adjusted for fallback and reascension or navigation lock passage.

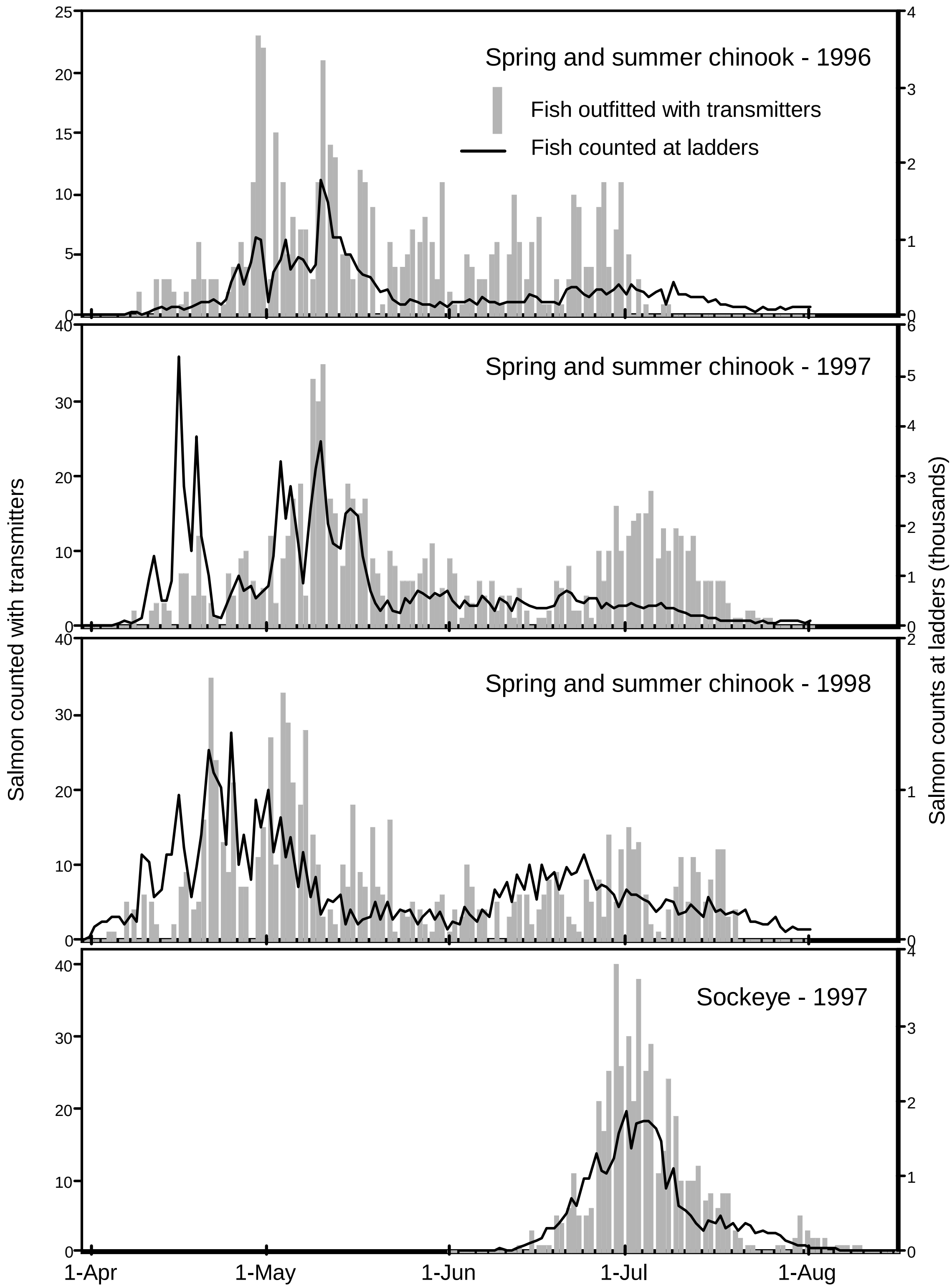

Figure 4. Daily spring and summer chinook salmon and sockeye salmon counts at The Dalles Dam and the number of salmon with transmitters that passed the dam in 1996, 1997, and 1998.

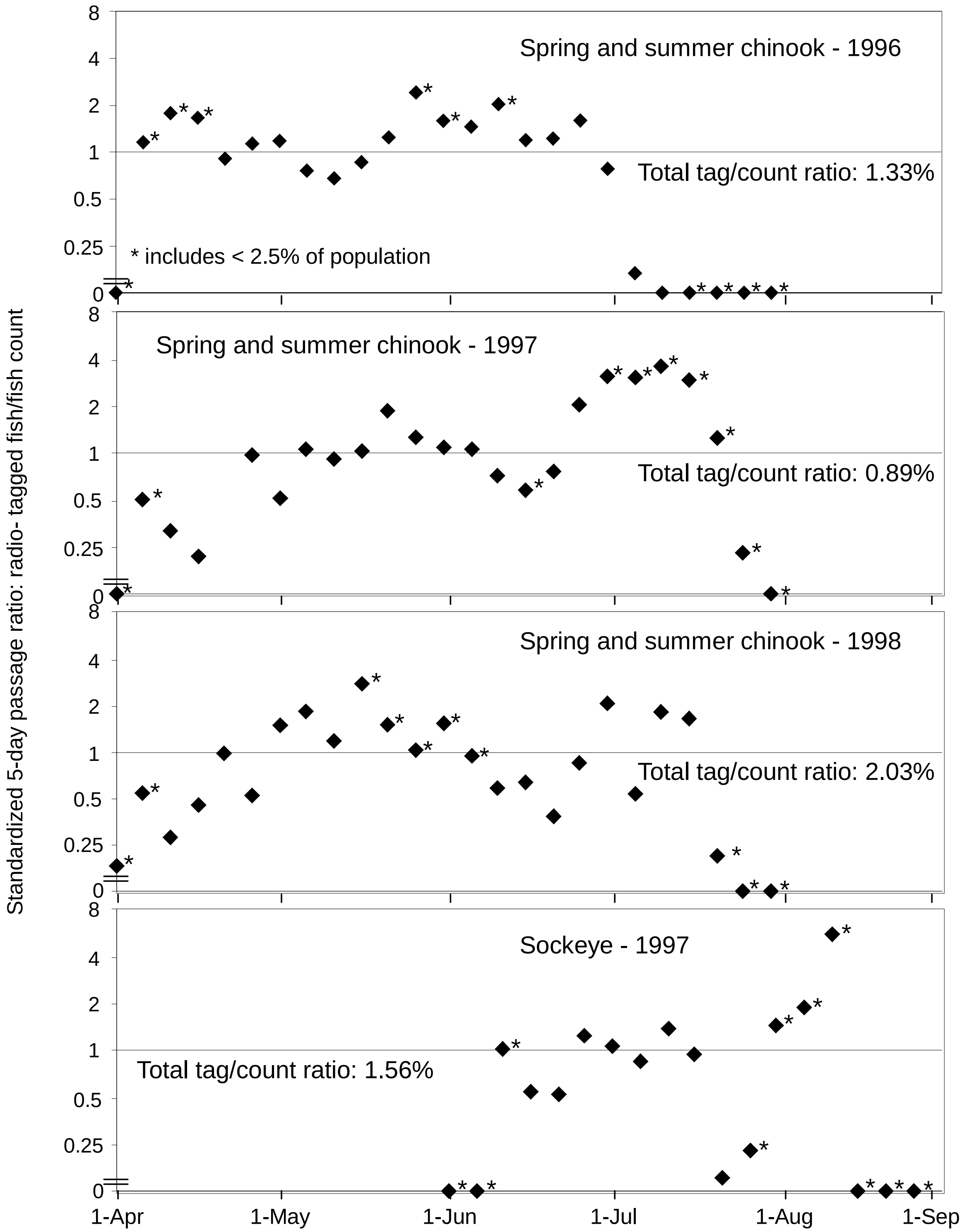

Figure 5. Standardized proportions of radio-tagged spring and summer chinook salmon and sockeye salmon passing The Dalles Dam to the total counts at the dam during 5-d blocks in 1996, 1997, and 1998. Blocks that include less than 2.5% of the total run noted with an asterisk. Log (~base 2) scale used to show relative distance from total sampling rate.

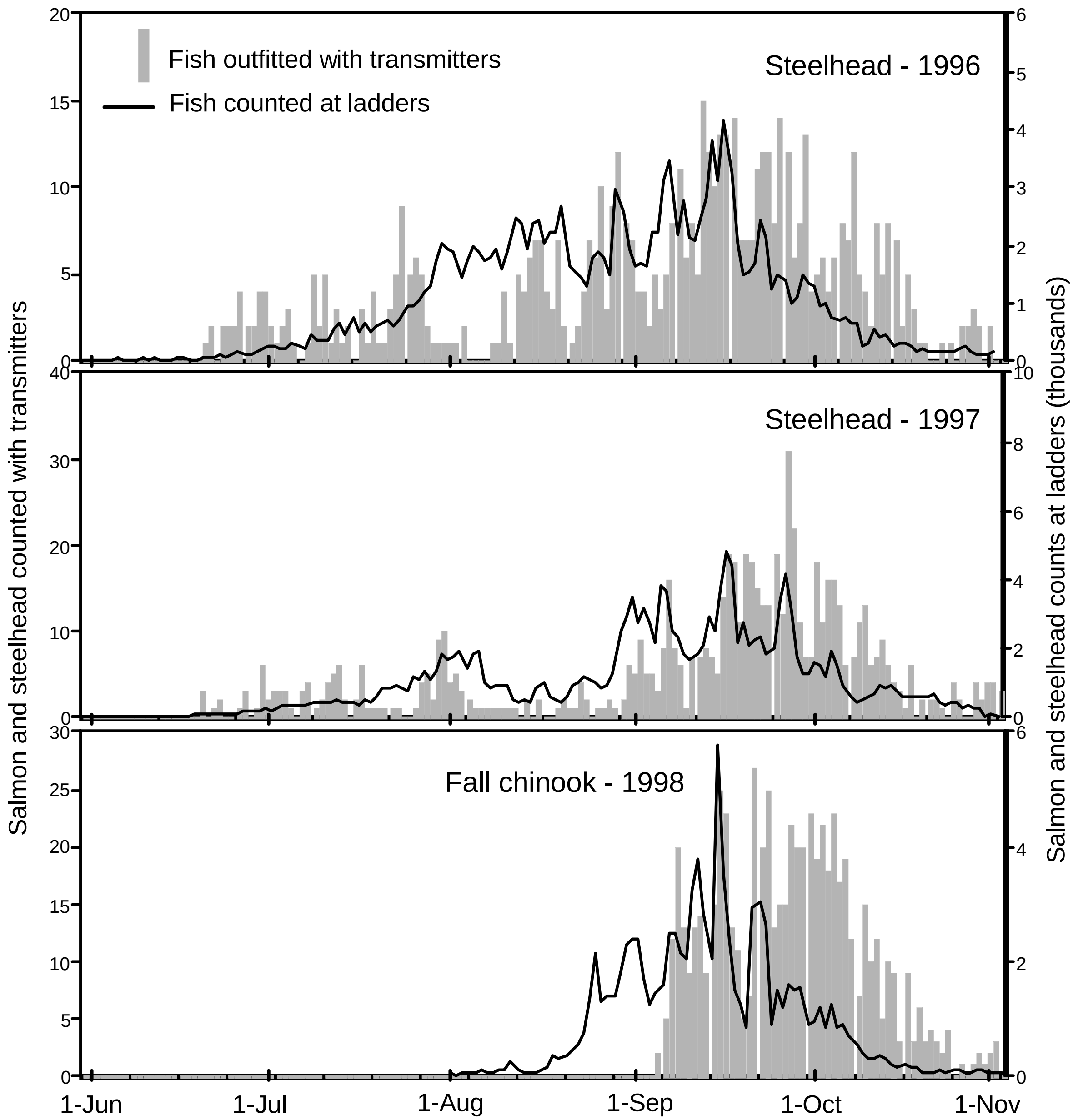

Figure 6. Daily steelhead and fall chinook salmon counts at The Dalles Dam and the number of steelhead and salmon with transmitters that passed the dam in 1996, 1997, and 1998.

Dam when salmon with transmitters were substantially less abundant than the count of salmon passing through ladders.

Most sockeye salmon passed The Dalles Dam between 20 June and 20 July in 1997 (Figure 4), and tagged fish made up 1-2% of the run during that time. Most steelhead passed The Dalles Dam from late June through October in both 1996 and 1997, and during most of the migration radio-tagged fish made up 0.2 to 1.0% of the fish passing the dam (Figure 6). Radio-tagged steelhead made up a

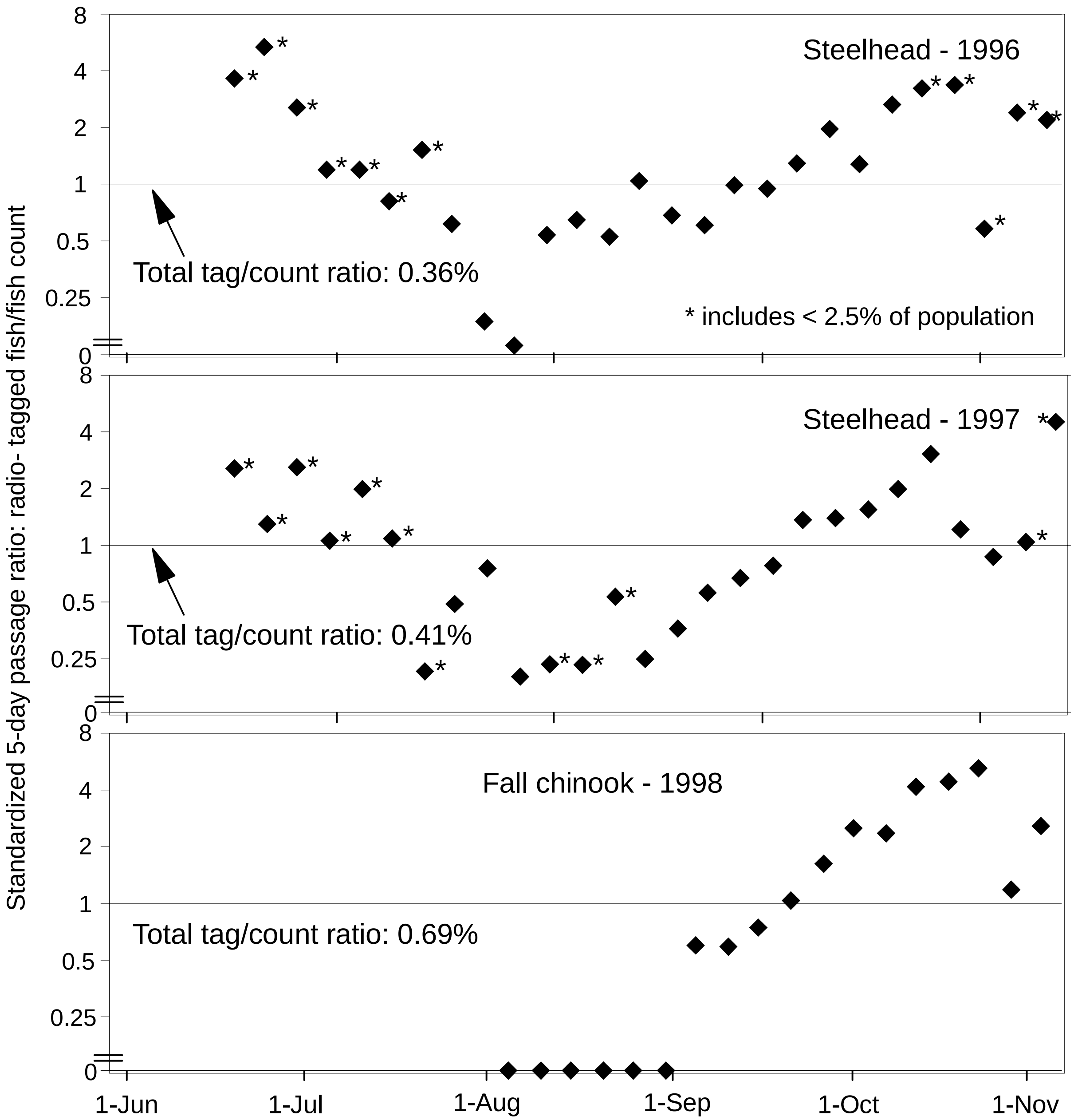

Figure 7. Standardized proportions of radio-tagged steelhead and fall chinook salmon passing The Dalles Dam to the total counts at the dam during 5-d blocks in 1996, 1997, and 1998. Blocks that include less than 2.5% of the total run noted with an asterisk. Log (~base 2) scale used to show relative distance from total sampling rate.

higher percentage of the fish passing the dam early and late in the migration than during the main period of passage.

Environmental conditions at The Dalles Dam were different among the three years of study. Flow, spill, and dissolved gas levels were lowest in 1998, highest in 1997, and intermediate in 1996 (Figures 8 and 9). Secchi disk visibility was generally lowest in 1997, highest in 1998, and intermediate in 1996, with the greater differences between and within years early in the migration season (Figure 9). Water temperatures had similar trends in all three years, but temperatures in 1998 were higher than prior years.

In a between-years comparison of mean monthly values, 1997 had the highest mean flow for all months and the highest mean spill for the months of May, June, July, and August (Figure 10.) The 1998 means were the lowest for flow and spill in all months compared. Dissolved gas concentrations in 1998 were the lowest among years for all months except June, and 1998 mean Secchi disk readings were highest in all months (Figure 10).

Flow and spill conditions in the three years of study represented a high flow year (1997), a moderately high flow year (1996), and a near average flow year (1998) at The Dalles Dam. Timing and size of the spring and summer chinook salmon runs, however, were somewhat atypical during the three years. In 1996, the run was smaller than the 15-year average (1983 to 1997) at The Dalles Dam (Figure 11) and peaked about two weeks later than average. The 1997 chinook salmon run was larger than average and the run was bimodally distributed, with peaks in mid April and early May. The nadir in the 1997 run of chinook salmon in late April coincided with high turbidity (Secchi disk visibility about 1.5 ft) and peak dissolved gas concentrations (Figure 9). The 1998 run was somewhat smaller than the 15-year average, but passage distribution was similar to average. Timing of sockeye salmon passage in 1997 and steelhead passage in 1996 and 1997 were similar to 15-year averages. The 1997 sockeye run was slightly smaller than the 15-year average. Passage of 1996 steelhead was higher than average through August, but the run overall was close to average. Passage of 1997 steelhead was lower than average in August, but counts were higher than average later in the migration (Figure 11). Fall chinook salmon counts in 1998 were lower than the 15-year average, especially during early September.

Methods

Processing of radio-telemetry data from spring and summer chinook salmon, sockeye salmon, steelhead, and fall chinook salmon outfitted with radio transmitters in the years 1996 to 1998 was at similar levels of completion at the time this report was prepared. All migration data were coded and assembled for all species and years. Telemetry data from all monitored dams, fixed receivers at tributary sites, and mobile-tracking efforts were combined in ‘general migration’ data files, along with recapture information. In the general migration file, all fallback events at all dams were verified or eliminated based on upriver and other supplementary records.

As we further analyze general migration files, some changes in fallback analyses are likely, but we believe the changes will be small. We would expect to correct < 2% of the fish as to their fallback history, and minimal adjustments in percentages of fish that fell back, fallback rates, and other summary information.

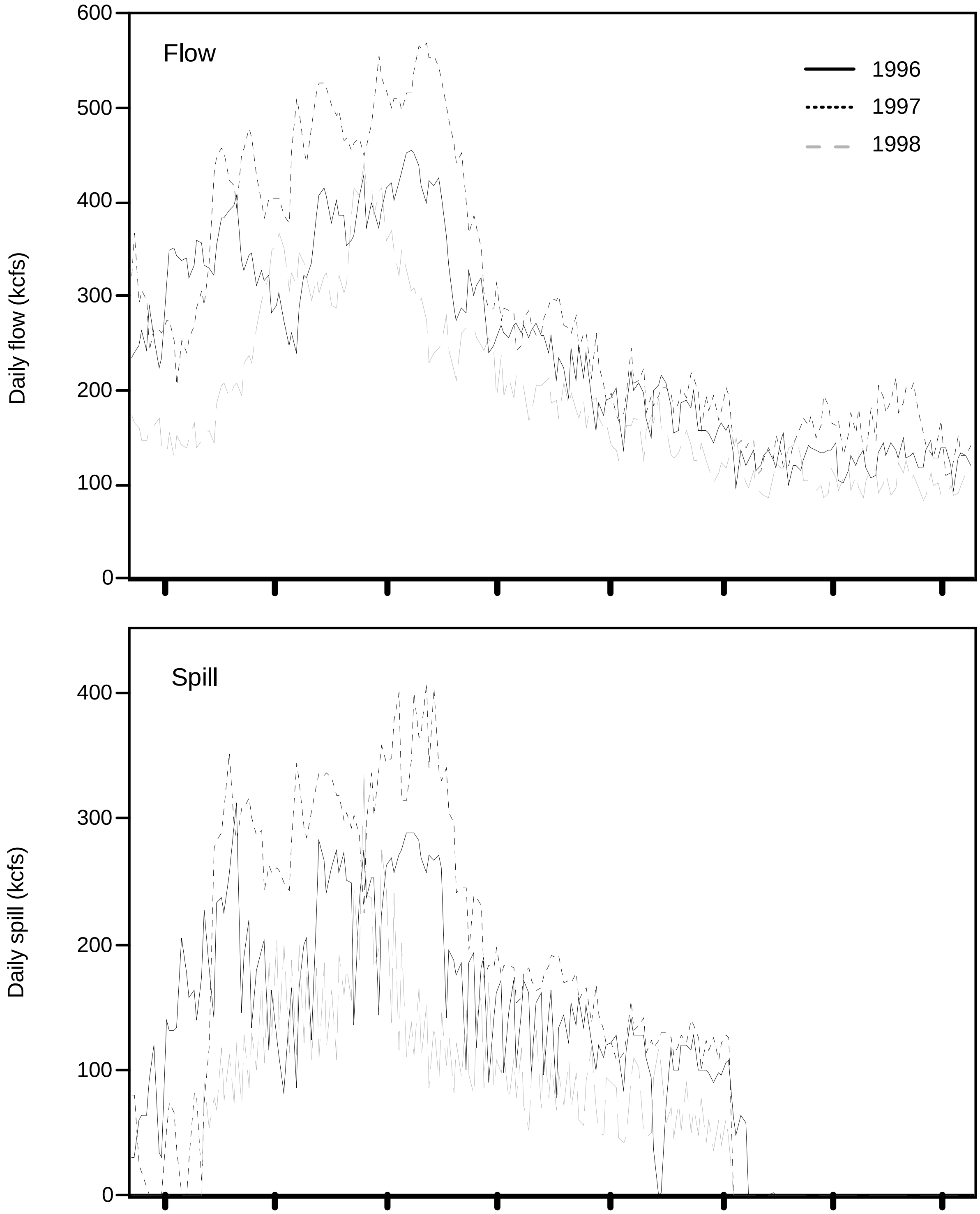

Figure 8. Daily flow and spill at The Dalles Dam in 1996, 1997, and 1998.

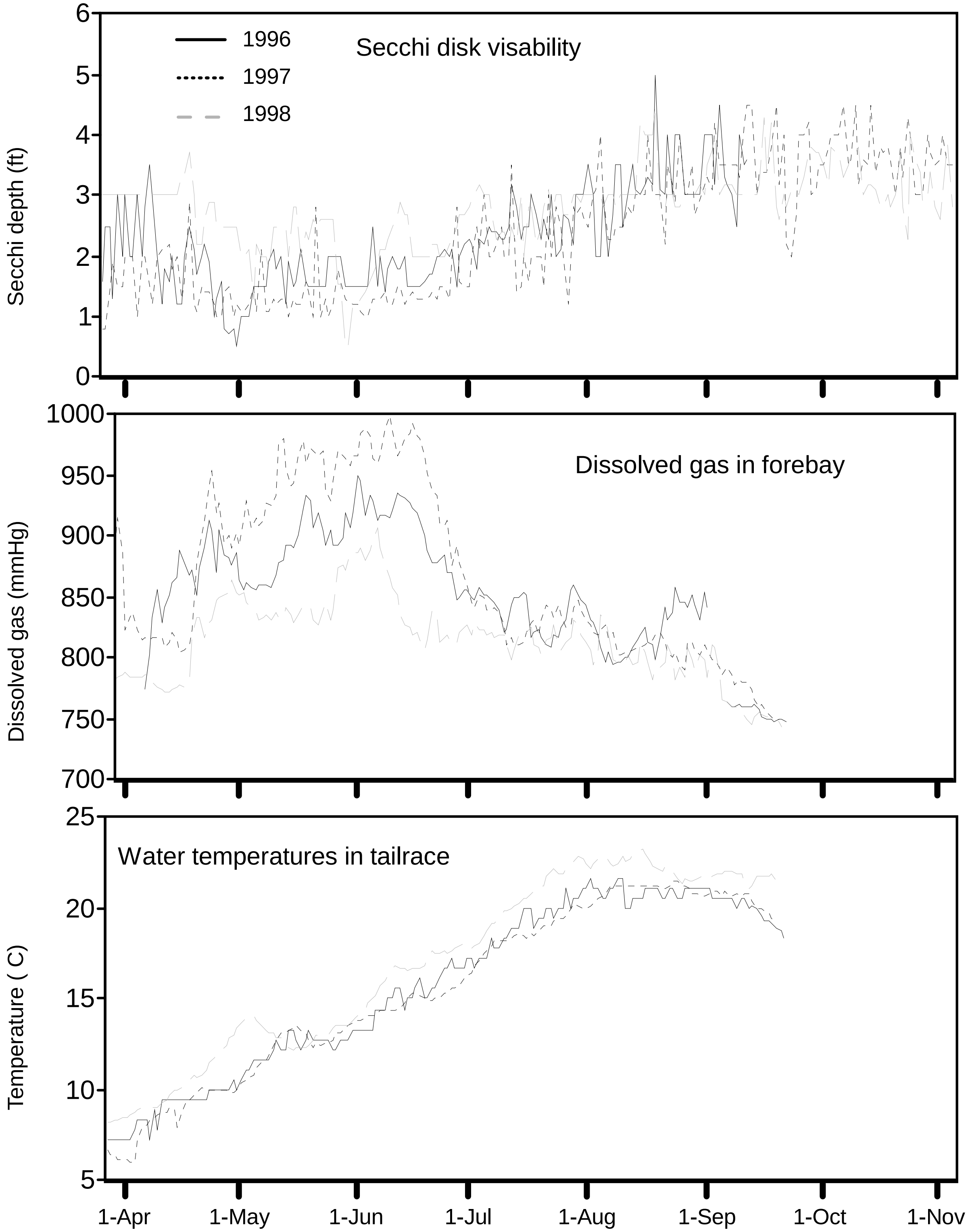

Figure 9. Daily Secchi disk visibility in the forebay, dissolved gas levels in the forebay, and water temperature in the tailrace at The Dalles Dam in 1996, 1997, and 1998.

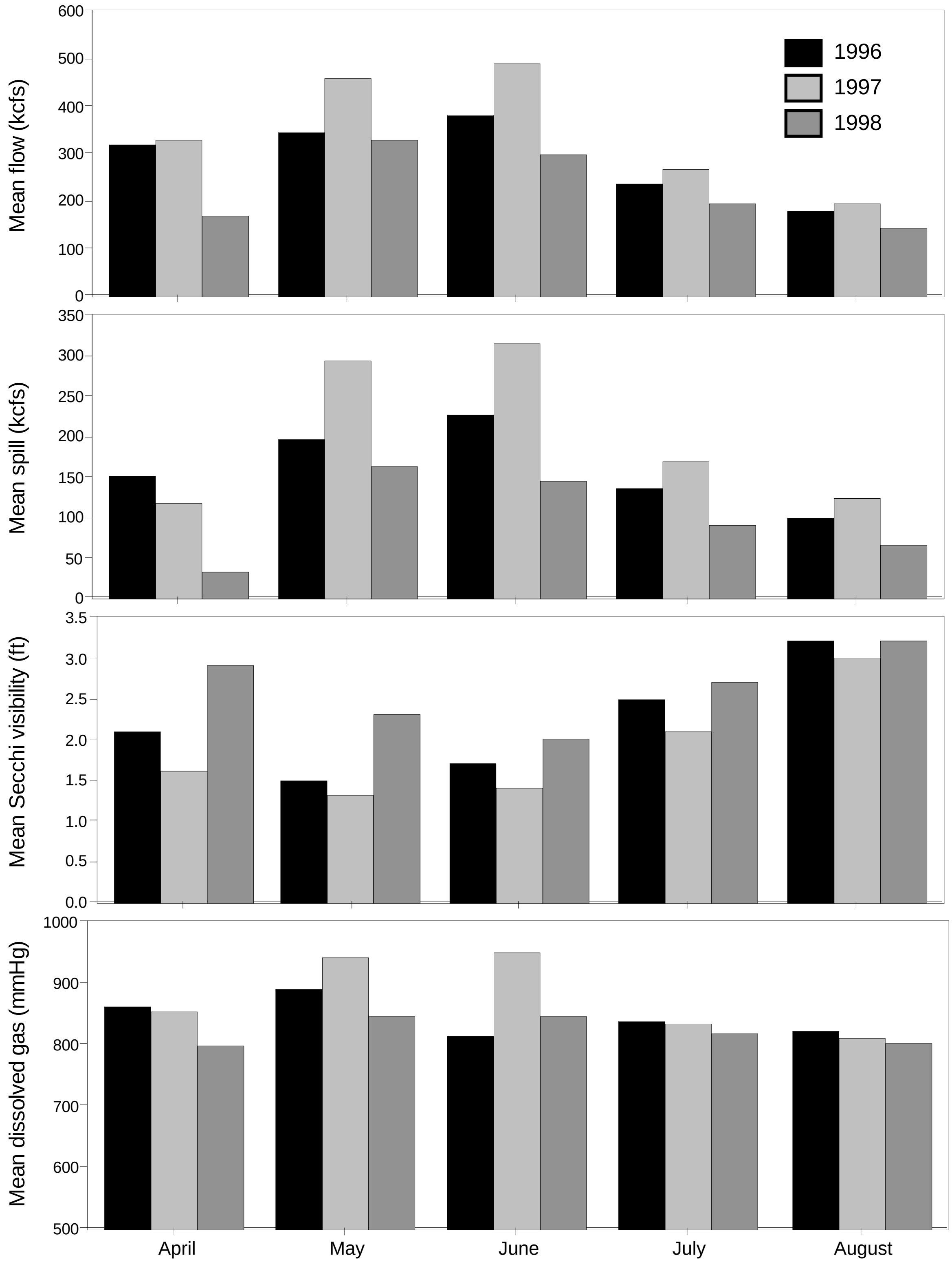

Figure 10. Monthly mean values for flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay at The Dalles Dam in 1996, 1997, and 1998.

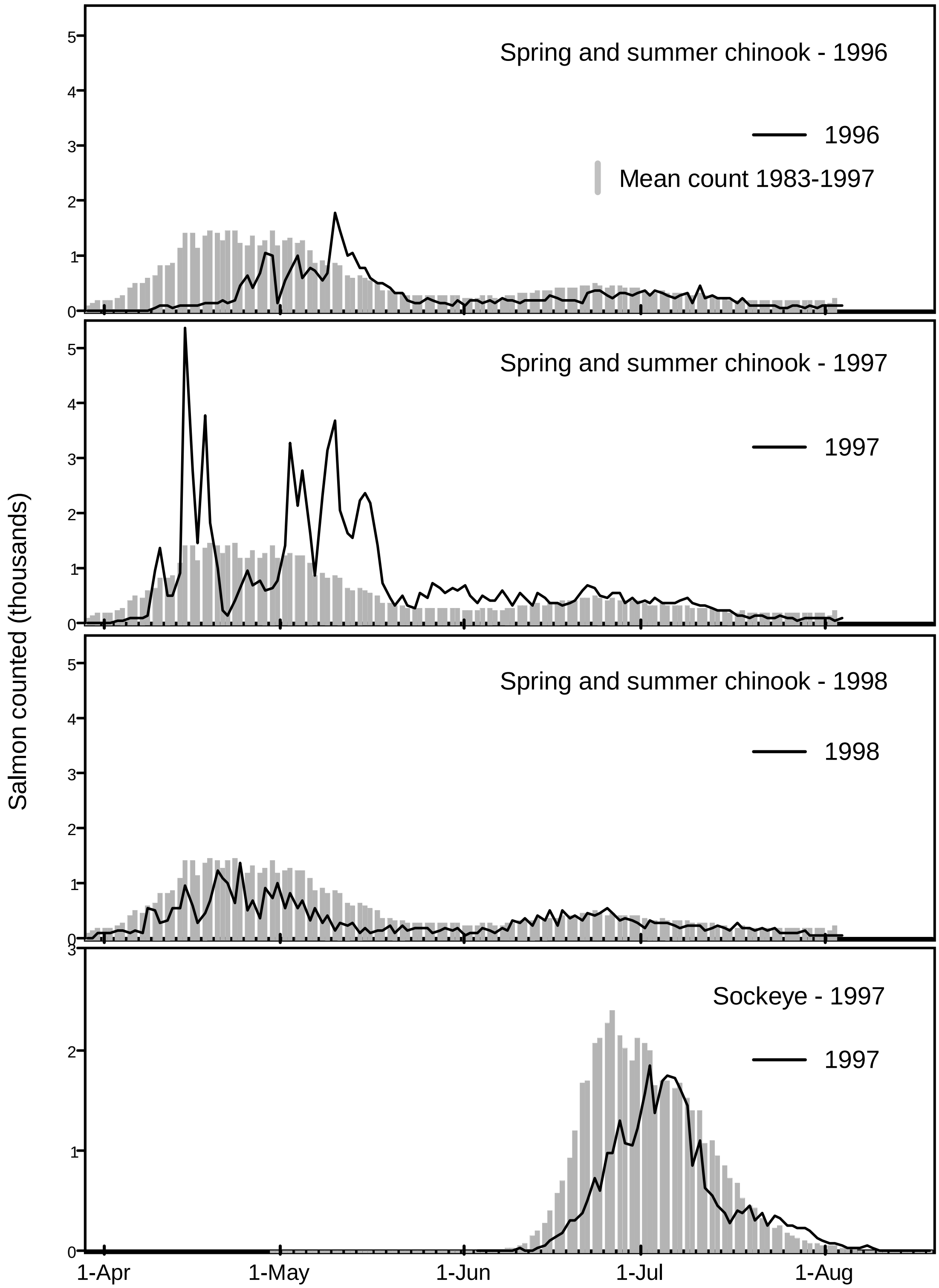

Figure 11. Daily spring and summer chinook salmon, sockeye salmon, steelhead, and fall chinook salmon counts at The Dalles Dam in 1996, 1997, and 1998, with average counts from 1984 to 1998.

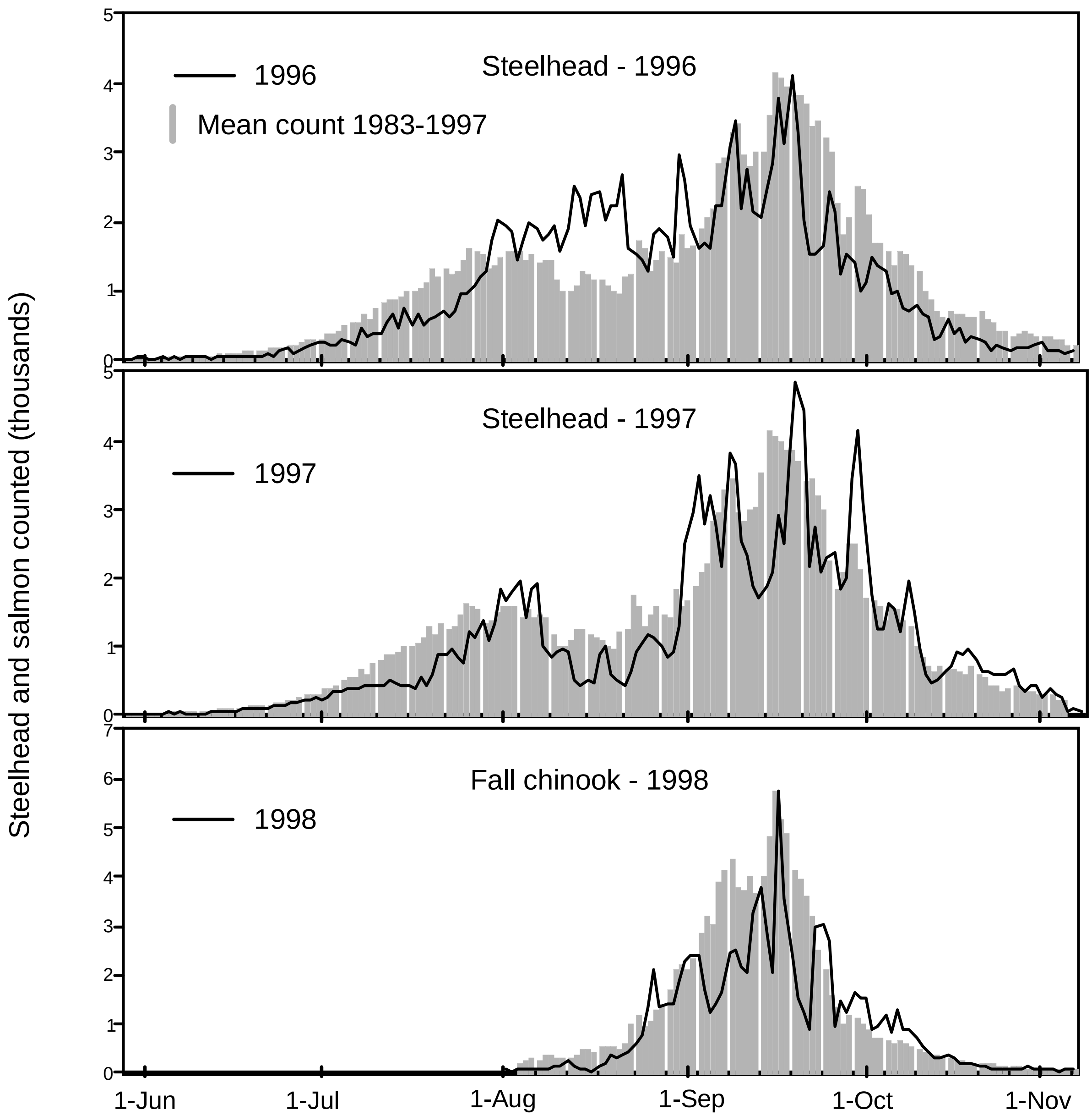

Figure 11 cont.

Antenna coverage relevant to monitoring fallback behavior at The Dalles Dam varied slightly between years (Figure 12). Coverage in 1996 was limited to Yagi antennas on both sides of the river 4 and 4.8 km downstream from the dam, underwater antennas at the tops of the ladders, and one antenna in the transition pool at the bottom of the Oregon-shore ladder. Coverage was expanded for 1997 and 1998 with the addition of underwater antennas at selected entrances to fishways and in transition pools.

Results

Fallback Percentages and Rates for Spring and Summer Chinook Salmon

The percentage of unique spring and summer chinook salmon with transmitters that fell back over The Dalles Dam (13.2% in 1996, 14.2% in 1997, and 11.0% in 1998) was calculated by dividing the number of unique salmon with transmitters that fell back by the number of unique salmon known to have passed The Dalles Dam via any route (Table 1). When only fish recorded at top-of-ladder receivers were used as the denominator, fallback percentages were 15.2% in 1996, 14.3% in 1997, and 11.1% in 1998 (Table 1). The percentages of unique fish that fell back did not reflect multiple fallbacks by individual fish or multiple passages past the dam and should not be used as correction factors for counts of fish passing through fishways. Percentages of salmon with radio transmitters that fell back at The Dalles Dam each year could be extrapolated to estimate the proportion of salmon in each of the annual runs that fell back at the dam.

Fallback rates, the number of fallback events divided by the number of unique chinook salmon with transmitters known to have passed The Dalles Dam were 18.2% in 1996, 18.4% in 1997, and 13.8% in 1998 (Table 2). When only fish recorded at top-of-ladder receivers were used as the divisor, fallback rates were 20.9% in 1996, 18.6% in 1997, and 13.9% in 1998. The latter rates excluded fish that passed the dam via the navigation lock and those that were not recorded at the tops of fishways due to receiver outages or malfunctioning transmitters. Differences between the two rates within a year were relatively small because most fish passed the dam via the fishways and a high percentage were recorded. The 95% confidence intervals assuming normally distributed errors and a normal binomial approximation for chinook salmon fallback rates were +/- 3.9%. Confidence intervals in Table 2 were based on pooled data for all radio-tagged fish only in each year and did not address over- or undersampling or temporal differences in fallback behavior for the total run. We also calculated 95% confidence intervals using a stratified sampling method, where passage and fallback rates for consecutive 5-d blocks were weighted by total ladder counts at the dam during each block. Figure 13 shows fallback rates for radio-tagged fish for each block and the total daily ladder count at the dam. We assumed blocks were independent and computed standard errors for each block and a weighted

Table 1. Number of unique spring and summer chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) with transmitters that fell back (FB) at The Dalles Dam, number known to have passed the dam, number recorded at the tops of fishways at the dam, and the percentage of fish that fell back in 1996, 1997 and 1998.

Year Species	Fish that fell back at dam	Number known to pass dam	Recorded at top of fishways	FB percent of fish known to pass dam	FB percent of fish that passed fishways
1996 CK	66	500	435	13.2 (10.3-16.3)	15.2 (11.9-18.6)
1997 CK	101	713	705	14.2 (11.6-16.7)	14.3 (11.7-16.9)
1998 CK	84	763	754	11.0 (8.7-13.2)	11.1 (8.9-13.4)
1996 SH[1]	35	584	558	6.0 (4.1-7.9)	6.3 (4.3-8.3)
1996 SH[2]	23	582	557	4.0 (2.4-5.5)	4.1 (2.5-5.8)
1997 SH[1]	45	677	661	6.7 (4.8-8.5)	6.8 (4.9-8.8)
1997 SH[2]	27	671	655	4.0 (2.5-5.5)	4.1 (2.6-5.7)
1997 SK	24	492	485	4.9 (3.0-6.8)	4.9 (3.0-6.9)
1998 FCK	65	628	616	10.4 (8.0-12.7)	10.6 (8.1-13.0)

[1] Includes all passages and fallbacks of radio-tagged steelhead

[2] Includes passages and fallbacks of steelhead through 31 October of tagging year

Table 2. Number of fallback (FB) events by spring and summer chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) with transmitters at The Dalles Dam, the number known to have passed the dam, the number recorded at the tops of fishways at the dam, and the fallback rates for 1996, 1997, and 1998.

Year Species	Total FB events	Number known to pass dam	Recorded[a] at top of fishways	FB rate of fish known to pass dam	FB rate of fish that passed fishways
1996 CK	91	500	435	18.2 (14.9-21.7)	20.9 (17.2-24.9)
1997 CK	131	713	705	18.4 (15.5-21.2)	18.6 (15.7-21.5)
1998 CK	105	763	754	13.8 (11.3-16.2)	13.9 (11.5-16.4)
1996 SH[1]	40	584	558	6.8 (4.8-8.9)	7.2 (5.0-9.3)
1996 SH[2]	25	582	557	4.3 (2.6-5.9)	4.5 (2.8-6.2)
1997 SH[1]	52	677	661	7.7 (5.7-9.7)	7.9 (5.8-9.9)
1997 SH[2]	29	671	655	4.3 (2.8-5.9)	4.4 (2.9-6.0)
1997 SK	25	492	484	5.1 (3.1-7.0)	5.2 (3.2-7.1)
1998 FCK	74	628	616	11.8 (9.3-14.3)	12.0 (9.4-14.6)

[1] Includes all passages and fallbacks of radio-tagged steelhead

[2] Includes all passages and fallbacks of steelhead through 31 October of tagging year

average fallback rate during the time that radio-tagged fish were passing the dam. Weighted fallback rates were within 1% of those based on pooled data in all three years, and confidence intervals were similar for weighted and pooled rates (Figure 14).

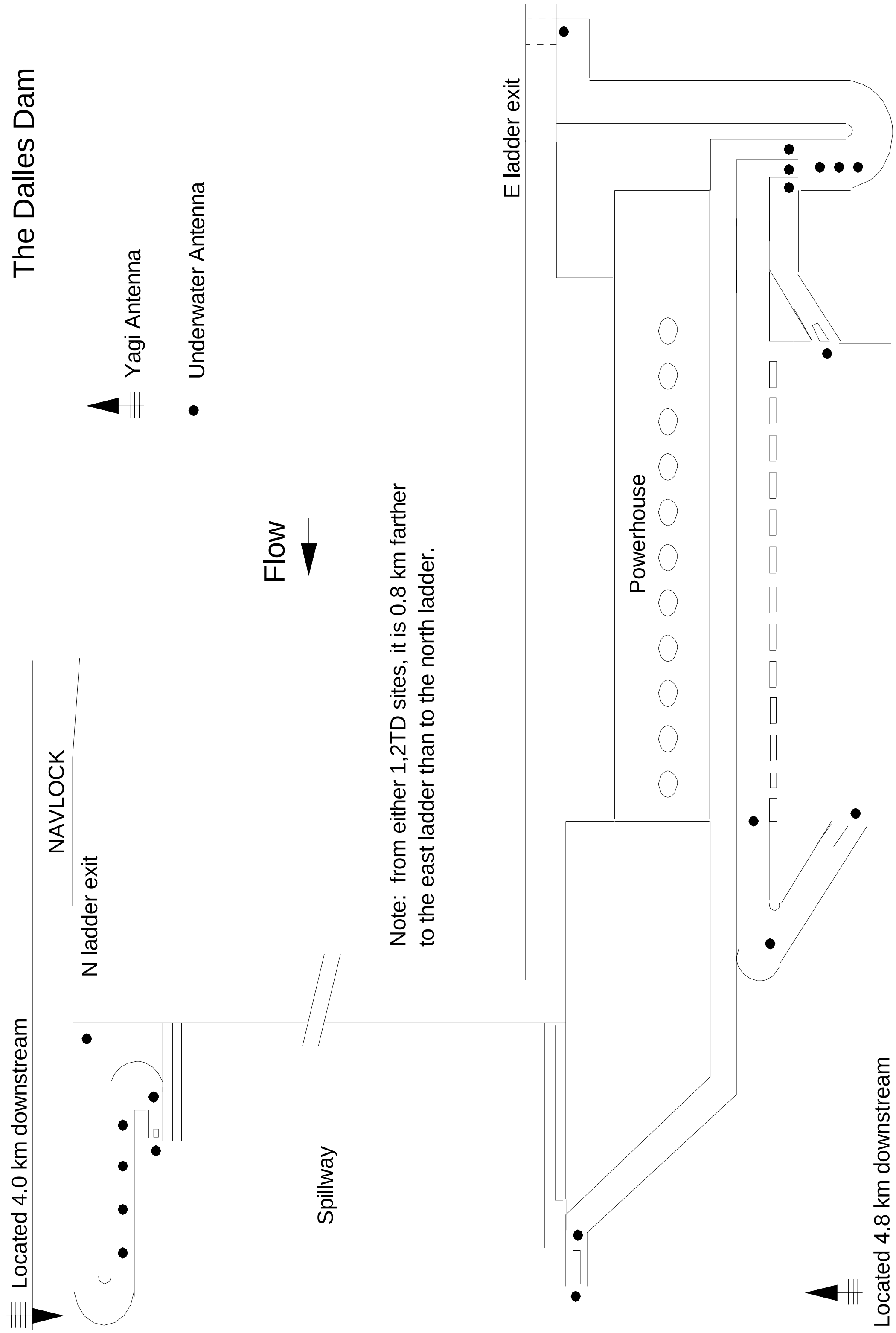

Figure 12. Location of aerial antennas at The Dalles Dam in 1996, 1997, and 1998, and underwater antennas in 1997 and 1998. See text for underwater antenna locations in 1996.

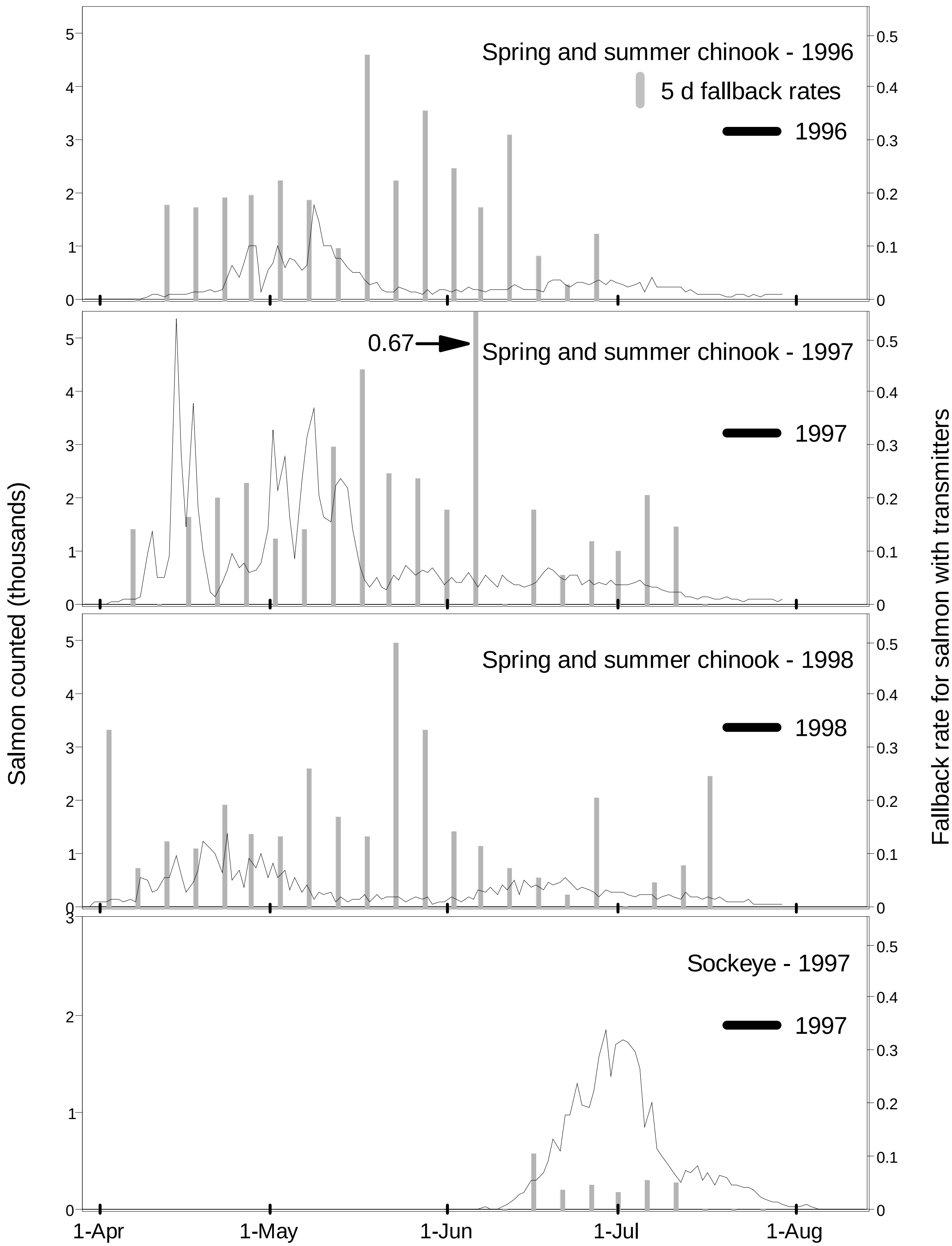

Figure 13. Fallback rates for chinook and sockeye salmon with transmitters based on 5-d blocks, with total salmon counts at The Dalles Dam ladders in 1996, 1997, and 1998.

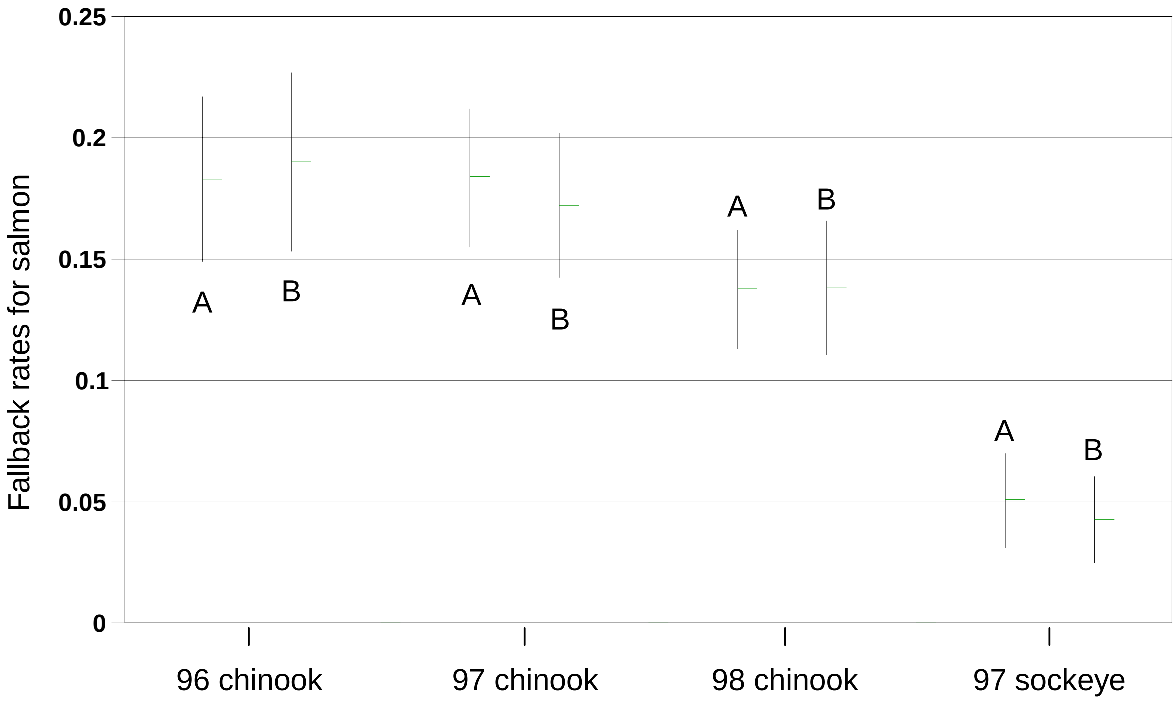

Figure 14. Fallback rates with 95% confidence intervals for radio-tagged spring and summer chinook salmon and sockeye salmon at The Dalles Dam in 1996, 1997, and 1998. Confidence intervals calculated by (A) pooling all telemetry data, (B) weighting 5-d blocks by total counts of salmon passing ladders and computing fallback rates and standard errors for each block.

Fallback rates, as defined here, offered a more comprehensive view of fallback behavior by spring and summer chinook salmon at The Dalles Dam because multiple fallbacks by individual fish were included. However, neither percent of unique salmon that fell back, nor fallback rates should be used to correct fishway count inflation caused by multiple passages of salmon that fell back. Fallback rates accounted for multiple fallbacks, but not multiple reascensions after fallback nor overestimates of escapement due to fish that fell back and did not reascend (see section on fishway count adjustment factors).

Of 66 spring and summer chinook salmon that fell back at The Dalles Dam in 1996, 52 (79%) fell back once, 9 (14%) fell back twice and 5 (8%) fell back three or more times; 48% of the fish that fell back ultimately reascended and passed the dam. Of 101 chinook salmon that fell back in 1997, 79 (78%) fell back once, 16 (16%) fell back twice, 5 (5%) fell back 3 times, and one fell back 5 times; 70% of the fish that fell back ultimately reascended and passed the dam. Of 84 chinook salmon that fell back in 1998, 68 (81%) fell back once, 13 (15%) fell back twice, 2 (2%) fell back three times, and 1 fell back five times; 63% of the fish that fell back ultimately reascended and passed the dam.

Spring and summer chinook salmon with transmitters that fell back over The

Dalles Dam had a variety of upriver movements before they fell back. Although we could not monitor the exact time fish fell back, in most cases we could estimate fallback times to within a few hours of the event, using tailrace, fishway, or upstream telemetry records. Some fallback events were likely related to environmental conditions in the forebay when fish exited from the tops of fishways. We believe environmental conditions would be most likely to influence fallbacks in the hours immediately after a fish exited from the tops of ladders, and less so after fish migrated upriver out of the forebay. For this reason, we separated all fallback events into two groups, those that occurred within 24 h of a fish's exit from the top of a fishway and those that fell back more than 24 h after they left fishways. We also identified all chinook salmon that were recorded at sites upstream from The Dalles Dam prior to fallback events at The Dalles Dam.

In 1996, 25% of all fallback events by spring and summer chinook salmon at the Dalles Dam occurred less than 24 h after the fish exited from the top of a fishway (Table 3), and 11% occurred less than 12 h after passage. Sixty-two of the fish with transmitters migrated upriver and were recorded at fixed-site receivers at tributaries or at upriver dams before they moved back downstream and fell back over The Dalles Dam. The remaining 13% of fallback events in 1996 occurred more than 24 h after passing dams, but fish were not recorded at receivers upriver from the dam (Table 3).

Table 3. Number of fallback (FB) events by spring and summer chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) with transmitters at The Dalles Dam, the number and percent that fell back within 24 h of passing the dam, the percent recorded upriver before falling back and the percent that fell back more than 24 h after passing but were not recorded upriver in 1996, 1997, and 1998.

Year Species	Total FB events at dam	Number that FB in <24 h	Percent that FB in <24 h	Percent FB's > 24 h: Recorded upriver	Percent FB's > 24 h: Not recorded upriver
1996 CK	91	23	25	62	13
1997 CK	131	42	32	62	6
1998 CK	105	31	30	60	10
1996 SH[1]	40	8	20	70	10
1996 SH[2]	25	8	32	56	12
1997 SH[1]	52	14	27	67	6
1997 SH[2]	29	12	41	52	7
1997 SK	25	18	72	24	4
1998 FCK	74	9	12	85	3

[1] Includes all passages and fallbacks of radio-tagged steelhead
[2] Includes all passages and fallbacks of steelhead through 31 October of tagging year

In 1997, 32% of all fallback events occurred less than 24 h after passage and 19% occurred less than 12 h after passage. In 1998, 30% of all fallback events occurred less then 24 h after passage, and 11% occurred less than 12 h after passage. Sixty-two percent of spring and summer chinook salmon that fell back in 1997, and 60% of those that fell back in 1998 were recorded at upriver fixed receivers before falling back (Table 3).

The percentages of spring and summer chinook salmon that fell back after passing the dam via the Washington-shore (north-shore) or Oregon-shore (south-shore) fishways differed between years, but we found no clear trend over the three years. In 1996, 18.0% of the unique fish recorded at the top of the south-shore fishway fell back, compared to 11.7% that fell back after passing via the north-shore fishway, a difference that was not significant (P = 0.08, Z test) (Table 4). In 1997, 13.8% of the unique fish that passed the south-shore fishway fell back, compared to 16.9% that fell back after passing via the north-shore fishway (P = 0.26). In 1998, 10.7% of the unique fish that passed the south-shore fishway fell back, compared to 12.6% that fell back after passing the north-shore fishway (P = 0.12) (Table 4).

Fallback rates, the number of fallback events divided by the number of unique fish past a fishway, were also different for the two fishways. In 1996, the fallback rate for the south-shore fishway was 21.6% and the rate for the north-shore fishway was 14.3%, a difference that neared significance (P = 0.06, Z test) (Table 5). In 1997, the fallback rate for the south-shore fishway was 16.1% and the rate for the north-shore fishway was

Table 4. Number of unique spring and summer chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) with transmitters recorded at the tops of the south-shore (SS) and north-shore (NS) fishways at The Dalles Dam, the number of unique fish that fell back (FB), and the percentage of fish that passed each fishway and fell back in 1996, 1997, and 1998.

Year Species	Unique fish at top of SS ladder	Unique fish that fell back	% past SS ladder that FB	Unique fish at top of NS ladder	Unique fish that fell back	% past NS ladder that FB
1996 CK	305	55	18.0	154	18	11.7
1997 CK	448	62	13.8	296	50	16.9
1998 CK	412	44	10.7	381	48	12.6
1996 SH[1]	482	26	5.4	100	9	9.0
1996 SH[2]	480	16	3.3	97	6	6.2
1997 SH[1]	622	43	6.9	60	3	5.0
1997 SH[2]	614	26	4.2	54	1	1.9
1997 SK	301	7	2.3	195	18	9.2
1998 FCK	536	51	9.5	96	14	14.6

[1] Includes all passages and fallbacks of radio-tagged steelhead
[2] Includes all passages and fallbacks of steelhead through 31 October of tagging year

Table 5. Number of unique chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) with transmitters recorded at the tops of the south-shore (SS) and north-shore (NS) fishways at The Dalles Dam, the number of fallback events (FB), and the fallback rate by fishway in 1996, 1997, and 1998.

	Unique fish at top of ss fishway	Fallback events	SS fishway FB rate	Unique fish at top of NS fishway	Fallback events	NS fishway FB rate
1996 CK	305	66	21.6	154	22	14.3
1997 CK	448	72	16.1	296	59	19.9
1998 CK	412	52	12.6	381	53	13.9
1996 SH[1]	482	29	6.0	100	10	10.0
1996 SH[2]	480	17	3.5	97	7	7.2
1997 SH[1]	622	49	7.9	60	3	5.0
1997 SH[2]	614	28	4.6	54	1	1.9
1997 SK	301	7	2.3	195	18	9.2
1998 FCK	536	60	11.2	96	14	14.6

[1] Includes all passages and fallbacks of radio-tagged steelhead
[2] Includes all passages and fallbacks of steelhead through 31 October of tagging year

19.9% (P = 0.18). In 1998, the fallback rate for the south-shore fishway was 12.6% and the rate for the north-shore fishway was 13.9% (P = 0.33) (Table 5).

We also calculated the percentage of fallback events by spring and summer chinook salmon with transmitters based on the fishway passed. This calculation is presented to show the fishway of origin preceding fallback events. Chinook salmon passed via the south-shore fishway prior to 73% of all fallback events in 1996, 55% of all events in 1997, and 50% of all events in 1998 (Table 6). When we only considered fallbacks that occurred within 24 h of passing The Dalles Dam, chinook salmon had passed via the south-shore fishway prior to 70% of the 1996 events, 52% of the 1997 events, and 55% of the 1998 events (Table 6). More spring and summer chinook salmon passed via the south-shore fishway than the north-shore in all years, but fallback rates within 24 h of dam passage did not differ significantly between ladders in any year (P > 0.28, Z tests).

Fallback Percentages and Rates for Sockeye Salmon

The percentage of unique sockeye salmon with transmitters that fell back over The Dalles Dam in 1997 (4.9%) was calculated by dividing the number of unique fish with transmitters that fell back by the number of unique salmon known to have passed The Dalles Dam, regardless of route (Table 1). When only fish recorded at top-of-ladder receivers were used as the divisor, the 1997 fallback percentage was 4.9%, and the 95% confidence interval was 3.0% to 6.9% (Table1). The 95% confidence interval in Table 1 was based on the assumption of normally distributed errors and a normal binomial approximation; the interval was based on pooled data

Table 6. Number of fallback (FB) events and fallback events within 24 h of passing the south-shore (SS) and north-shore (NS) fishways at The Dalles Dam, and the percentage of events that occurred after chinook salmon (CK), sockeye salmon (SK), and steelhead (SH) passed each fishway in 1996, 1997, and 1998.

Year Species	Total number of FB events	Percent past SS fishway	Percent past NS fishway[b]	Fallback events within 24 h Number	% past SS fishway	% past NS fishway
1996 CK	91	73	24	23	70	30
1997 CK	131	55	45	42	52	48
1998 CK	105	50	50	31	55	45
1996 SH[1]	40	73	25	8	100	0
1996 SH[2]	25	68	28	8	100	0
1997 SH[1]	52	94	6	14	93	7
1997 SH[2]	29	97	3	12	92	8
1997 SK	25	28	72	18	17	83
1998 FCK	74	81	19	9	67	33

[1] Includes all passages and fallbacks of radio-tagged steelhead

[2] Includes all passages and fallbacks of steelhead through 31 October of tagging year

for all radio-tagged fish and did not address over- or undersampling or temporal differences in fallback behavior. (See Figure 14 for a comparison of 95% confidence intervals of sockeye salmon fallback rates calculated with unweighted pooled data and weighted data.)

Fallback rate, the number of fallback events divided by the number of unique sockeye salmon with transmitters known to pass The Dalles Dam in 1997 was 5.1%; the rate was 5.2% using only the number recorded at top-of-ladder receivers with a standard 95% confidence interval from 3.2% to 7.1% (Table 2). Confidence intervals in Table 2 were based on pooled data for all radio-tagged fish. We also calculated 95% confidence intervals for sockeye salmon using the 5-d stratified sampling method described previously for spring and summer chinook salmon. Fallback rates for 5-d blocks and total sockeye salmon ladder counts are shown in Figure 13. Because our sampling effort for sockeye salmon was generally proportional to the run, weighted fallback rates and 95% confidence intervals were similar to those for pooled data (Figure 14). (Note: a small number of passages and fallback events at the very end of the sockeye salmon migration were excluded from this analysis, as we believed the fallbacks were not representative of the run.)

Twenty-three of 24 sockeye salmon that fell back at The Dalles Dam in 1997 fell back once, and one fish fell back twice. Seventy-nine percent of the fish that fell back ultimately reascended and passed the dam.

Seventy-two percent of all fallback events by sockeye salmon in 1997 occurred less than 24 h after fish exited from the top of a fishway (Table 3), and 56% occurred less than 12 h after passage. Another 24% were recorded at upstream tributaries or dams before falling back at The Dalles Dam, and 4%

fell back more than 24 h after passage but were not recorded upstream (Table 3).

Fallback percentages were significantly different for sockeye salmon that passed via the Washington-shore (north-shore) fishway and those that passed via the Oregon-shore (south-shore) fishway in 1997. Some 2.3% of the unique fish recorded at the top of the south-shore fishway fell back, compared to 9.2% that fell back after passing via the north-shore fishway ($P < 0.001$, Z test) (Table 4). Because one fish fell back after passing each ladder, ladder fallback rates, the number of fallback events divided by the number of unique fish past a fishway, were the same as fallback percentages: 2.3% for the south-shore fishway and 9.2% for the north-shore fishway (Table 5).

We also calculated the percentage of fallback events by sockeye salmon with transmitters based on the fishway passed to show the fishway of origin preceding fallback events. Sockeye salmon with transmitters passed via the south-shore fishway prior to 28% of all fallback events in 1997, and via the north-shore fishway prior to 72% of all events. When we only considered fallbacks that occurred within 24 h of passing The Dalles Dam, sockeye salmon had passed via the south-shore fishway prior to 17% of the 1997 events, and via the north-shore fishway prior to 83% of all events (Table 6). Fallback rates within 24 h of dam passage were 1.0% for the south-shore fishway and 7.7% for the north-shore fishway, a significant difference ($P < 0.001$, Z test).

Fallback Percentages and Rates for Steelhead

A number of steelhead spend the winter in the lower Columbia River or tributaries before migrating to upriver spawning grounds in the spring (see Bjornn et al., 2001 for a summary of steelhead overwintering). Overwintering behavior and delayed migration differentiate steelhead from chinook and sockeye salmon and affect the analysis and interpretation of fallback events. Many steelhead tagged in 1996 and 1997 fell back at The Dalles Dam weeks or months after they had passed the dam, but prior to typical spawning times. We analyzed two subsets of fallback data for steelhead: the first included all fallbacks and passages at the dam and was comparable to analyses for chinook and sockeye salmon; the second only included data through 31 October of the year that steelhead were tagged. Less than 2% of radio-tagged fish passed the dam for the first time after 31 October, but 38% of all fallbacks by steelhead tagged in 1996 and 44% of all fallbacks by steelhead tagged in 1997 occurred after 31 October of the year they were tagged. We believe the two methods, considered together, provide more insight into fallback behavior by steelhead at The Dalles Dam.

All passages and fallbacks included: - The percentage of unique steelhead with transmitters that fell back over The Dalles Dam (6.0% for fish tagged in 1996, 6.7% for fish tagged in 1997) was calculated by dividing the number of unique fish with transmitters that fell back by the number of unique steelhead known to have passed The Dalles Dam, regardless of fallback timing (Table 1). When only fish recorded at top-of-ladder receivers were used as the divisor, the fallback percentage was 6.3% for fish tagged in 1996 and 6.8% for fish tagged in 1997. Standard 95% confidence intervals for steelhead fallback percentages were +/- 1.9% in 1996 and +/- 2.0% in 1997, assuming normally distributed errors and a normal binomial approximation (Table 1). The confidence intervals in Table 1 were based on pooled data for all radio-tagged fish only in each year and did not address over- or undersampling or temporal differences in fallback behavior for the total run.

Fallback rates, the number of fallback events divided by the number of unique steelhead with transmitters known to pass The Dalles Dam, were 6.8% (+/- 2.1%) for fish tagged in 1996 and 7.7% (+/- 2.0%) for fish tagged in 1997 (Table 2). When only fish recorded at top-of-ladder receivers were included, fallback rates were 7.2% (+/-2.2%) for 1996 fish and 7.9% (+/- 2.1%) for 1997 fish. Confidence intervals in Table 2 were based on pooled data for all radio-tagged fish in each tagging year.

Of 35 steelhead tagged in 1996 that fell back at The Dalles Dam, 30 (86%) fell back once and 5 (14%) fell back twice; 74% of the steelhead that fell back ultimately reascended and passed the dam. Of 45 steelhead tagged in 1997 that fell back at The Dalles Dam, 40 (89%) fell back once, 4 (9%) fell back twice and 1 fish fell back 4 times. Thirty-three (73%) of the steelhead that fell back ultimately reascended and passed the dam.

Twenty percent of all fallback events by steelhead tagged in 1996 and 27% of all events by fish tagged in 1997 occurred less than 24 h after fish exited from the top of a Dalles Dam fishway (Table 3). Seventy percent steelhead tagged in 1996 and 67% of those tagged in 1997 were recorded at upriver tributaries or dams before they fell back. The remaining 10% of events by 1996 steelhead and 6% of events by 1997 fish occurred more than 24 h after passing, but were not recorded upriver prior to falling back (Table 3).

Fallback percentages were not significantly different for steelhead tagged in 1996 that passed via the Washington-shore (north-shore) fishway and those that passed via the Oregon-shore (south-shore) fishway. About 5.4% percent of the unique fish recorded at the top of the south-shore fishway fell back, compared to 9.0% that fell back after passing via the north-shore fishway ($P = 0.17$, Z test) (Table 4). Fallback rates, the number of fallback events divided by the number of unique fish past a fishway, were also not significantly different for the two fishways for steelhead tagged in 1996. The fallback rate for the south-shore fishway was 6.0% and the rate for the north-shore fishway was 10.0% ($P = 0.15$) (Table 5).

Fallback percentages for steelhead tagged in 1997 were 6.9% for fish that passed via the south-shore fishway and 5.0% for fish that passed the north-shore fishway, a non-significant difference($P = 0.57$, Z test) (Table 4). Fallback rates for steelhead tagged in 1997, the number of fallback events divided by the number of unique fish past a fishway, were 7.9% for fish that passed the south-shore fishway and 5.0% for fish that passed the north-shore fishway ($P = 0.42$) (Table 5).

We also calculated the percentage of fallback events by steelhead with transmitters based on fishway passed to show the fishway of origin preceding fallback events. Steelhead tagged in 1996 passed via the south-shore fishway prior to 73% of all fallback events, and via the north-shore fishway prior to 25% of all events. When we only considered fallbacks that occurred within 24 h of passing The Dalles Dam, steelhead tagged in 1996 had passed via the south-shore fishway prior to all events (Table 6). Steelhead tagged in 1997 passed via the south-shore fishway prior to 94% of all fallback events, and via the north-shore fishway prior to 6% of all events. Steelhead had passed the south-shore fishway prior to 13 (93%) of 14 fallbacks that occurred within 24 h of passage. Fallback rates within 24 h of dam passage were not significantly different for the south- and north-shore fishways (P =0.19 in 1996; P = 0.83 in 1997, Z tests).

Passages and fallbacks through 31 October of tagging year: - Twenty-three of 35 (66%) steelhead tagged in 1996 that fell back at The Dalles Dam fell back at least once before 1 November; 12 fish fell back 15 times after 31 October 1996, with 7 of the events in 1997. Among steelhead tagged in 1997, 27 of 45 (60%) that fell back at The Dalles Dam fell back at least once before 1 November; 20 fish fell back 23 times after 31 October, with 12 of the events in 1998. We calculated the percentage of unique steelhead with transmitters that fell back over The Dalles Dam through 31 October of the tagging year (4.0% for fish tagged in 1996, 4.0% for fish tagged in 1997) by dividing the number of unique fish with transmitters that fell back by the number of unique steelhead known to have passed The Dalles Dam (Table 1). When only fish recorded at top-of-ladder receivers were used as the divisor, the fallback percentage was 4.1% (+/- 1.7%) for fish tagged in 1996 and 4.1% (+/- 1.6%) for fish tagged in 1997 (Table 1). Standard 95% confidence intervals for steelhead fallback percentages were calculated assuming normally distributed errors and a normal binomial approximation and were based on pooled data for all radio-tagged fish only through 31 October in each year.

Fallback rates, the number of fallback events divided by the number of unique steelhead with transmitters known to pass The Dalles Dam through 31 October were 4.3% in 1996 and 4.3% in 1997 (Table 2). When only fish recorded at top-of-ladder receivers were included, the fallback rate was 4.5% (+/- 1.7%) for 1996 fish and 4.4% (+/- 1.6%) for 1997 fish. We also calculated 95% confidence intervals using the 5-d stratified sampling method described previously for chinook salmon (Figure 15). It is important to note that fallback rates depicted in Figure 15 show rates for steelhead that eventually fell back, including events for fish that passed before 1 November but fell back later. Unlike spring and summer chinook and sockeye salmon which mainly fell back during the same 5-d block that they passed the dam, many steelhead fell back weeks or months after passing The Dalles Dam. Despite the gap between passage date and fallback date for some steelhead, weighted fallback rates were similar to pooled rates for fish outfitted with transmitters in both 1996 and 1997 (Figure 16.)

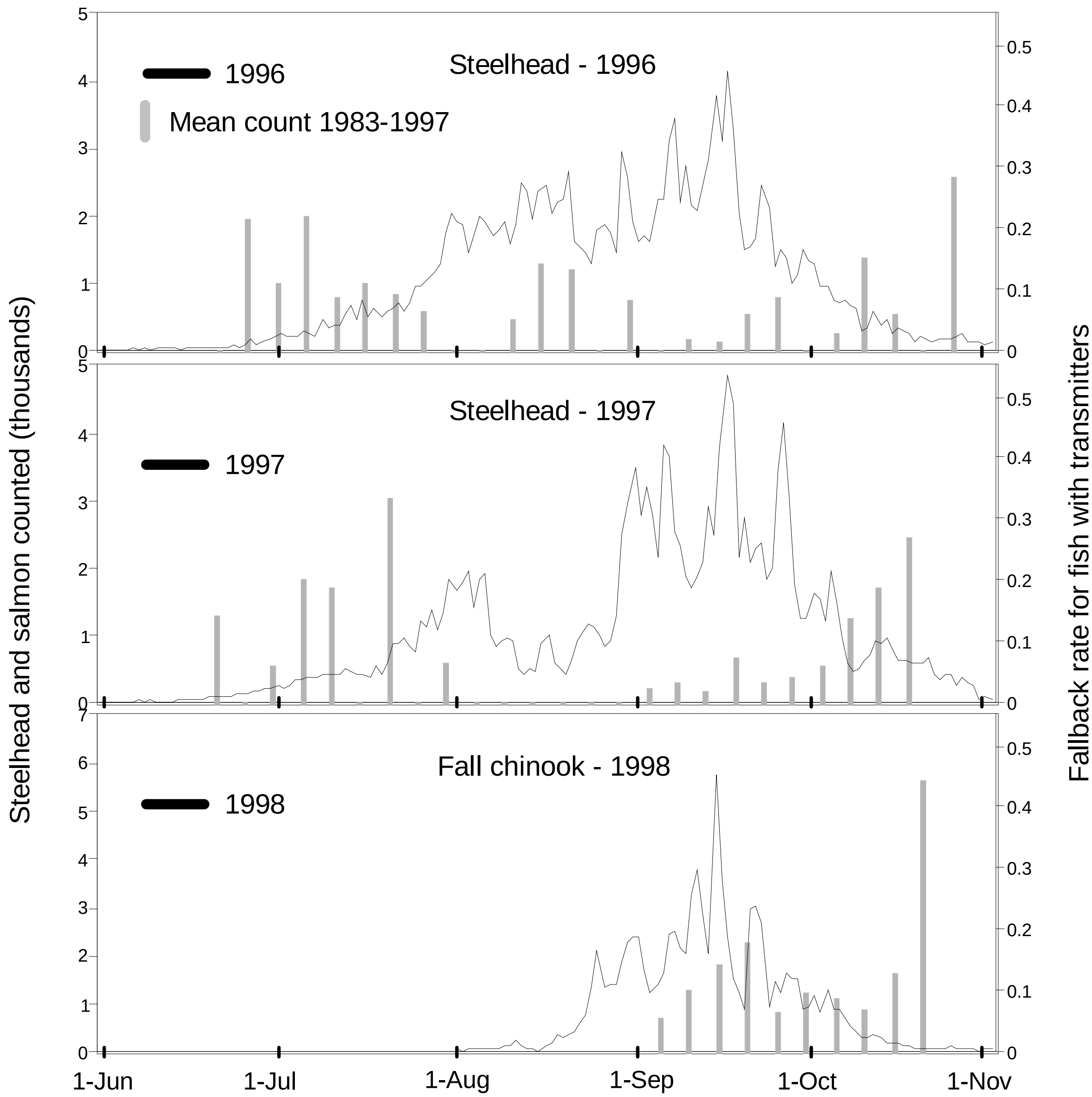

Figure 15. Fallback rates for steelhead and fall chinook salmon with transmitters based on 5-d blocks, with total counts at The Dalles Dam ladders in 1996, 1997, and 1998.

Of 23 steelhead that fell back at The Dalles Dam through 31 October 1996, 21 (91%) fell back once and 2 (9%) fell back twice; 87% ultimately reascended and passed the dam. Of 27 steelhead that fell back at The Dalles Dam through 31 October 1997, 25 (93%) fell back once and 2 (7%) fell back twice; 74% ultimately reascended and passed the dam.

Thirty-two percent of 25 fallback events by steelhead through 31 October 1996 occurred less than 24 h after the fish exited from the top of a ladder at The

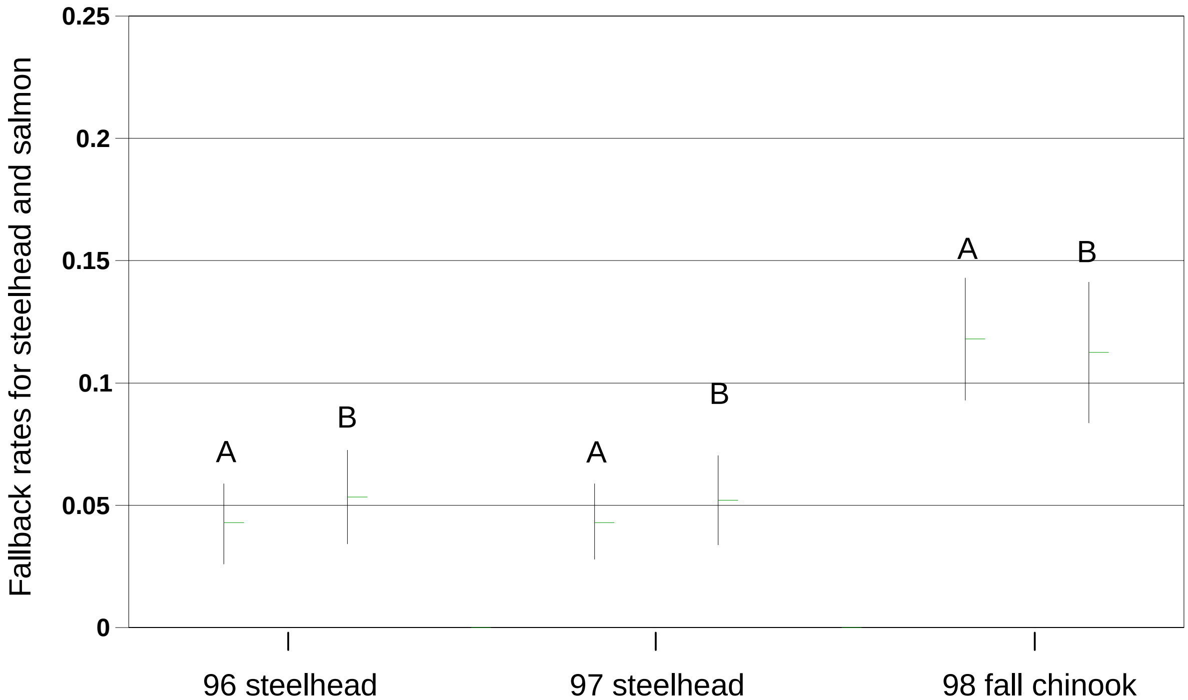

Figure 16. Fallback rates with 95% confidence intervals for radio-tagged steelhead and fall chinook salmon at The Dalles Dam in 1996, 1997, and 1998. Confidence intervals calculated by (A) pooling all telemetry data, (B) weighting 5-d blocks by total counts of salmon passing ladders and computing fallback rates and standard errors for each block.

Dalles Dam; 56% were recorded at upstream tributaries or dams before they fell back, and 12% fell back more than 24 h after passage, but were not recorded upstream (Table 3). Forty- one percent of 29 fallback events by steelhead through 31 October 1997 occurred less than 24 h after the fish exited from the top of a ladder; 52% were recorded at upstream tributaries or dams before they fell back, and 7% fell back more than 24 h after passage but were not recorded upstream.

Fallback percentages were not significantly different for steelhead tagged in 1996 that passed via the north-shore fishway and those that passed via the south-shore fishway. Through 31 October, 3.3% of the unique fish that were recorded at the top of the south-shore fishway fell back, compared to 6.2% that fell back after passing via the north-shore fishway ($P = 0.18$, Z test) (Table 4). Fallback rates, the number of fallback events divided by the number of unique fish past a fishway, were also not significantly different for the two fishways for steelhead tagged in 1996. Through 31 October, the fallback rate for the south-shore fishway was 3.5% and the rate for the north-shore fishway was 7.2% ($P = 0.10$) (Table 5).

Fallback percentages for steelhead tagged in 1997 through 31 October were 4.2% for fish that passed via the south-shore fishway and 1.9% for fish that passed the north-shore fishway (Table 4). Fallback rates for steelhead tagged in 1997 through 31 October were 4.6% for fish that passed the south-shore fishway and 1.9% for fish that passed the north-shore fishway (Table 5). Differences in percentages and rates between ladders were not significant (P ~ 0.37, Z tests).

We also calculated the percentage of fallback events by steelhead with transmitters based on the fishway passed to show the fishway of origin preceding fallback events. Through 31 October steelhead tagged in 1996 passed via the south-shore fishway prior to 68% of all fallback events, and via the north-shore fishway prior to 28% of all events. When we only considered fallbacks that occurred within 24 h of passing The Dalles Dam, steelhead tagged in 1996 had passed via the south-shore fishway prior to all events (Table 6). Through 31 October, steelhead tagged in 1997 passed via the south-shore fishway prior to 97% of all fallback events, and via the north-shore fishway prior to 3% of all events. Steelhead had passed the south-shore fishway prior to 11 (92%) of 12 fallbacks that occurred within 24 h of passage. Fallback rates within 24 h of dam passage were not significantly different for the south- and north-shore fishways (P =0.20 in 1996; P = 0.97 in 1997, Z tests).

Fallback Percentages and Rates for Fall Chinook Salmon

The percentage of unique fall chinook salmon with transmitters that fell back over The Dalles Dam in 1998 (10.4%) was calculated by dividing the number of unique fish with transmitters that fell back by the number of unique fish known to have passed The Dalles Dam, regardless of route (Table 1). When only fish recorded at top-of-ladder receivers were used as the divisor, the 1998 fallback percentage was 10.6%, and the 95% confidence interval was 8.1% to 13.0% (Table1). The 95% confidence interval in Table 1 was based on the assumption of normally distributed errors and a normal binomial approximation; the interval was based on pooled data for radio-tagged fish only and did not address over- or undersampling or temporal differences in fallback behavior. (See Figure 16 for a comparison of 95% confidence intervals of fall chinook salmon fallback rates calculated with unweighted pooled data and weighted data.)

Fallback rate, the number of fallback events divided by the number of unique fall chinook salmon with transmitters known to pass The Dalles Dam in 1998 was 11.8%; the rate was 12.0% using only the number recorded at top-of-ladder receivers with a standard 95% confidence interval from 9.4% to 14.6% (Table 2). Confidence intervals in Table 2 were based on pooled data for all radio-tagged fish. We also calculated 95% confidence intervals for fall chinook salmon using the 5-d stratified sampling method described previously for spring and summer chinook salmon. Fallback rates for 5-d blocks and total sockeye salmon ladder counts are shown in Figure 15. Because our sampling effort for fall chinook salmon did not include the early portion of the run and was not generally proportional to the portion sampled, weighted fallback rates and 95% confidence intervals were wider than those for pooled data (Figure 16). The difference in weighted and pooled rates for the portion of the run that was sampled, however, was less than 1%.

Fifty-nine of 65 (91%) fall chinook salmon that fell back at The Dalles Dam in 1998 fell back once, five fish fell back twice, and one fish fell back five times. Twenty-three percent of the fish that fell back ultimately reascended and passed the dam.

Twelve percent of all fallback events by fall chinook salmon in 1998 occurred less than 24 h after the fish exited from the top of a fishway (Table 3). Eighty-five percent were recorded at upstream tributaries or dams before falling back at The Dalles Dam, and 3% fell back more than 24 h after passage but were not recorded upstream (Table 3).

Fallback percentages were not significantly different for fall chinook salmon that passed via the Washington-shore (north-shore) fishway and those that passed via the Oregon-shore (south-shore) fishway in 1998. Some 9.5% of the unique fish recorded at the top of the south-shore fishway fell back, compared to 14.6% that fell back after passing via the north-shore fishway ($P = 0.13$, Z test) (Table 4). Ladder fallback rates, the number of fallback events divided by the number of unique fish past a fishway, were 11.2% for the south-shore fishway and 14.6% for the north-shore fishway, a difference that was not significant ($P = 0.34$) (Table 5).

We also calculated the percentage of fallback events by fall chinook salmon with transmitters based on the fishway passed to show the fishway of origin preceding fallback events. Fall chinook salmon with transmitters passed via the south-shore fishway prior to 81% of all fallback events in 1998, and via the north-shore fishway prior to 19% of all events. When we only considered fallbacks that occurred within 24 h of passing The Dalles Dam, fall chinook salmon had passed via the south-shore fishway prior to 66% of the events, and via the north-shore fishway prior to 33% of events (Table 6). Fallback rates within 24 h of dam passage were 1.1% for the south-shore fishway and 3.1% for the north-shore fishway, a difference that was not significantly different ($P = 0.13$, Z test).

Escapement Past The Dalles Dam Based on Adjusted Counts

Counts of adult salmon and steelhead that pass up the ladders at the dams are used as indices of abundance of the runs at that point in their migration. The counts are indices of upriver escapement, rather than complete counts, because some fish pass the dams via the navigation locks, and because fish that fall back over the dams and do or do not reascend over the dam add a positive bias to the counts. Adjustment of the counts for fish that pass through the navigation locks and for fallbacks at Columbia and Snake river dams has been calculated only when adult tagging studies have been conducted. In previous studies, fallback rates varied among species and years, with river flow and spill at dams, as well as with the configuration of top-of-ladder exits at specific dams (Bjornn and Peery, 1992; Liscom et al, 1979). At The Dalles Dam we monitored fallbacks and reascensions, but not passage through the navigation lock for adult salmon and steelhead with transmitters and used that data to calculate adjustment factors for counts in 1996, 1997, and 1998. Adjustments were then applied to counts of fish counted in the ladders and reported in the Annual

Fish Passage Reports (USACE, 1996; 1997; 1998) to obtain more accurate estimates of the number of fish escaping upstream from the dam.

We believe the most accurate estimate of escapement past the dam includes counts of fish in the ladders at the dam, the number of fish that fell back, the number that reascended through the ladders, and the number of fish that pass upstream through the navigation lock. Fallback and reascension through ladders creates a positive bias in the number of fish counted as they pass up the ladders, while passage through the navigation lock is unaccounted for in counts of fish passing up the ladders. Fish that pass through the lock compensate for the positive bias in fish counts due to fallback and reascension, but the amount of compensation depends on the number of fallbacks and the number of fish passing through the lock. However, we did not monitor lock passage at The Dalles Dam in any year, so reported adjustments were likely underestimates of escapement. (In an attempt to estimate passage through the lock, we counted fish recorded at tailrace receivers that were not recorded in ladders while receivers were functioning, but were recorded at sites upstream from The Dalles Dam. Based on those criteria, we suspected that 0.3% to 0.8% of radio-tagged spring and summer chinook salmon, 0.7% to 0.9% of steelhead, 1.2% of sockeye salmon, and 0.8% of fall chinook salmon passed upstream via the lock. The potential compensation from lock passage was not included in Tables 7 and 8, but we noted potential compensation in the text for each species and year.)

We estimated escapement of fish past The Dalles Dam by calculating adjustment factors based on passage of fish with transmitters and then applied adjustments to the total number of fish counted at the dam. The first adjustment factor (AF) was calculated by the formula:

$$AF_1 = (LP_K + NLP_K - FB_{UF} + R_{UF}) / TLP_K$$

Where:

LP_K was the number of unique fish with transmitters known to have passed the dam via the ladders (assumes that unrecorded fish passed dam via ladder),

NLP_K was the number of unique fish with transmitters known to have passed the dam via the navigation lock,

FB_{UF} was the number of unique fish that fell back at the dam one or more times,

R_{UF} was the number of unique fish that reascended the dam and stayed upstream from the dam regardless of the number of times it fell back, and

TLP_K was the total number of times unique fish with transmitters were known to have passed the dam via ladders (includes initial and all reascensions).

The TLP_K term was the count of radio-tagged fish equivalent of the total USACE count that passed through the ladders. When adjustment factor AF was applied to the counts of fish that passed through the ladders, the adjusted number approximated the total escapement past dams.

Estimates of escapement derived from the adjustment factors were based on the assumption that fish with transmitters were good surrogates for the remainder of the fish in the run passing the dam. We calculated adjustments AF using pooled data for the entire range of passage by fish with transmitters and all fish that fell back were included. If there was temporal variability in fallback and reascension rates or tagged fish were not representative of the run then the adjustment factors based on pooled data may be biased. To address potential bias, we also calculated adjustment factors using a stratified sampling method that calculated factors for consecutive 5-d blocks during the time that radio-tagged fish were passing The Dalles Dam. Each block was weighted by the total number of fish counted passing ladders during that block. Both pooled and weighted AF values were most appropriate for the time period when radio-tagged fish were passing the dam, and less so during other times.

Spring and summer chinook salmon: - Pooled adjustment factors (AF) for spring and summer chinook salmon at The Dalles Dam were 0.840 in 1996, 0.839 in 1997, and 0.875 in 1998 (Table 7). Weighted AF values and 95% confidence intervals based on all data for radio-tagged fish differed from pooled values by less than 0.02 in all years, an indication that our sampling was reasonably representative and that temporal variation in spring and summer chinook salmon fallback and reascension rates were relatively minor (Figure 17).

We calculated escapements of spring and summer chinook salmon past The Dalles Dam by multiplying fish counts reported by USACE by pooled and weighted AFs (Table 8). In 1996 the USACE adult spring and summer chinook salmon count at The Dalles Dam was 36,900 fish. The adjusted count using the pooled AF at was 30,996 with a positive bias of 5,904 fish (19.0%) (Table 8). The 1997 USACE adult chinook salmon count

Table 7. Unique fish with transmitters known to have passed The Dalles Dam via ladders (LP_K) and navigation lock (NLP_K), unique fish that fell back one or more times (FB_{UF}), unique fish that reascended (R_{UF}), total number of times fish with transmitters were known to have passed through ladders (TLP_K), and pooled fish count adjustment factors (AF) for spring and summer chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) with transmitters in 1996 to 1998.

Dam	LP_K[a]	NLP_K[b]	FB_{UF}	R_{UF}	TLP_K	pooled AF_1
1996 CK	500	n/a	66	32	555	0.840
1997 CK	715	n/a	101	71	816	0.839
1998 CK	763	n/a	84	54	838	0.875
1996 SH	584	n/a	35	27	615	0.937
1997 SH	677	n/a	45	33	718	0.926
1997 SK	492	n/a	24	19	512	0.951
1998 FCK	628	n/a	65	15	615	0.888

[a] Includes fish that passed dam unrecorded, presumably via ladders
[b] Navigation lock was not monitored in any years; see text for estimated passage

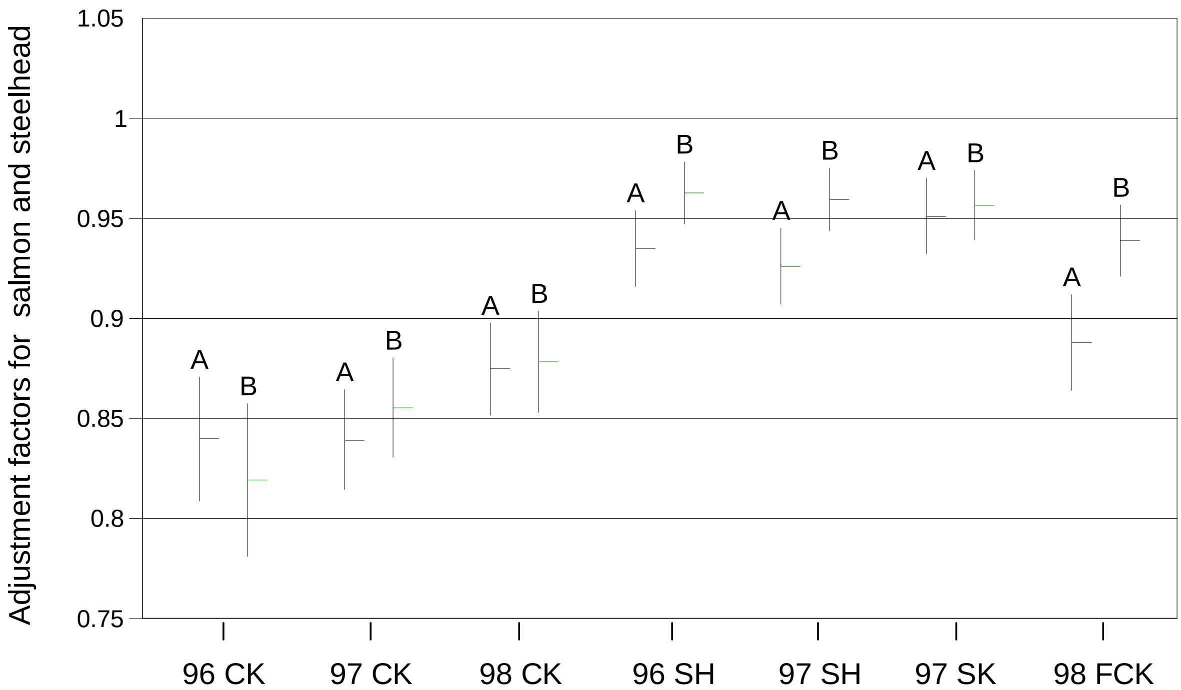

Figure 17. Values for escapement adjustment factor for chinook salmon, steelhead, sockeye salmon, and fall chinook salmon at The Dalles Dam from 1996 to 1998. 95% confidence intervals calculated by (A) pooling all radio-telemetry data and taking standard binomial distribution, and (B) weighting 5-d blocks of telemetry data by total ladder counts and computing standard errors for each block.

Table 8. Reported USACE counts of spring and summer chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) passing through ladders at The Dalles Dam, estimated escapements using pooled adjustment factors, 95% confidence intervals, and bias in the counts in 1996 to 1998 as escapement indices.

	USACE ladder escapement	Pooled adjustment		Weighted escapement bias
		Estimated escapement	Bias	
1996 CK	36,900	30,996 (+/- 1,144)	5,904	6,679
1997 CK	89,566	75,146 (+/- 2,239)	14,420	12,181
1998 CK	40,687	35,601 (+/- 936)	5,086	4,964
1996 SH	162,447	152,213 (+/- 3,086)	10,234	6,001
1997 SH	164,657	152,472 (+/- 3,129)	12,185	6,586
1997 SK	32,430	30,841 (+/- 616)	1,589	1,394
1998 FCK	92,932	82,524 (+/- 2,230)	10,408	5,669

at Bonneville Dam was 89,566 fish and with a positive bias of 14,420 fish (19.2%). The 1998 USACE adult chinook salmon count was 40,687 fish and the adjusted count using the pooled AF was 35,601 with a positive bias of 5,086 fish (14.3%) (Table 8). Standard 95% confidence intervals for the adjusted escapements were within +/- 3.1%, or approximately +/- 1,100 fish in 1996, 2,200 fish in 1997, and 900 fish in 1998.

Pooled AF values in Table 7 did not include estimated passage through the navigation lock. Adjustment values increased by ~ 0.006 in 1996 and 1997 and ~ 0.001 in 1998 with the inclusion of estimated lock passage and positive biases decreased by about 220 fish in 1996, 630 fish in 1997, and 40 fish in 1998.

Because weighted adjustment factors for chinook salmon were not substantially different from pooled factors, weighted escapement biases were similar to pooled biases at 6,679 fish (22.1%) in 1996, 12,181 fish (15.7%) in 1997, and 4,964 fish (13.9%) in 1998 (Table 8). Biases based on pooled data were slightly lower than weighted biases in 1997 (19.0%) and 1998 (19.2%), and slightly higher in 1996 (14.3%).

Sockeye salmon: - We calculated pooled and weighted adjustment factors (AF) for sockeye salmon at The Dalles Dam using the same methods described above for spring and summer chinook salmon. The pooled AF was 0.951, and included all passages and fallbacks by sockeye salmon (Table 7). We calculated escapements of sockeye salmon past The Dalles Dam by multiplying fish counts reported by USACE by the pooled adjustment factor. The adult count in 1997 was 32,430 fish, and the adjusted escapement count was 30,841 fish (+/- 616) with a positive bias of 1,589 (5.2%) (Table 8).

The pooled AF value in Table 7 did not include an estimated passage rate of 1.2% through the navigation lock. The pooled AF increased by ~ 0.011 to 0.962 with the inclusion of estimated lock passage and positive bias decreased by about 360 sockeye salmon.

The weighted AF for sockeye salmon was 0.957 with all radio-tagged fish included, with a positive bias of 1,394 fish (4.5%) (Table 8). The AF values and 95% confidence intervals were similar for both weighted and pooled AFs, an indication that our sampling was reasonably representative and that temporal variation in spring and summer chinook salmon fallback and reascension rates were relatively minor (Figure 17).

Steelhead: - We calculated pooled and weighted adjustment factors (AF) for steelhead at The Dalles Dam using the same methods described above for spring and summer chinook salmon. Pooled AFs were 0.937 for steelhead tagged in 1996 and 0.926 for those tagged in 1997, and included all passages and fallbacks by steelhead (Table 7).

We calculated escapements of steelhead past The Dalles Dam by multiplying fish counts reported by USACE by the pooled AFs. The adult count for the 1996-1997 run- year was

162,447 fish, and the adjusted escapement count was 152,213 fish with a positive bias of 10,234 (6.7%). The 1997-1998 run-year count was 164,657, and the adjusted count was 152,472 fish with a positive bias of 12,185 fish (8.0%) (Table 8). The 95% confidence intervals for pooled adjustments were +/- 3,100 steelhead in the 1996-1997 run-year and +/- 3,100 fish in the 1997-1998 run-year (Table 8).

Pooled AF values in Table 7 did not include estimated passage rates of 0.9% and 0.7% through the navigation lock in the two years. Pooled AFs increased by about 0.006 with the inclusion of estimated lock passage and positive biases decreased by about 980 fish in the 1996-1997 run-year, and 1,150 fish in the 1997-1998 run.

The weighted AFs for steelhead in both the 1996-1997 and 1997-1998 run-years were higher than pooled AF values by about 0.03 (Figure 17). Weighted adjustments were higher primarily because relatively few radio-tagged steelhead fell back and reascended during 5-d blocks when peak counts of steelhead were passing The Dalles Dam, and fallback rates for radio-tagged fish were highest early and late in the migrations when few fish were passing the dam (see Figure 15). In addition, because ladder counts were not collected after 31 October at The Dalles Dam, we could not include in calculations those fallbacks and reascensions by radio-tagged steelhead that occurred after 31 October. Weighted AFs were 0.963 for fish tagged in 1996 and 0.960 for fish tagged in 1997 when we included all 5-d blocks for which we had passage data. Positive biases using weighted AFs were about 6,000 fish (3.8%) in the 1996-1997 run-year and 6,590 fish (4.2%) in the 1997-1998 run-year (Table 8).

Fall chinook salmon: - We calculated pooled and weighted adjustment factors (AF) for fall chinook salmon at The Dalles Dam in 1998 using the same methods described above for spring and summer chinook salmon. As discussed previously, however, we did not outfit fall chinook salmon with transmitters during the August portion of the fall chinook salmon run, and escapement adjustments described below are therefore most applicable to the post-August portion of the run. We would expect that fallback and reascension rates for fall chinook salmon at The Dalles Dam were higher in August when spill was occurring than during the no-spill period that began 1 September.

The pooled AF was 0.888, and included all passages and fallbacks by fall chinook salmon (Table 7). We calculated escapements of fall chinook salmon past The Dalles Dam by multiplying fish counts reported by USACE by the pooled adjustment factor. The full-season adult count in 1998 was 92,932 fish, and the adjusted escapement count was 82,524 fish (+/- 2,230) with a positive bias of 10,408 (12.6%) (Table 8). The 1998 fall chinook salmon count from 1 September to 31 October was 74,271. When we applied the pooled AF to this portion of the run only, the positive bias was 8,320 (12.6%).

The pooled AF value in Table 7 did not include an estimated passage rate of 0.8% through the navigation lock. The pooled AF increased by ~ 0.007 to 0.895 with the inclusion of estimated lock passage, and positive bias decreased by about 650 fall chinook salmon.

As with steelhead, the weighted AF for fall chinook salmon was higher than the pooled AF value because the highest fallback rates were recorded when relatively few fall chinook salmon were passing the dam (Figure 17; also see Figure 15). The weighted AF was 0.939 with all radio-tagged fish included, with a positive bias of 5,669 fish (6.5%) (Table 8).

Fallback Routes by Radio-Tagged Salmon and Steelhead

Spring and summer chinook salmon: - Antenna and receiver configurations at The Dalles Dam in all years did not allow us to monitor the exact location and time of fallback events, but we could determine the approximate time of fallback using the first telemetry records in the tailrace or in fishways after the fallback event. Most (> 75%) spring and summer chinook salmon that fell back were recorded first at one of the receivers in the tailrace after falling back and we believe most of those fish fell back over the spillway, although some may have fallen back via unmonitored routes (i.e. through the powerhouse, navigation lock, ice/trash sluiceway, or juvenile bypass). In both 1996 and 1997, 100% of the recorded fallback events by radio-tagged fish were on days when spill was occurring. In 1998, 94% of all events were on days with spill.

With limited fishway receiver coverage in 1996, 93% of all fallback events by chinook salmon were first recorded downstream from the dam at tailrace sites. In 1997 and 1998, about 80% of all fallback events were first recorded at tailrace sites. The remaining ~ 20% in both years were first recorded about evenly at antennas in the powerhouse fishways and at fishway entrances adjacent to the spillway. The location of the first telemetry record after fallback should be used only as a very general indicator of fallback route. Due to limited fishway monitoring and no forebay monitoring, inferences based on first downstream record should be made with caution.

In 1997 and 1998, 55% to 57% of fallback events that occurred within 24 h after the fish left the top of a fishway were first recorded at tailrace sites. Another 23% to 24% were first recorded at antennas in fishway entrances adjacent to the spillway. In 1996, spillway fishway entrances were not monitored, and 87% of all salmon that fell back within 24 h were first recorded at tailrace receivers.

Sockeye salmon: - As with chinook salmon, we believe most sockeye salmon with transmitters that fell back over The Dalles Dam in 1997 fell back over the spillway. All recorded fallback events by radio-tagged fish were on days when spill was occurring. After all fallback events, 40% of the sockeye salmon were first recorded at the tailrace sites, 36% were first recorded at powerhouse sites, and 24% were first recorded at sites adjacent to the spillway. Twenty-eight percent of sockeye salmon that fell back within 24 h of passing the dam were first recorded after the fallbacks at tailrace sites, and 33% were first recorded at fishway entrances adjacent to the spillway.

As with spring and summer chinook salmon, however, inferences regarding fallback routes based on first downstream telemetry records at The Dalles Dam by sockeye salmon should be made with caution.

Steelhead: - Approximately 43% of fallback events by steelhead tagged in 1996 and 29% of events by steelhead tagged in 1997 fell back on days when spill was occurring at The Dalles Dam. With limited fishway receiver coverage in 1996, two-thirds of all fallback events were first recorded at tailrace sites and one-third were first recorded at fishway receivers. Seven of 8 fallbacks that occurred within 24 h of passage in 1996 were first recorded at fishway receivers. Half of the fallback events within 24 h of passage occurred on days with spill.

In 1997, 67% of all fallback events were first recorded at tailrace sites, 21% were first recorded at powerhouse fishway sites, and 12% were first recorded at fishway entrances adjacent to the spillway. For the events that occurred within 24 h of passage in 1997, 21% were first recorded at tailrace sites, 50% were first recorded at the powerhouse fishway receivers, and 29% were first recorded at fishway entrances adjacent to the spillway.

As with other species, inferences regarding fallback routes based on first downstream telemetry records at The Dalles Dam should be made with caution.

Fall chinook salmon*: -* Because radio-tagged fall chinook salmon did not begin passing The Dalles Dam until after 1 September, almost 100% of the tagged fish passed the dam during no-spill conditions. Based on records at Bonneville and McNary dams, where 63% (Bonneville) and 78% (McNary) of recorded fallbacks by fall chinook salmon were via the navigation locks, we suspect that many fall chinook salmon fallbacks at The Dalles Dam were also via the lock.

After all fallback events at The Dalles Dam, 84% of the fall chinook salmon were first recorded at the tailrace sites, 8% were first recorded at powerhouse sites, and 8% were first recorded at sites adjacent to the spillway. As with other species, inferences regarding fallback routes based on first downstream telemetry records at The Dalles Dam should be made with caution.

Effects of Environmental Factors on Spring/Summer Chinook Salmon Fallbacks

Flow, spill, turbidity, and dissolved gas levels at The Dalles Dam varied inter- and intra-annually during the spring and summer chinook salmon migrations from 1996 to 1998 (see Figures 8, 9, and 10). In previous studies, fallback rates have increased with increased flow and spill at Columbia and Snake River dams, but methods and results from those studies usually involved small numbers of marked fish or were not strictly comparable (see Bjornn and Peery, 1992). We examined relationships between flow, spill, turbidity, water temperature, dissolved gas levels, water temperature, and fallback behavior of spring and summer chinook salmon for each year (1996 to 1998), and used multiple regression models to explore the combined effect of several environmental factors.

We used a variety of linear and logistic regression models to test univariate relationships between fallbacks by spring and summer chinook salmon and environmental conditions at The Dalles Dam. The range of methods were an attempt to accommodate shortcomings in experimental design: first, the tagging schedule at Bonneville Dam (10 d with tagging, 4 d without tagging) created minor problems with proportionality of radio-tagged fish to the overall run; second, independent of the tagging schedule, daily passage and fallback rates by salmon with transmitters varied throughout the migration; and third, environmental variables varied continuously, making discreet comparisons of fallback rates at specific environmental conditions difficult. (The 60%/30% spill test for juvenile passage in 1998 was the closest approximation to a controlled test, although total daily spill changed continuously during the test.) To address these concerns we analyzed fallback rates using moving average techniques, multi-day blocks, blocks based on flow, spill, and Secchi disk visibility, variable-day blocks based on passage of at least 25 salmon with transmitters, and T-Tests and logistic regressions of binary (fallback/no fallback) data sets.

One of the preliminary comparisons we made was that of daily fallback events by radio-tagged fish divided by the total count of salmon passing through the fishways. If radio-tagged salmon were representative of the overall run (see Figure 5), then such a ratio might be a measure of the proportion of fish that fell back each day that could be related to environmental variables. The regression lines of fallback proportion versus flow and spill increased in 1996 and 1998 (Figures 18 and 19), but flow and spill accounted for a small proportion of the variability of that measure of fallback rate in any of the three years (r^2 = 0.03 to 0.11). The low correlations in 1997 were caused in part by the disproportionately high number of radio-tagged fish that passed the dam and fell back in July; 1997 data points in Figures 18 and 19 with high fallback ratios at flow < 300 kcfs and spill < 200 kcfs were almost all for days in July. When we standardized daily ratios to the annual sampling proportion and removed 4 outlying days in July, r^2 values for 1997 improved to ~ 0.10. Standardizing ratios made minimal adjustments in r^2 values for 1996 and 1998. We included all fallback events in this analysis for all years, although many fish had migrated upriver to tributary sites or other dams before they returned to The Dalles Dam and fell back. When we limited the analysis to fallbacks that occurred within 24 h of exit from the top of a fishway, overall trends were similar.

We also calculated daily fallback/daily passage ratios for radio-tagged fish only. With this method, fallback ratios on individual days ranged widely. Many days had fallback ratios of 0.00 and some had ratios as high as 1.0 when few radio-tagged fish passed the dam but one or more fell back.

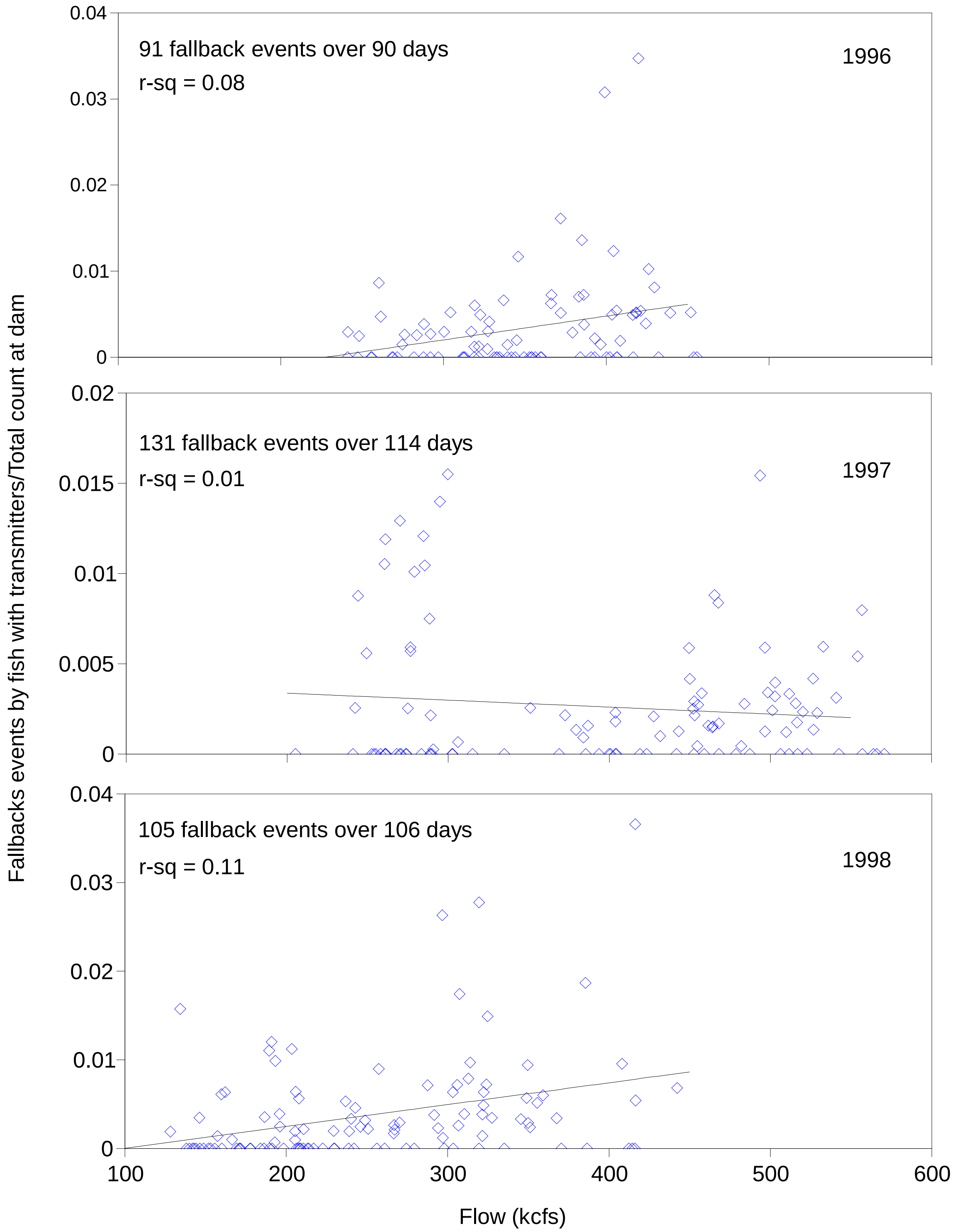

Figure 18. Relation of the ratio (fb_n/c_n) of spring and summer chinook salmon with transmitters that fell back (fb_n) divided by the number counted (c_n) each day at The Dalles Dam to daily flow in 1996, 1997, and 1998.

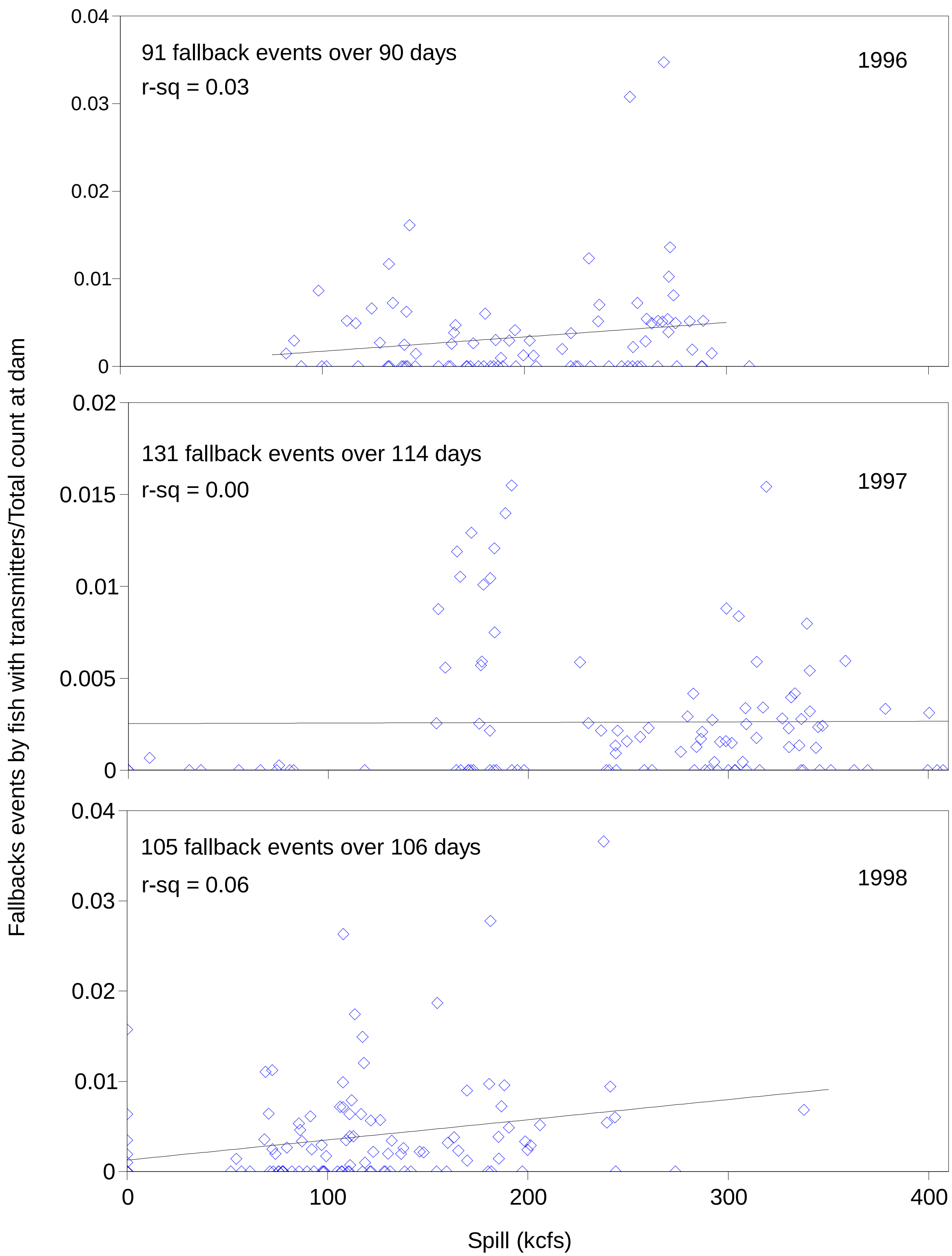

Figure 19. Relation of the ratio (fb_n/c_n) of spring and summer chinook salmon with transmitters that fell back (fb_n) divided by the number counted (c_n) each day at The Dalles Dam to daily spill in 1996, 1997, and 1998.

Fallback ratios for 5-d moving average: - To moderate the fallback ratio variability problem on individual days, we calculated daily fallback ratios using the moving average number of fallback events over 5 days and the number of spring and summer chinook salmon with transmitters recorded at the tops of fishways over the same 5 days (moving average ratio). Fallback events that occurred more than 24 h after a fish exited from the top of a fishway were not included in the analysis because many fish that fell back more than 24 h after passage had migrated upriver, and we believe environmental conditions at the dam were not the primary reason those fish fell back at The Dalles Dam. Correlations between moving average ratios and environmental variables at the dam (flow, spill, turbidity, dissolved gas, temperature) were strong in some cases as explained below. However, r^2 values reported for moving average ratios should only be viewed as indicative of general trends, as autocorrelation and variance errors were likely created by moving average techniques.

In 1996, 23 chinook salmon with transmitters fell back within 24 h of passage at The Dalles Dam. Using only these fallback events, the highest moving average ratios of 5-d mean fallback events to 5-d mean passage occurred during early and mid-May (Figure 20). A fallback ratio nadir occurred during the second week in May and the ratio was zero during parts of June and July. The moving average fallback ratios based on only salmon with transmitters were positively correlated with daily flow, spill, and dissolved gas, and negatively correlated with Secchi disk visibility between 10 April and 8 July, the period when all radio-tagged spring and summer chinook salmon passed The Dalles Dam in 1996. Relatively low proportions of the variability in the 5-d fallback ratio were accounted for by flow, spill, or dissolved gas (r^2 ~ 0.05, 0.09, and 0.06, Figure 21). Secchi disk visibility had a higher correlation with the moving average fallback ratios in 1996, with an r^2 value of ~ 0.16 (Figure 21).

In 1997, 42 chinook salmon with transmitters fell back within 24 h of passage at The Dalles Dam. Fish with transmitters began to pass the dam in early April, but the first fallback within 24 h did not occur until the end of the month (Figure 22). Nadirs for the moving average fallback ratio occurred mid-June in 1997 and again in late June; the highest ratio values were in late May and the second half of July. A relatively small number of fallback events inflated ratios at the end of July when few chinook salmon with transmitters were passing the dam. Fallback ratios were positively correlated with daily flow, spill, and dissolved gas, and negatively correlated with Secchi disk visibility between 9 April and 21 July, the period when 99% of all radio-tagged spring and summer chinook salmon passed The Dalles Dam in 1997 (Figure 23). The r^2 values for regressions of all environmental variables with the moving average fallback ratio were less than ~ 0.07. Low correlation coefficients were due in part to fallbacks by several summer chinook salmon that fell back in July when few fish with transmitters were passing the dam. When we only included fish that passed before 1-July in the ratio analysis (76% of all passages), r^2 values improved to ~ 0.16 for flow, ~ 0.18 for spill, ~ 0.25 for dissolved

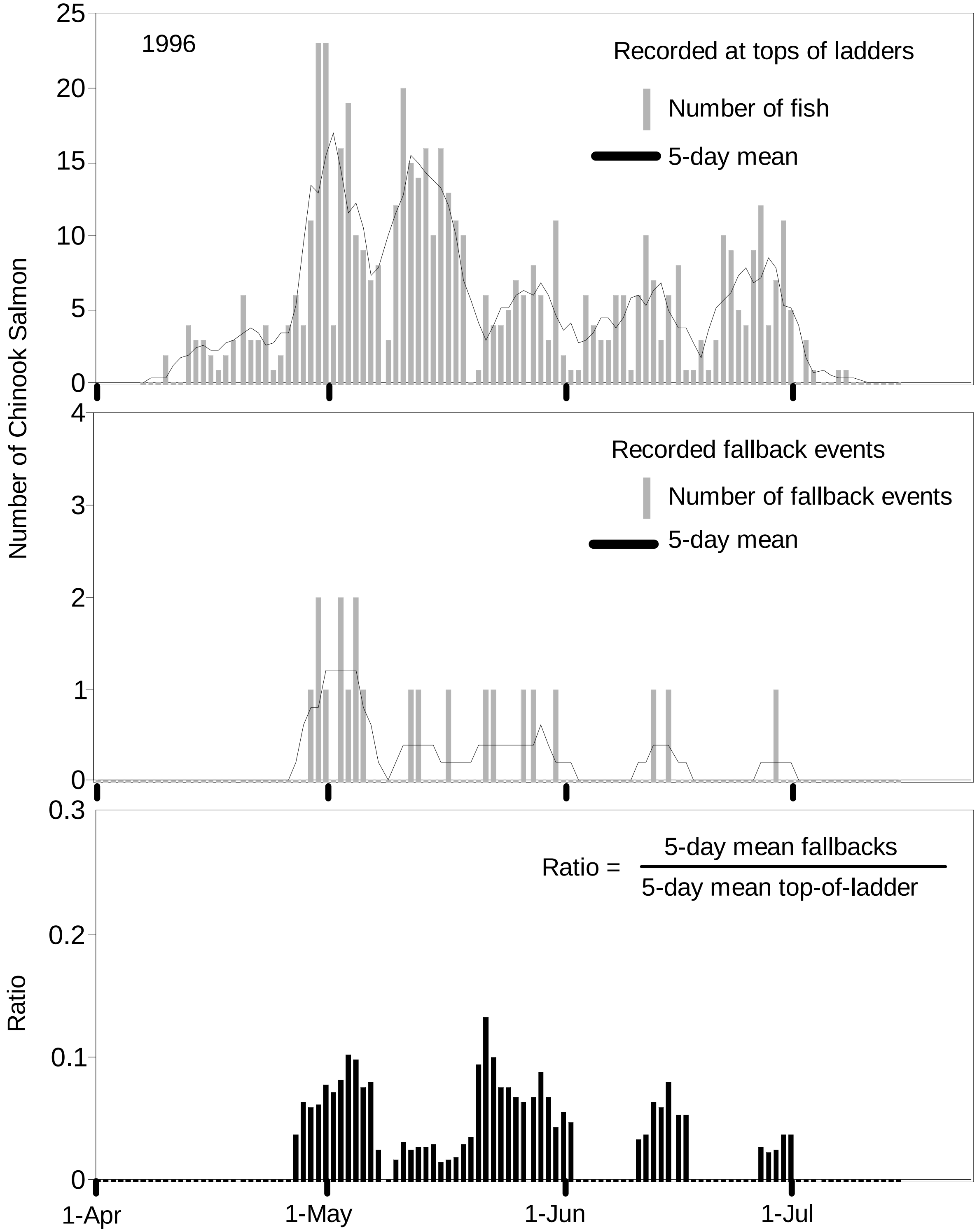

Figure 20. Daily number and 5-d moving average of recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for spring and summer chinook salmon with transmitters in 1996.

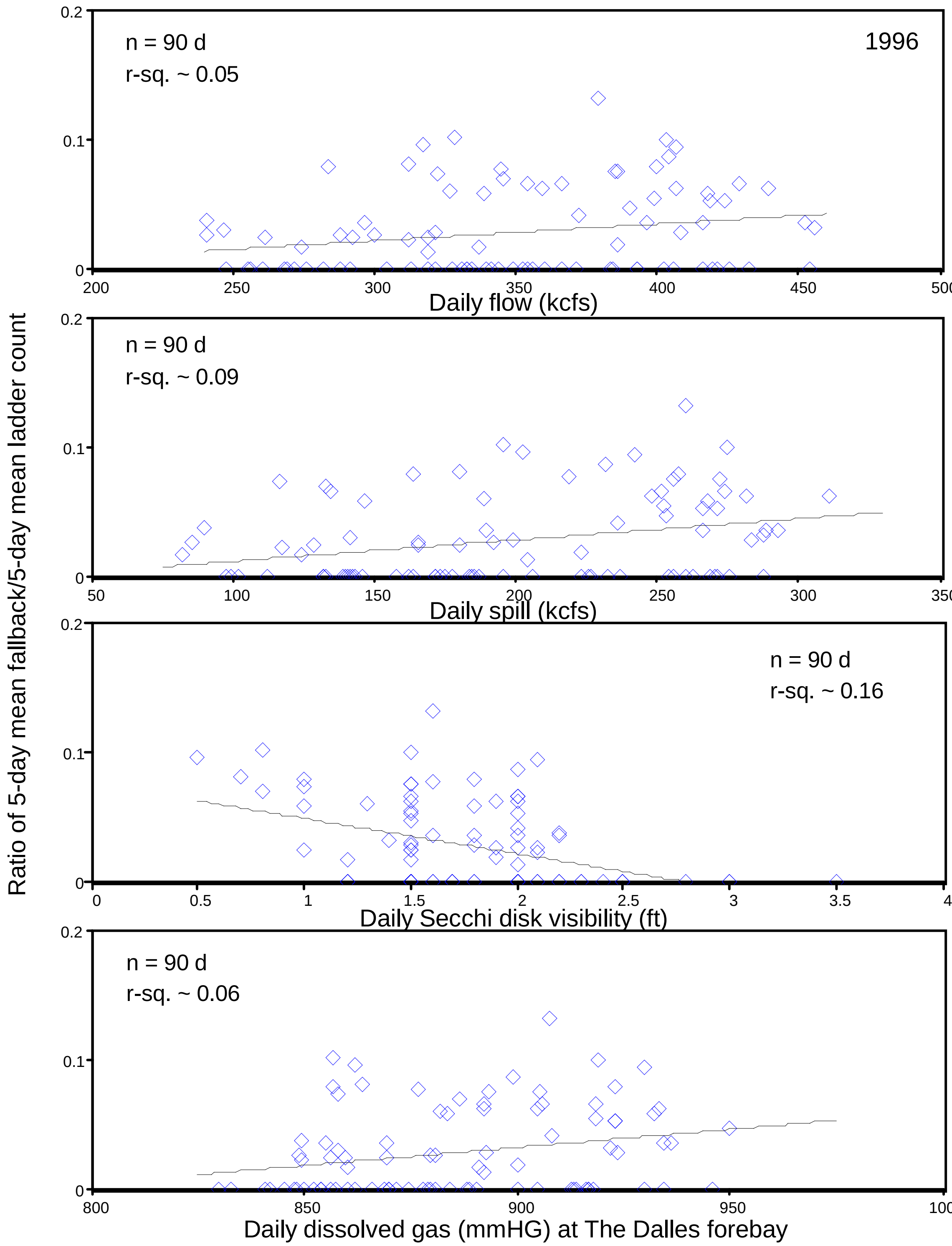

Figure 21. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at The Dalles Dam in 1996. r-sq values approximate

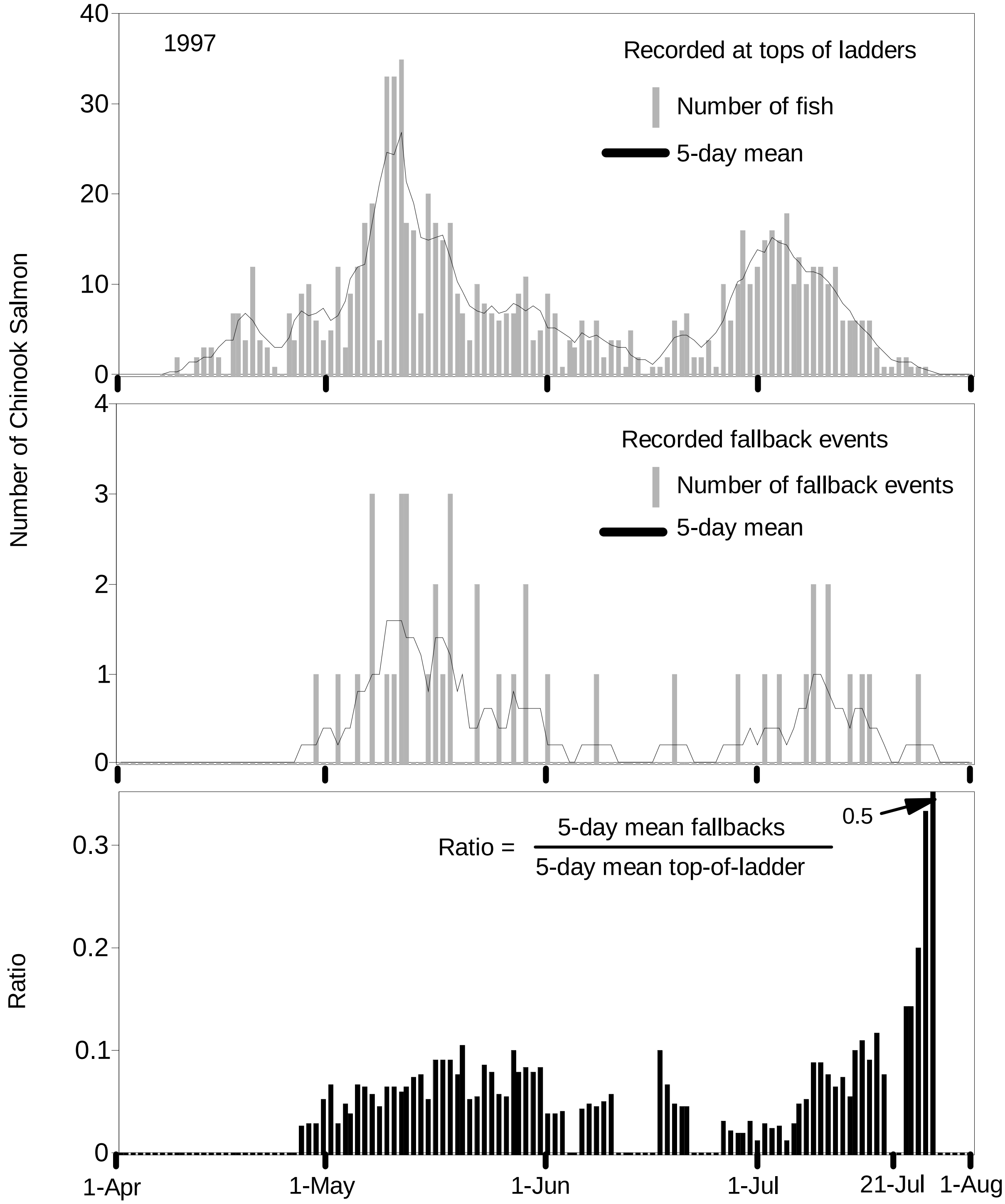

Figure 22. Daily number and 5-d mean recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for spring and summer chinook salmon with transmitters in 1997.

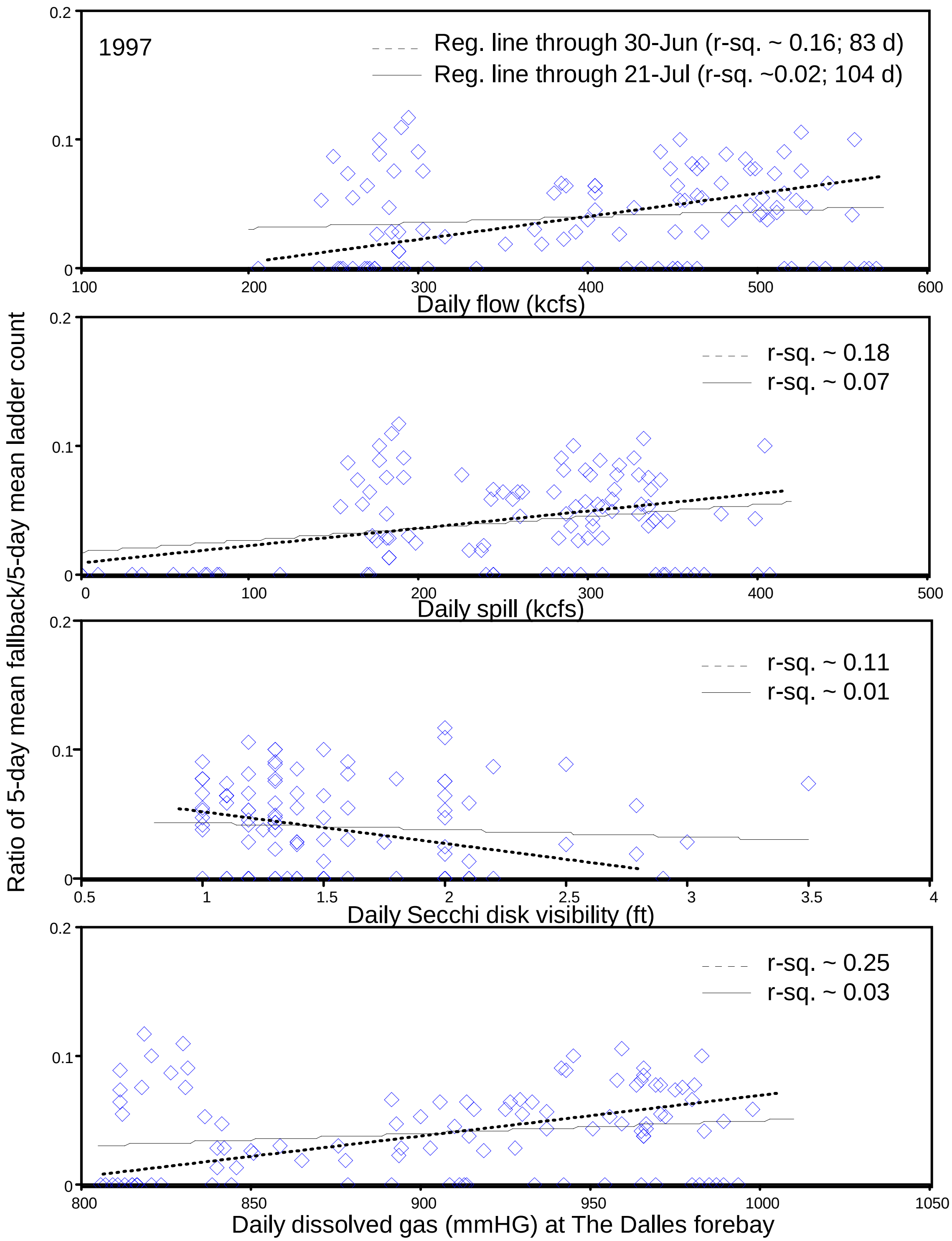

Figure 23. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at The Dalles Dam in 1997. r-sq values approximate

gas, and ~ 0.11 for Secchi disk visibility (Figure 23).

In 1998, 31 spring and summer chinook salmon with transmitters fell back within 24 h of passage at The Dalles Dam. Fish with transmitters began to pass the dam in the first week of April, and the first fallbacks within 24 h of passage did not occur until mid-April (Figure 24). Unlike 1996 and 1997, the moving average fallback ratio did not have clear peaks and nadirs in 1998. For almost 3 weeks in late May and June, there was only one recorded fallback within 24 h of passage (Figure 24). Ratio values were negatively correlated with flow, spill, and dissolved gas between and positively correlated with Secchi visibility between 5 April and 19 July, the period when all radio-tagged spring and summer chinook salmon passed The Dalles Dam in 1998 (Figure 25). The r^2 values were all less than ~ 0.10, and slopes were the opposite of expected in part because of two fallback events during the two-week period of no spill in early April that affected ratios for ten days. As in 1997, we also recorded a group of fallbacks by summer chinook salmon in July when few fish with transmitters were passing the dam.

Water temperature and moving-average fallback ratios: - We observed different fallback responses by spring and summer chinook salmon to increasing water temperature between years. In 1996, the moving-average fallback ratios had a weak negative correlation with water temperature; as temperatures rose through the migration, fallback ratios decreased (Figure 26). In 1997, the response was more parabolic, with low fallback ratios early in the season at low temperatures, an increase in ratios to about 13 °C, followed by decreasing ratios through early July when temperatures were 16-17 °C. Fallback ratios for 1997 chinook salmon increased rapidly when temperatures exceeded 18 °C (Figure 26). We observed a a weak positive relationship between water temperature and fallback ratios for the 1998 chinook salmon.

Fallback ratios for consecutive 5-d blocks: - In a third approach to analysis of environmental factors and fallbacks, we again used passage of chinook salmon with transmitters and fallbacks within 24 h of passing The Dalles Dam, but grouped data in consecutive 5-d blocks and calculated fallback ratios and mean values for the independent variables for each block. With this method, each fallback event affected only the ratio for the block in which it occurred. In the 5-d moving average method, each fallback event affected 5 daily fallback ratios, and the relative contribution of each event may have been magnified. Because fish passage was not uniform over the chinook salmon migration, consecutive 5-d blocks had unequal numbers of fish in each block. In addition, fallback ratios and mean values for independent variables varied with the blocking sequence start date. To account for this variability, we ran analyses on the five possible block sequences over the date range that radio-tagged chinook salmon passed The Dalles Dam for each year. For ease of comparison with results from other methods, we present only data for 5-d blocks starting on the first day that radio-tagged salmon began passing the dam. For the three

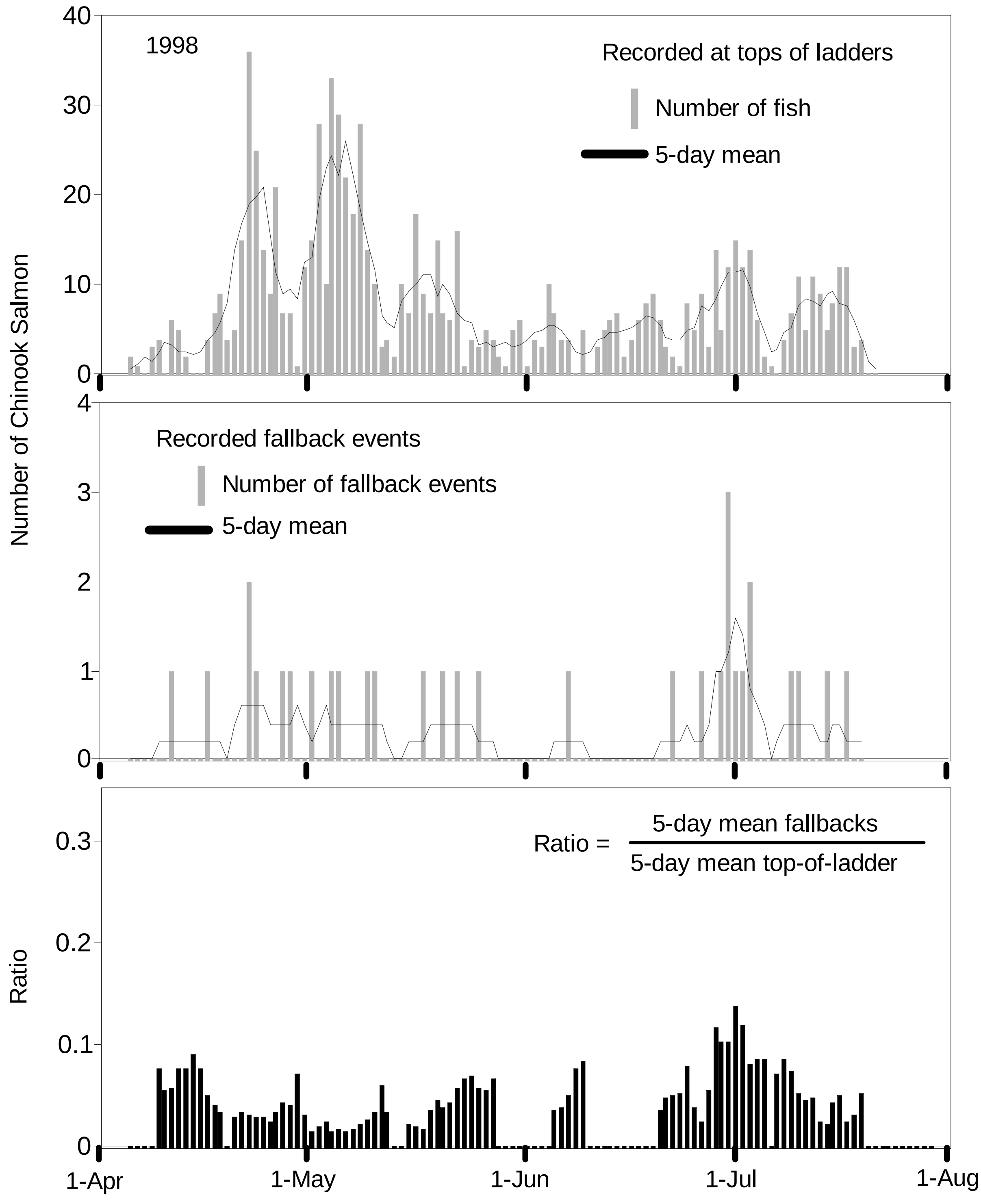

Figure 24. Daily number and 5-d mean recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for spring and summer chinook salmon with transmitters in 1998.

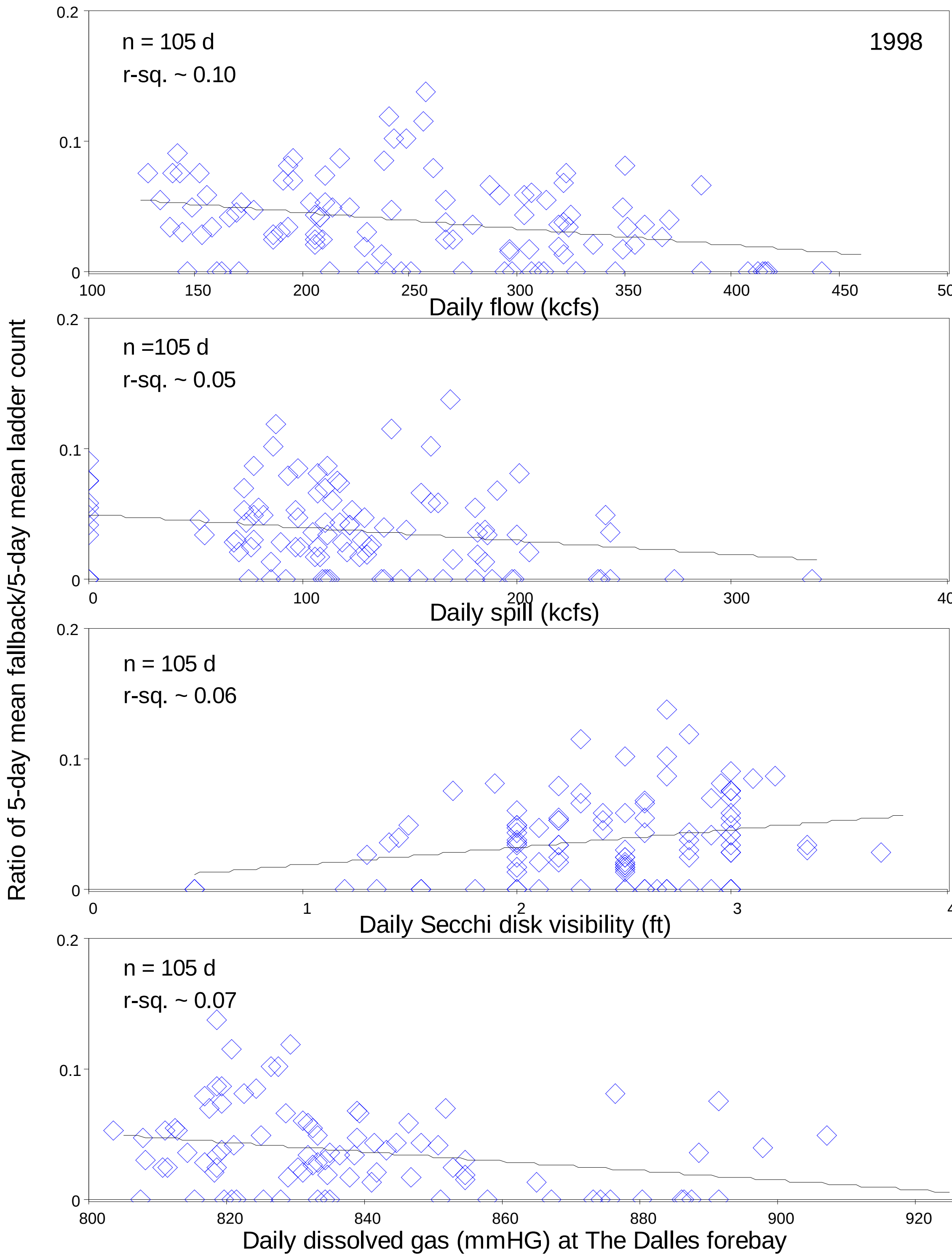

Figure 25. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at The Dalles Dam in 1998. r-sq values approximate

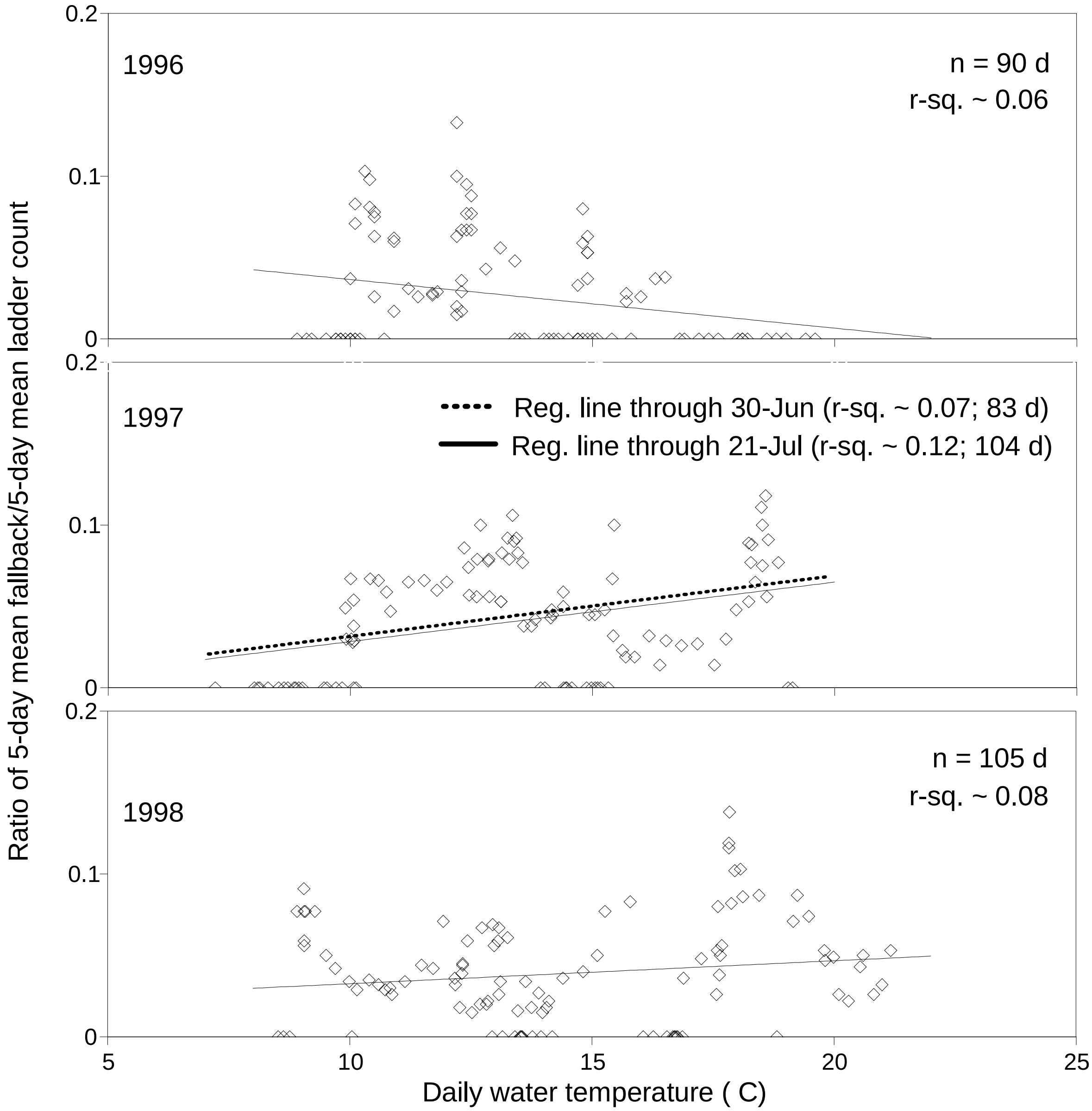

Figure 26. Regressions of daily mean water temperature in the tailrace with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at The Dalles Dam for 1996, 1997, and 1998. r-sq values approximate

years, the average number of fish/block was between 32 and 38, and standard deviations were from 21 to 29 fish.

For each year and environmental variable, we ran standard regressions as well as regressions weighted for the number of fish in each block and logistic regressions that used maximum likelihood methods to account for variability in both the number of fallback events and the number of fish in each block. Results from the 5-d block method were generally similar to those for the variable-day-bin method (see below). P values tended to be higher for the variable-day-bin method in 1996, but lower in both 1997 and 1998. To avoid result duplication, we report statistical results for both methods, but present graphics only for the variable-day-bin method.

In 1996, fallback ratios based on 5-d blocks were negatively correlated with Secchi depth visibility, and all models were significant. The r^2 values were 0.22 for the unweighted linear model ($P = 0.06$) and 0.38 for the weighted linear model ($P = 0.01$); P was 0.02 for the logistic model. Fallback ratios were positively correlated with all weighted and unweighted linear models and logistic models for flow, spill, and dissolved gas, but no models were significant at $P < 0.05$. The r^2 values for weighted and unweighted linear regressions were < 0.04 for flow ($P > 0.40$), < 0.08 for spill ($P > 0.25$), and 0.10 for dissolved gas ($P > 0.20$). Fallback ratios were negatively correlated with water temperature, but models were not significant ($P = 0.22$ for logistic model; $P = 0.87$ for unweighted linear model; $P = 0.22$ for weighted linear model).

Using all 1997 data through 21 July (99% of all passages) , fallback ratios based on 5-d blocks were negatively correlated with Secchi depth visibility, and positively correlated with flow, spill, dissolved gas, and water temperature. No linear or logistic models were significant ($P > 0.12$ for all models), and r^2 values for all linear models were < 0.07. When we limited data to all passages through 30 June (76% of all passages), regression slopes were again positive for flow, spill, dissolved gas, and temperature and negative for Secchi visibility, but one or more models neared significance for each variable. For flow, r^2 values were 0.13 for the unweighted linear model ($P = 0.16$) and 0.10 for the weighted linear model ($P = 0.10$); P was 0.16 for the logistic model. For spill, r^2 values were 0.22 for the unweighted linear model ($P = 0.03$) and 0.20 for the weighted linear model ($P = 0.04$); P was 0.11 for the logistic model. For dissolved gas, r^2 values were 0.19 for the unweighted linear model ($P = 0.08$) and 0.26 for the weighted linear model ($P = 0.03$); P was 0.08 for the logistic model. P values for water temperature were > 0.45 for linear models, and 0.83 for the logistic model. For Secchi visibility, r^2 values were 0.18 for the unweighted linear model ($P = 0.09$) and 0.24 for the weighted linear model ($P = 0.04$); P was 0.09 for the logistic model.

In 1998, fallback ratios based on 5-d blocks were not significantly correlated with any environmental variables ($P > 0.20$). In addition, results in 1998 were generally the opposite of those for 1996 and 1997: flow, spill, dissolved gas, and water temperature were all negatively correlated with fallback ratios, and Secchi depth visibility was positively correlated. All r^2 values were < 0.07 for linear models.

Fallback ratios for variable-day bins*: -* In a fourth approach, we grouped passage by spring and summer chinook salmon during consecutive days until at least 25 fish with transmitters had passed the dam. This produced 18 to 27 bins, with an average of approximately 30 fish/bin (standard deviation ~ 6 fish) for each year. Twenty-fish bins had substantially higher variance. We then calculated mean flow, spill, Secchi disk visibility, and a fallback ratio for each bin, and tested logistic and weighted and unweighted linear regression models for each year. Because there was relatively low variability in the number of fish/bin, weighting had limited impact on results. As with any grouping method, some variability and sensitivity was lost among independent variables by taking mean bin values.

We created 18 bins for the 1996 data set, with a mean of 4.8 d/bin (median 4 d/bin). Correlations between the bin fallback ratios and mean flow, spill, and dissolved gas were near zero, with very slightly decreasing ratios as flow and spill increased; logistic regressions using maximum likelihood methods produced similar trends (Figure 27). Bins in early May had the highest fallback ratios, coincident with Secchi depths of less than 1 ft, the lowest during the 1996 migration. The unweighted regression of mean Secchi disk visibility and fallback ratio for each bin produced an r^2 value of 0.43 ($P = 0.003$); weighting for the number of fish/bin increased the r^2 value to 0.44. The logistic regression model showed the probability of falling back decreased from about 0.12 at < 1 ft Secchi disk visibility to about 0.02 at Secchi disk visibility of > 2 ft (Figure 27). Fallback ratios were negatively correlated with water temperature. The r^2 values for unweighted and weighted regressions were about 0.06 ($P > 0.25$), and results were similar for the logistic regression ($P = 0.27$) (Figure 27).

For the 1997 data through 21 July (99% of all data), we created 26 bins with a mean of 4.2 d/bin (median 3 d/bin). Correlations between the bin fallback ratios and mean flow, spill, and dissolved gas were low ($r^2 < 0.10$), although bin ratios were lowest in early April when spill and flow were relatively low; the group of fallbacks in July again produced relatively high ratios during that time when flow and spill were also relatively low. With all data included, linear and logistic regressions showed slight increases in fallback with increasing flow, spill, dissolved gas, and temperature, and almost no relationship between fallback and Secchi disk visibility (Figure 28). When we removed the five bins that covered July (approximately 30% of all passages by radio-tagged chinook salmon in 1997), the linear and logistic relations between flow, spill, and dissolved gas and the fallback ratio were significant at $P < 0.05$ (Figure 29). The r^2 values for weighted and unweighted linear models improved to between 0.19 and 0.26 for flow, spill, and dissolved gas, with all correlations positive. Linear and logistic models were not significant for Secchi disk visibility ($P > 0.45$) or water temperature ($P > 0.18$) (Figure 29).

For 1998, we created 27 bins with a mean of 3.9 d/bin (median 3 d/bin). Correlations between the bin fallback ratios and mean flow, spill, and dissolved gas were negative, and r^2 values for unweighted and weighted linear models were < 0.05 (Figure 30). Fallback ratios increased with Secchi disk visibility and water temperature, but no linear or logistic models were significant. As in 1997, some of the highest bin fallback ratios occurred during late June/early July, but removal of all blocks after 25 June had little impact on model fitting. Removal of just one bin with the highest fallback ratio (ratio of 0.156 occurred late in June when 5 of 32 chinook salmon fell back within 24 h of passing the dam) also had limited impact on model fit.

Fallback ratios for groups based on environmental conditions: - In a fifth approach, we grouped fish by daily flow and spill conditions for each year and calculated fallback ratios for each group. We only used fallbacks within 24 h of passage, and as with the 5-d-block

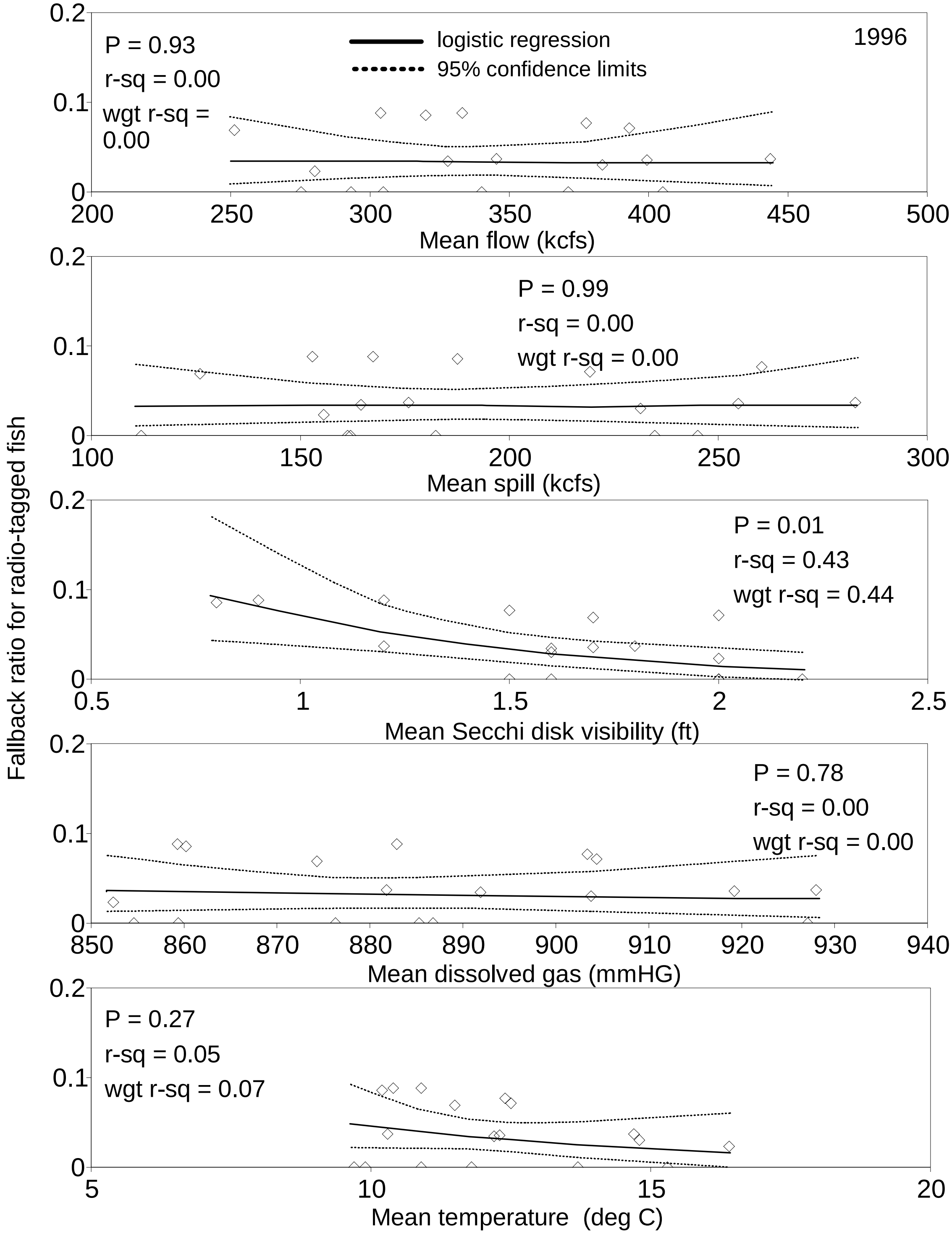

Figure 27. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of chinook salmon fallbacks within 24 h at The Dalles Dam in 1996; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width time bins that included at least 25 fish.

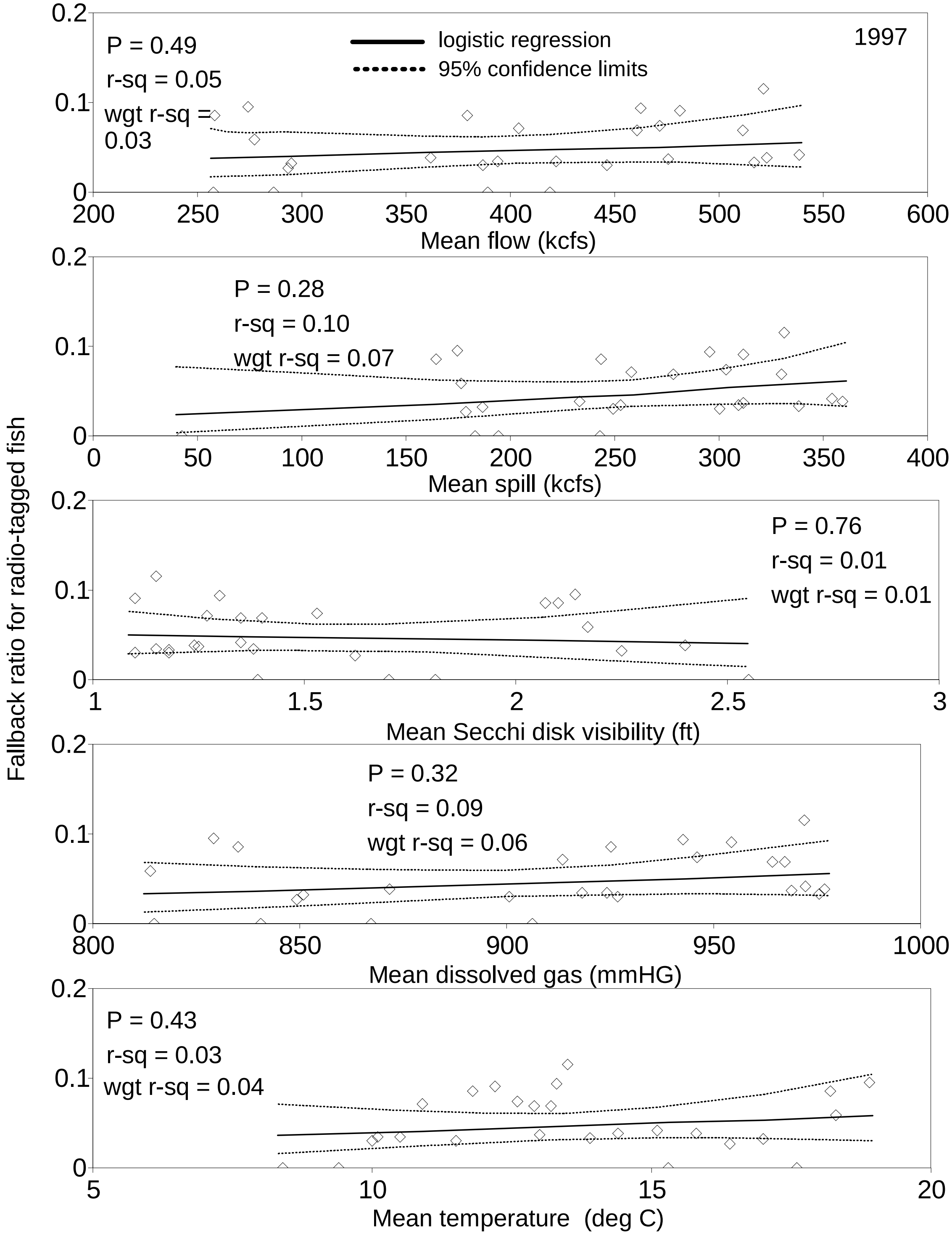

Figure 28. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of chinook salmon fallbacks within 24 h at The Dalles Dam in 1997; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width time bins that included at least 25 fish.

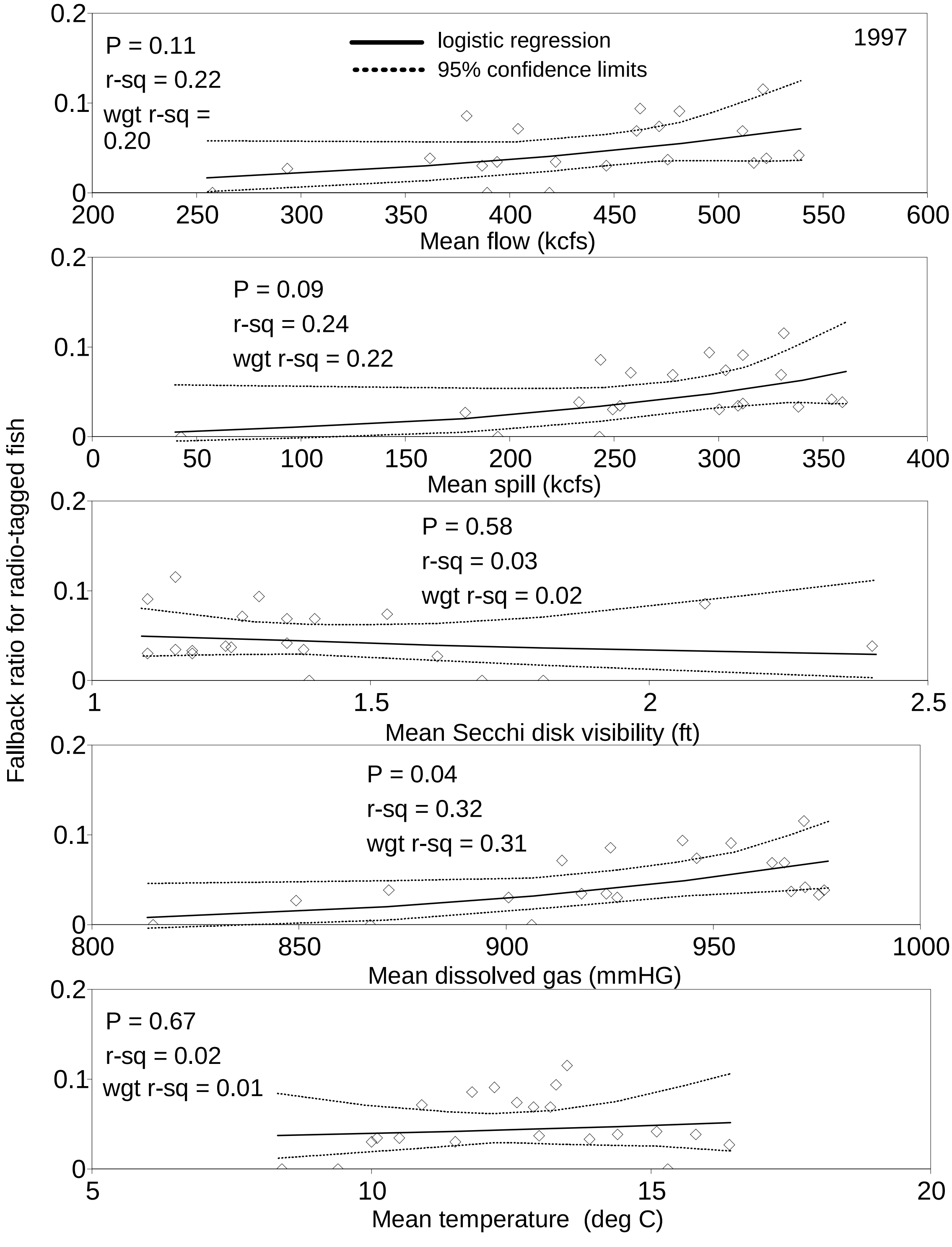

Figure 29. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of chinook salmon fallbacks within 24 h at The Dalles Dam through June, 1997; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width time bins that included at least 25 fish.

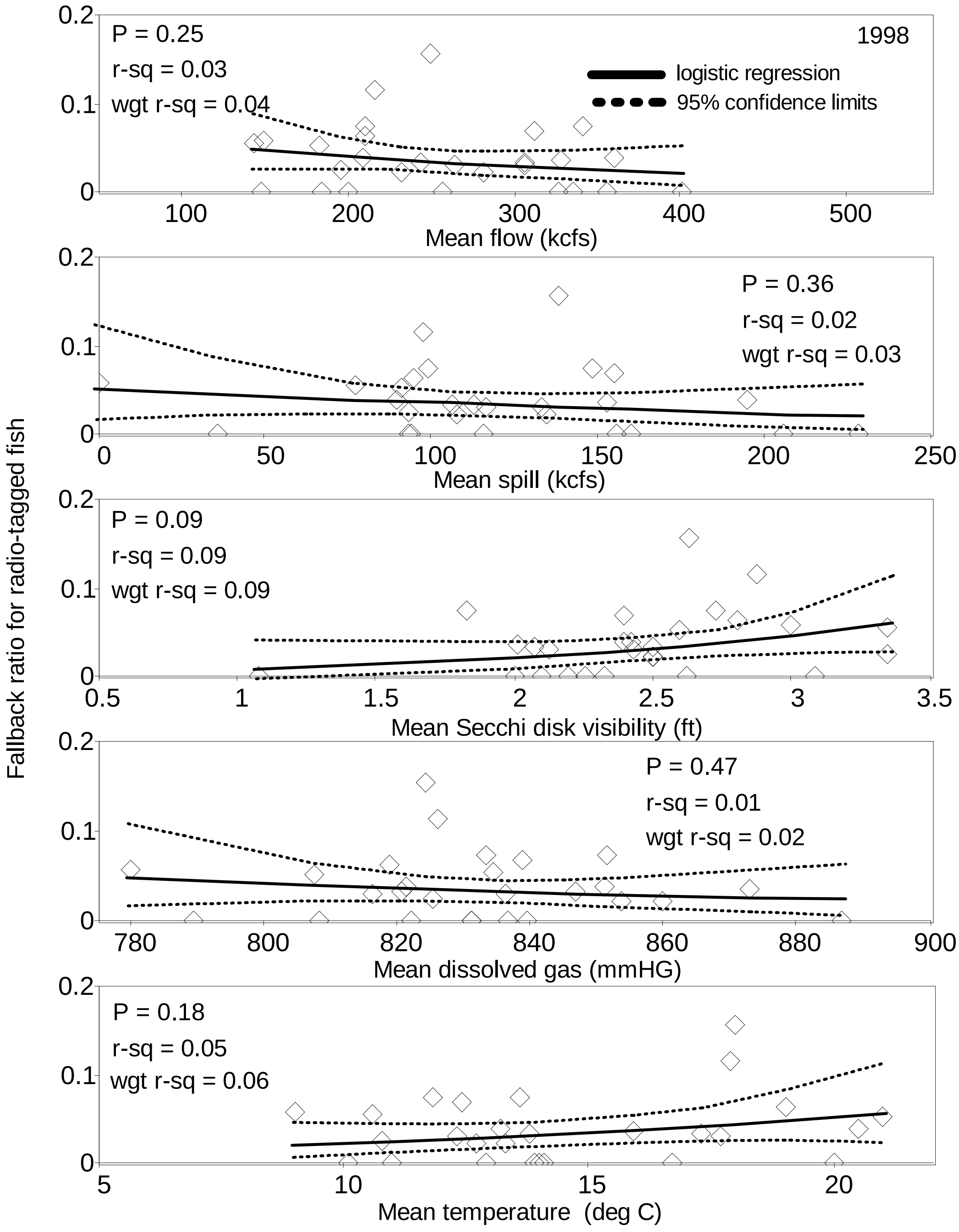

Figure 30. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of chinook salmon fallbacks within 24 h at The Dalles Dam in 1998; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width time bins that included at least 25 fish.

method, groups based on flow or spill had unequal numbers of fish. With this method, fish from different portions of the run were pooled together, raising statistical concerns when applying results to the run at large. We believe, however, that it was a viable method for comparing fallback rates for radio-tagged fish at specific spill and flow conditions given the lack of uniformly distributed conditions during the spring and summer chinook salmon migrations.

In 1996, flow at The Dalles Dam during the passage of radio-tagged spring and summer chinook salmon ranged from about 240 kcfs to 460 kcfs (Table 9). We grouped chinook salmon based on mean daily flow increments of 10 kcfs. The 21 groups had a mean of 23 chinook salmon per group (median of 19). For the 127 passages of the dam during flows less than 300 kcfs, 2 radio-tagged chinook salmon fell back (Table 9), and the aggregated fallback ratio was 0.016.

Forty-nine percent of 489 recorded passages of The Dalles Dam occurred at flows less than 330 kcfs, for which the aggregated fallback ratio was 0.046. Of all passages by radio-tagged chinook salmon at The Dalles Dam, 251 (51%) occurred at flows greater than 330 kcfs. The aggregated fallback ratio for all passage when flows were 330 kcfs or more was 0.040, slightly lower than the ratio for passage when flows were less than 330 kcfs.

Weighted and unweighted linear models, as well as logistic models, showed little correlation between flow and fallback ratios. Lack of fit was driven in part by 10 flow increments (35% of all passages) with fallback ratio of zero scattered throughout the range (Table 9). When we limited models to flows with non-zero fallback ratios (65% of all passages), we observed weak positive Correlations (r^2 about 0.07; P = 0.38) between fallback ratio and flow.

In 1997, flow at The Dalles Dam during the passage of radio-tagged spring and summer chinook salmon ranged from about 200 kcfs to more than 550 kcfs. We grouped chinook salmon based on mean daily flow increments of 10 kcfs. The 32 groups with fish had a mean of 25 chinook salmon per group (median of 18) (Table 9). Forty-eight percent of 813 recorded passages of salmon at The Dalles Dam occurred at flows less than 400 kcfs, for which the aggregated fallback ratio was 0.043. Of all passages by radio-tagged chinook at The Dalles Dam, 419 (52%) occurred at flows greater than 400 kcfs. The aggregated fallback ratio for all passages when flows exceeded 400 kcfs or more was 0.060, about 2% higher than the ratio when flows were less than 400 kcfs.

The correlation coefficient between flow and fallback ratios when all data was included was near zero, and a logistic model was not significant (P = 0.58). Lack of correlation was caused in part by 17 flow increments (20% of all passages) with fallback ratios of zero scattered throughout the range (Table 9). In addition, 4 of 25 chinook salmon fell back within 24 h during flows of 240 to 250 kcfs, creating an outlying fallback ratio of 0.160. Removing that flow level from the weighted linear model produced a weak positive correlation (r^2 = 0.10; P = 0.08). Removing additional groups with fallback ratios of zero, leaving 77% of all passages in the model, further improved

Table 9. Recorded passages (past dam), fallbacks within 24 h of dam passage (24 h FB), and fallback ratios (FB/ recorded passages) by flow increments for spring and summer chinook salmon at The Dalles Dam in 1996, 1997, and 1998.

	1996			1997			1998		
Flow	Past dam	24 h FB	FB ratio	Past dam	24 h FB	FB ratio	Past dam	24 h FB	FB ratio
120-129							5	0	0.00
130-139							9	0	0.00
140-149							50	3	0.06
150-159							28	1	0.04
160-169							13	0	0.00
170-179							18	0	0.00
180-189							40	2	0.05
190-199							38	2	0.05
200-209				3	0	0.00	70	4	0.06
210-219				--	--	--	25	1	0.04
220-229				--	--	--	46	1	0.02
230-239				--	--	--	27	1	0.04
240-249	39	1	0.03	25	4	0.16	40	5	0.13
250-259	3	0	0.00	11	0	0.00	38	1	0.03
260-269	16	1	0.06	13	1	0.07	26	0	0.00
270-279	21	0	0.00	54	1	0.02	17	1	0.06
280-289	20	0	0.00	91	4	0.04	1	0	0.00
290-299	28	0	0.00	21	1	0.05	71	3	0.04
300-309	14	0	0.00	15	0	0.00	53	2	0.04
310-319	38	5	0.13	16	0	0.00	37	0	0.00
320-329	59	4	0.07	--	--	--	43	1	0.02
330-339	39	2	0.05	4	0	0.00	7	0	0.00
340-349	31	1	0.03	--	--	--	37	1	0.00
350-359	19	1	0.05	16	0	0.00	45	1	0.02
360-369	11	1	0.09	10	0	0.00	14	1	0.07
370-379	18	1	0.11	45	4	0.09	4	0	0.00
380-389	23	0	0.00	51	2	0.04	8	0	0.00
390-399	18	0	0.00	19	0	0.00	--	--	--
400-409	36	2	0.06	74	4	0.05	1	0	0.00
410-419	11	1	0.09	9	0	0.00	22	0	0.00
420-429	17	0	0.00	7	0	0.00	--	--	--
430-439	12	1	0.08	3	0	0.00	--	--	--
440-449	--	--	--	23	2	0.09	5	0	0.00
450-459	16	0	0.00	65	6	0.09			
460-469				52	4	0.08			
470-479				5	0	0.00			
480-489				31	2	0.06			
490-499				24	0	0.00			
500-509				44	2	0.05			
510-519				35	4	0.11			
520-529				29	1	0.03			
530-539				4	0	0.00			
540-549				3	0	0.00			
>550				10	0	0.00			

* lines indicate midpoint of passage counts for radio-tagged chinook salmon.

the weighted model fit to $r^2 = 0.25$ (P = 0.07).

In 1998, flow at The Dalles Dam during the passage of radio-tagged spring and summer chinook salmon ranged from approximately 120 kcfs to 450 kcfs. We grouped chinook salmon based on mean daily flow increments of 10 kcfs. The 30 groups had a mean of 28 chinook salmon per group (median of 27). Forty-nine percent of 838 recorded passages of The Dalles Dam occurred at flows less than 250 kcfs, for which the aggregated fallback ratio was 0.049. Of all passages by radio-tagged chinook salmon at The Dalles Dam, 429 (51%) occurred at flows greater than 250 kcfs. The aggregated fallback ratio for all passage when flows were 250 kcfs or more was 0.026, about half the ratio for passage when flows were less than 250 kcfs.

There was a weak negative correlation between flow and fallback ratios when all data was included in weighted and unweighted linear models, and logistic models. P values were 0.19 for the logistic model, 0.22 for the unweighted linear model, and 0.10 for the weighted linear model. Lack of correlation was caused in part by 13 flow increments (19% of all passages) with fallback ratio of zero scattered throughout the range (Table 9). In addition, 5 of 40 chinook salmon fell back within 24 h during flows of 240 to 250 kcfs, creating an outlying fallback ratio of 0.125. Removing that flow level and all groups with fallback ratios of zero resulted in a negative correlation with $r^2 = 0.26$ (P = 0.05) for the weighted linear model with 77% of all data included.

In 1996, spill at The Dalles Dam during the passage of radio-tagged spring and summer chinook salmon ranged from about 80 kcfs to 320 kcfs (Table 10). Using 10-kcfs increments, 23 groups were formed that had a mean of 21 fish per group (median of 21). Of 489 passages of The Dalles Dam, 254 (52%) occurred at spills of less than 190 kcfs the aggregated fallback ratio was 0.043. The remaining 235 passages (48%) occurred at spills greater than 190 kcfs and the aggregated fallback ratio was also 0.143.

There was almost no correlation between spill and fallback ratios when all data was included in weighted and unweighted linear models, and logistic models. Although 7 spill groups had fallback ratio of zero, those levels only accounted for about 11% of all passages, and their removal from the models led to only minor changes in fit. Two spill levels (200-210 kcfs and 240-250 kcfs) appeared to have outlying ratio values, but removing those points had little affect on the model outputs.

In 1997, spill at The Dalles Dam during the passage of radio-tagged spring and summer chinook salmon ranged from 0 to 400 kcfs (Table 10). Using 10-kcfs increments, 30 groups with fish were formed with a mean of 27 fish per group (median of 19). Of 813 recorded passages by chinook salmon, 386 (47%) occurred at spills of less than 250 kcfs, and the aggregated fallback ratio for those fish was 0.044. The remaining 427 fish (53%) fell back when spill levels were greater than 250 kcfs and had an aggregated fallback ratio of 0.059. For 46 passages by chinook salmon when spill was less than 150 kcfs, no fallback events were recorded.

There were weak positive correlations between spill and fallback ratios when all data was included. The unweighted linear model had a significant r^2 of 0.15 (P = 0.05); the weighted model (P = 0.42) and logistic model (P = 0.37) were not significant. Two spill levels (150-160 kcfs and 320-330 kcfs) appeared to have outlying ratio values at 0.174 and 0.177; removal of the groups improved model fit to r^2 of 0.22 (P = 0.02) for the unweighted, 0.08 (P = 0.17) for the weighted model, and P = 0.12 for the logistic model. Removing 12 spill groups with fallback ratios of zero, leaving 75% of all passages in the model, did not further improve fit.

In 1998, spill at The Dalles Dam during the passage of radio-tagged spring and summer chinook salmon ranged from 0 to 340 kcfs (Table 10). Using 10-kcfs increments, 20 groups were formed that had a mean of 41 fish per group (median of 40). Two fallback events were recorded for 44 passages by chinook salmon when spill was zero (Table 10). Of 838 recorded passages by chinook salmon, 443 (53%) occurred when spill was less than 120 kcfs, and the aggregated fallback ratio for those fish was 0.047. The 395 (47%) fish that passed when spill was greater than 120 kcfs had an aggregated fallback ratio of 0.025, almost half that of fish that passed at lower spill levels.

There was little correlation between spill and fallback ratios when all data was included in weighted and unweighted linear models, and logistic models (P > 0.20 in all cases. Although 6 flow increments had fallback ratio of zero, including about 12% of all passages, their removal from models did not improve fit. The general trend appeared to be decreasing fallback ratios with increasing spill in 1998.

We did not analyze relationships between turbidity, dissolved gas levels, or water temperature and fallback ratios using the grouping method.

T-Tests and logistic regressions of binary data (fallback vs. no fallback): - For each year, we created a binary data set that included every passage of The Dalles Dam by spring and summer chinook salmon with transmitters. Fish that fell back within 24 h of passage received a ‘1’ and fish that did not fall back within 24 h received a ‘0.’ We then tested whether fish that fell back passed the dam under significantly different environmental conditions than those that did not fall back, using both standard t-tests to show general comparisons (data pooled for all passages) and logistic regression to show fallback probabilities and confidence intervals. Because a substantial number of fish fell back at The Dalles Dam within 1 to 5 d of passing the dam in all years, we also tested whether those fish passed under significantly different conditions than those that did not fall back within 5 d of passage.

In 1996, there were 548 known-date passages by spring and summer chinook salmon with transmitters at The Dalles Dam. Following passage, 21 fish (3.8%) fell back within 24 h of passing and 527 did not. Mean flow, spill, and dissolved gas levels were minimally higher for chinook salmon that did not fall back within 24 h, but differences were not significant (P > 0.85) (Table 11). Mean Secchi disk visibility was significantly lower for fish that fell back (P = 0.004); mean water temperature was also lower for fish that fell back, but the difference was not significant (P = 0.21).

Table 10. Recorded passages (past dam), fallbacks within 24 h of dam passage (24 h FB), and fallback ratios (FB/ recorded passages) by spill volume for spring and summer chinook salmon at The Dalles Dam in 1996, 1997, and 1998.

	1996			1997			1998		
Spill	Past dam	24 h FB	FB ratio	Past dam	24 h FB	FB ratio	Past dam	24 h FB	FB ratio
0-9				7	0	0.00	47	2	0.04
10-19				4	0	0.00	--	--	--
20-29				--	--	--	--	--	--
30-39				3	0	0.00	--	--	--
40-49				--	--	--	--	--	--
50-59				--	--	--	20	0	0.00
60-69				2	0	0.00	28	1	0.04
70-79				12	0	0.00	89	5	0.06
80-89	29	1	0.03	14	0	0.00	50	6	0.12
90-99	4	0	0.00	--	--	--	56	1	0.02
100-109	1	0	0.00	--	--	--	71	5	0.07
110-119	15	1	0.07	4	0	0.00	82	1	0.01
120-129	19	1	0.05	--	--	--	56	1	0.02
130-139	16	1	0.06	--	--	--	64	1	0.02
140-149	39	1	0.03	--	--	--	28	0	0.00
150-159	2	0	0.00	24	3	0.17	9	1	0.11
160-169	30	1	0.03	15	1	0.07	75	4	0.05
170-179	32	2	0.06	59	1	0.02	--	--	--
180-189	67	3	0.05	87	4	0.05	68	1	0.01
190-199	30	1	0.03	32	1	0.03	27	1	0.04
200-209	11	2	0.18	--	--	--	33	0	0.00
210-219	22	1	0.05	--	--	--	--	--	--
220-229	24	0	0.00	4	0	0.00	--	--	--
230-239	21	1	0.05	32	1	0.03	7	0	0.00
240-249	7	1	0.14	87	5	0.06	13	1	0.08
250-259	33	2	0.06	52	4	0.08	--	--	--
260-269	14	0	0.00	21	0	0.00	--	--	--
270-279	32	1	0.03	20	3	0.15	10	0	0.00
280-289	31	1	0.03	42	4	0.10	--	--	--
290-299	6	0	0.00	58	3	0.05	--	--	--
300-309	--	--	--	74	3	0.04	--	--	--
310-319	4	0	0.00	26	0	0.00	--	--	--
320-329				17	3	0.18	--	--	--
330-339				55	4	0.07	5	0	0.00
340-349				35	0	0.00			
>350				27	1	0.04			

* lines indicate midpoint of passage counts for radio-tagged chinook salmon.

In 1997, there were 813 known-date passages by spring and summer chinook salmon with transmitters at The Dalles Dam. Following passage, 42 fish (5.2%) fell back within 24 h of passing and 771 did not (Table 11). Although mean flow, spill, and dissolved gas levels were higher for chinook salmon that fell back within 24 h, the differences were not significant (P > 0.30). There was no significant difference in mean Secchi disk visibility (P = 0.76) or temperature (P = 0.47) during passage of fish that fell back. Excluding all passages in July, which led to large improvements in models described previously for 1997, did not result in significant differences in mean flow (P = 0.15), spill (P = 0.14), dissolved gas (P = 0.10), Secchi disk visibility (P = 0.70), or temperature (P = 0.68).

In 1998, there were 838 known passages by spring and summer chinook salmon with transmitters at The Dalles Dam. Following passage, 31 fish (3.7%) fell back within 24 h of passing and 807 did not (Table 11). We found no significant differences in mean flow (P = 0.16), spill (P 0.17), or dissolved gas levels (P = 0.74) for chinook salmon that fell back within 24 h, but means were higher in all cases for fish that did not fall back within 24 h. There were no significant differences in mean Secchi disk visibility (P = 0.23) or water temperature (P =0.17) for the two groups.

We also tested for significant differences in environmental conditions for fish that fell back within 5 d of passing the dam (Table 12). Extending the time horizon for fallback events allowed us to classify approximately twice as many fish as fallbacks for each year. Tests of mean environmental conditions, however, produced results very similar to those for fallbacks that occurred within 24 h of passage. With the exception of Secchi visibility in 1996 (P = 0.02), we found no significant differences in mean environmental conditions for radio-tagged chinook salmon that fell back within 5 d of passage in 1996, 1997, or 1998 (Table 12).

Logistic regression models that used the full binary data sets for spring and summer chinook salmon produced few significant results. The probability of falling back within 24 h of passage increased slightly with flow in both 1996 (P = 0.86) and 1997 (P = 0.58), and decreased in 1998 (P = 0.16) (Figure 31). The probability of falling back decreased with spill in 1996 (P = 0.88) and 1998 (P = 0.17), and increased with spill in 1997 (P = 0.34) (Figure 31). The probability of falling back within 24 h decreased with increased Secchi visibility in 1996 (P = 0.004) and 1997 (P = 0.76), and increased in 1998 (P = 0.23). The probability of falling back in 24 h increased with increased dissolved gas in 1996 (P = 0.21) and 1997 (P = 0.41), and decreased in 1998 (P = 0.64). The probability of falling back in 24 h increased with increased water temperature in 1997 (P = 0.76) and 1998 (P = 0.18), and decreased with temperature in 1996 (P = 0.21).

Effects of juvenile spill test on chinook salmon fallback in 1998: - The spill test for juvenile passage at The Dalles Dam in 1998 alternated daily between approximately 30% and 60% of total flow. The spill test for juveniles provided an opportunity to examine if two different proportions of spill affected fallbacks within 24 h by adult spring and summer chinook salmon with transmitters. It is important to note that total flow varied continuously during this time and that the test was not of discreet spill levels, but was a test of the impact of spilling a set percentage of total flow.

Radio-tagged chinook salmon were passing the dam over a period of 91 d with spill. Percent spill was between 34% and 38% of total flow on 36 d (40%), and between 56% and 60% on 37 d (41%) (Figure 32). Thirty-six percent of all radio-tagged fish passed the dam on days when spill was at the lower level and 42%

Table 11. Number of spring and summer chinook salmon (CK), sockeye salmon (SK), steelhead (SH), and fall chinook salmon (FCK) that either did or did not fall back within 24 h of passing The Dalles Dam and mean daily flow, spill, Secchi dish visibility, dissolved gas, and water temperature on the date of each fishes' passage in 1996, 1997, and 1998.

Year Species	Number	%	Mean total flow	Mean total spill	Mean Secchi depth	Mean dissolved gas	Mean water temp
1996 CK (548 passages)							
FB in 24 h	21	3.8	339	194	1.3**	884	11.8
did not FB	527	96.2	337	196	1.6**	883	12.4
1997 CK (813 passages)							
FB in 24 h	42	5.2	402	259	1.6	910	14.0
did not FB	771	94.8	395	247	1.6	903	13.6
1998 CK (838 passages)							
FB in 24 h	31	3.7	241	110	2.6	831	15.0
did not FB	807	96.3	260	124	2.5	833	14.2
1997 SK (512 passages)							
FB in 24 h	18	3.5	326	205	2.1	858	16.8
did not FB	494	96.5	316	198	2.0	855	17.0
1997 SK (494 passages from 20 June to 4 August)							
FB in 24 h	17	3.4	333	209	2.1	862	16.5
did not FB	477	96.6	310	194	2.0	852	17.1
1996 SH (615 passages; data available for > 97% of all passages)							
FB in 24 h	8	1.3	158	43	2.5	n/a	18.5
did not FB	607	98.7	159	45	2.3	n/a	19.0
1997 SH (718 passages)							
FB in 24 h	14	1.9	196	110*	n/a	n/a	n/a
did not FB	704	98.1	177	59*	n/a	n/a	n/a
1998 FCK (651 passages; data available for > 98% of passages)							
FB in 24 h	9	1.4	111	0	3.2	n/a	20.4
did not FB	642	98.6	107	0	3.2	n/a	20.6

* P < 0.05; ** P < 0.005 using standard t-test

Table 12. Number of spring and summer chinook salmon (CK), steelhead (SH), and fall chinook salmon (FCK) that either did or did not fallback within 5 d of passing The Dalles Dam and mean daily flow, spill, Secchi disk visibility, dissolved gas, and water temperature on the date of each fishes' passage in 1996, 1997, and 1998.

Year Species	Number	%	Mean total flow	Mean total spill	Mean Secchi depth	Mean dissolved gas	Mean water temp
1996 CK (548 passages)							
FB in 5 d	52	9.5	337	191	1.5*	885	12.2
did not FB	496	90.5	337	196	1.6*	883	12.4
1997 CK (813 passages)							
FB in 5 d	86	10.6	409	260	1.5	913	13.6
did not FB	727	89.4	393	247	1.6	902	13.6
1998 CK (838 passages)							
FB in 5 d	66	7.9	258	125	2.5	835	13.7
did not FB	772	92.1	259	124	2.5	833	14.3
1996 SH (615 passages; data available for > 97% of all passages)							
FB in 5 d	16	2.6	193*	74	2.3	n/a	18.2
did not FB	599	97.4	158*	44	2.3	n/a	19.0
1997 SH (718 passages)							
FB in 5 d	22	3.1	204*	71*	n/a	n/a	n/a
did not FB	696	96.9	177*	32*	n/a	n/a	n/a
1998 FCK (651 passages; data available for > 98% of passages)							
FB in 5 d	35	5.4	107	0	3.4	n/a	20.4
did not FB	616	94.6	107	0	3.2	n/a	20.6

* P < 0.05; ** P < 0.005 using standard t-test

passed on days when spill was at the higher level. Another 6% passed during zero spill, and the remaining fish passed when spill was at other levels. At zero spill, 2 of 47 tagged fish fell back within 24 h and the aggregated fallback ratio was 0.043. At the lower spill test level (34% to 38%), the aggregated fallback ratio was 0.047, and at the higher level (56% to 60%), the ratio was 0.026. Differences in fallback proportions at the lower and higher spill test levels were not significant (P = 0.14; Z-test).

However, a limitation to the spill-test analysis was that many fish were exposed to two spill levels. For example, fish could pass the dam at one spill level and be in the forebay when spill shifted to the alternate level. This appeared to be the case for approximately two-thirds of the fish that fell back within 24 h of

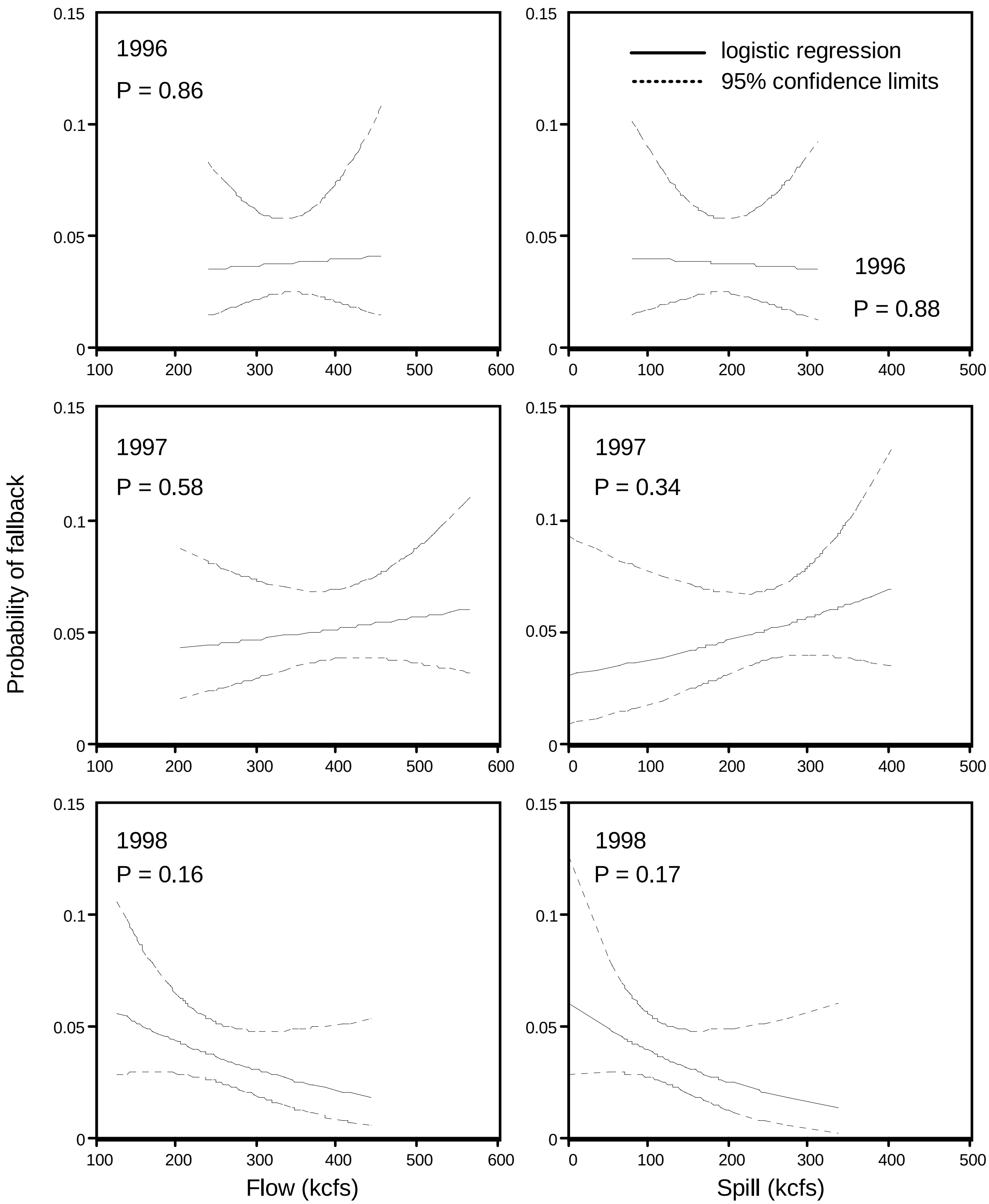

Figure 31. Probability of fallback by chinook salmon within 24 h of passing The Dalles Dam based on mean daily flow and spill in 1996, 1997, and 1998.

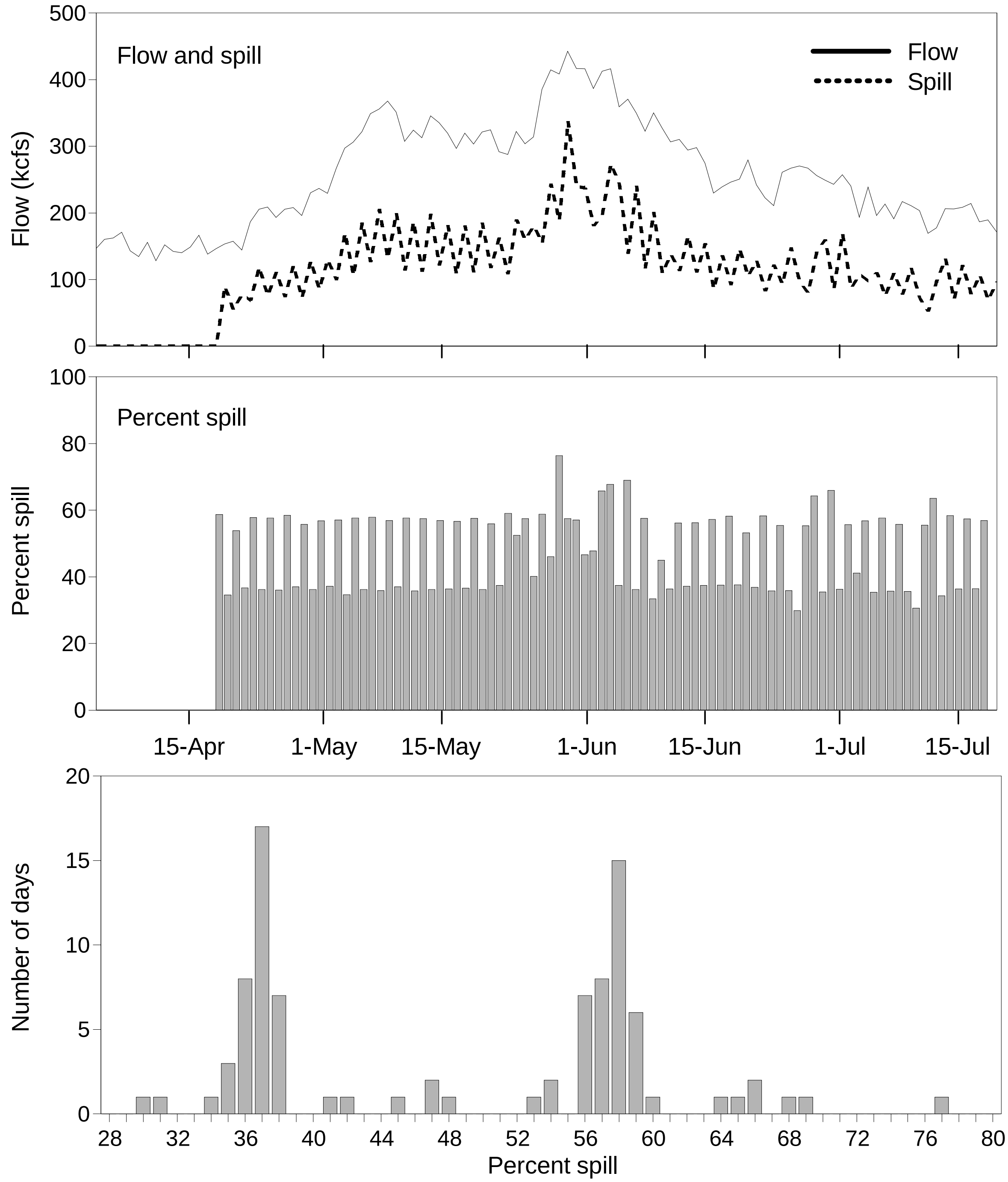

Figure 32. Flow, spill, and percent spill at The Dalles Dam in 1998 while spring and summer chinook salmon with transmitters were passing the dam. Bottom figure is distribution of days at each percent spill level.

passage. When we used the date of fallback instead of the date of passage in comparisons, aggregated fallback ratios were significantly higher at the lower spill level (0.057) than at the higher spill level (0.002) ($P = 0.01$). The latter comparison was also not an ideal test because some fallback fish were included in fallback ratios for days that they did not pass the dam.

Effects of Environmental Factors on Sockeye Salmon Fallbacks - 1997

The first comparison we made was that of daily fallback events by sockeye salmon with transmitters divided by the total count of sockeye salmon passing through the fishways. If the radio-tagged sockeye salmon were representative of the overall run (see Figure 5), then such a ratio would be a measure of the proportion of fish that fell back each day and could be related to environmental variables. With all sockeye data included, the fallback proportion decreased with increased flow and spill (Figure 33). The r^2 values were 0.10 for flow and 0.06 for spill, and negative correlations were driven mainly by a handful of fallback events in August when relatively few fish were passing the dam. We included all fallback events in the analysis, including 18 sockeye salmon (72%) that fell back within 24 h of passage, 3 (12%) that fell back within 5 d, and 4 (12%) that fell back more than 5 d after passing the dam.

We also calculated daily fallback/daily passage ratios for only radio-tagged sockeye salmon. With this method, fallback ratios on individual days ranged widely, particularly on days when few radio-tagged fish passed the dam but one or more fell back. To moderate the ratio variability problem, we calculated daily fallback ratios using the moving 5-d moving average number of fallback events and the number of sockeye salmon with transmitters recorded at the tops of fishways over the same 5 days. We did not include fallback events that occurred more than 24 h after a fish exited from the top of a fishway in the analysis because some fish had migrated upriver, and we believe environmental conditions at the dam at the time of passage were not the primary reason those fish fell back at The Dalles Dam.

Eighteen sockeye salmon with transmitters fell back within 24 h of passage at The Dalles Dam in 1997. Using only these fallback events, the highest ratios of 5-d mean fallback events to 5-d mean passage occurred during early August (Figure 34). However, during that period at the end of the sockeye salmon migration, just 1 fish fell back within 24 h of passage and 5 radio-tagged sockeye salmon passed the dam, producing high ratios for the 5 d. Ratios were generally low from mid-June to mid-July, with a nadir occurring during the first week of July (Figure 34).

Correlations for sockeye salmon were distorted by the single fallback event within 24 h of passage at the end of the migration period when flow, spill, and dissolved gas levels were low and Secchi disk depth visibility was high as well as several fallback ratios of zero during the first portion of the migration when flow, spill, and dissolved gas levels were high and Secchi disk visibility was low (Figure 35). With all

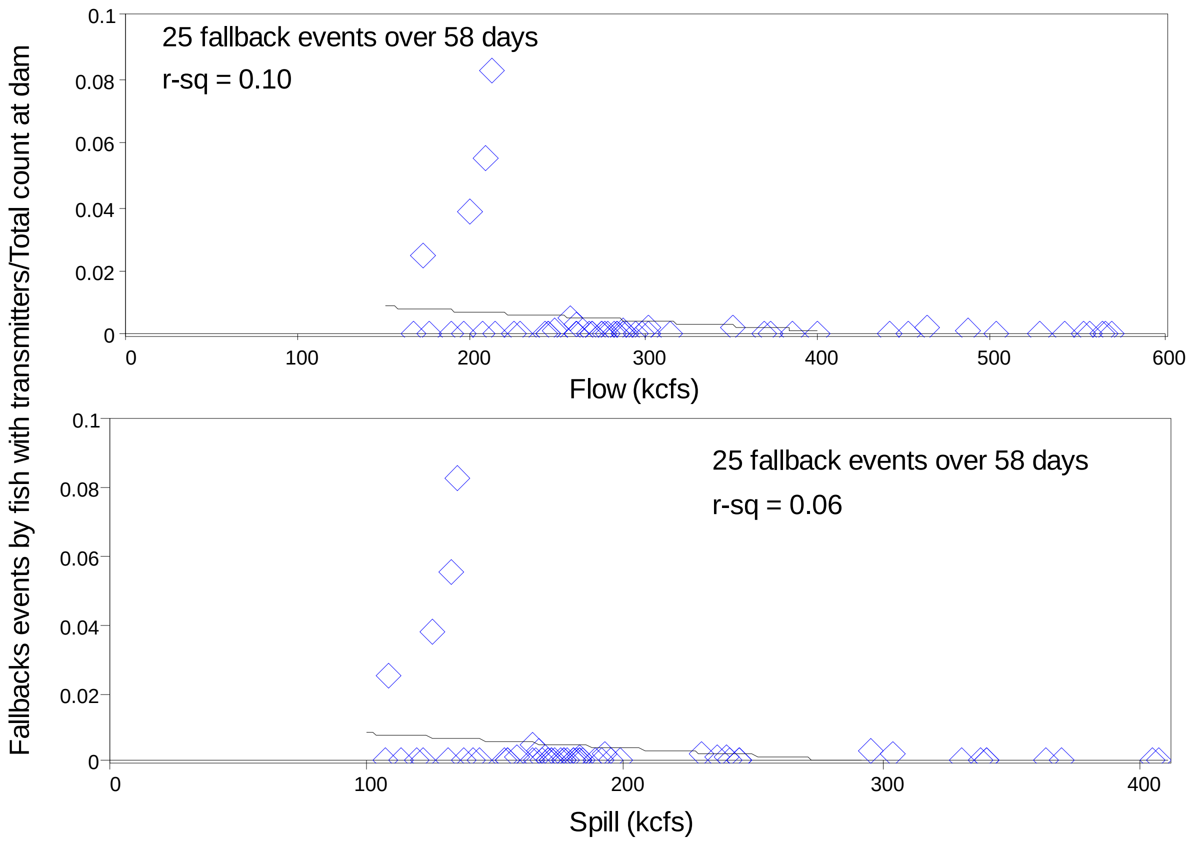

Figure 33. Relation of the ratio (fb_n/c_n) of sockeye salmon with transmitters that fell back (fb_n) divided by the number counted (c_n) each day at The Dalles Dam to daily spill and flow in 1997.

data included, moving average ratio values were negatively correlated with daily flow, spill, and dissolved gas, and positively correlated with Secchi disk visibility between 13 June and 9 August, the period when all radio-tagged sockeye salmon passed The Dalles Dam in 1997 (Figure 35). Approximate r^2 values for all variables were less than 0.07. When we removed the days with outlying fallback ratios early and late in the migration (3.5% of all passages), fallback ratios had strong positive correlations with flow, spill, and dissolved gas and were negatively correlated with Secchi disk visibility (Figure 36). The r^2 values were ~ 0.47 for flow. ~ 0.43 for spill, ~ 0.28 for dissolved gas, and ~ 0.21 Secchi disk visibility.

The relationship between water temperature and the moving-average fallback ratio for sockeye salmon in 1997 was very similar to that we observed for the 1997 chinook salmon data. For all data from 20 June through 4 August,fallback ratios decreased as water temperatures increased from approximately 15^o to 18^o C; fallback ratios increased for about 10 days at temperature between 18^o and 19^o C (Figure 37). Approximately 5% of the radio-tagged sockeye salmon passed The Dalles Dam at temperatures greater than

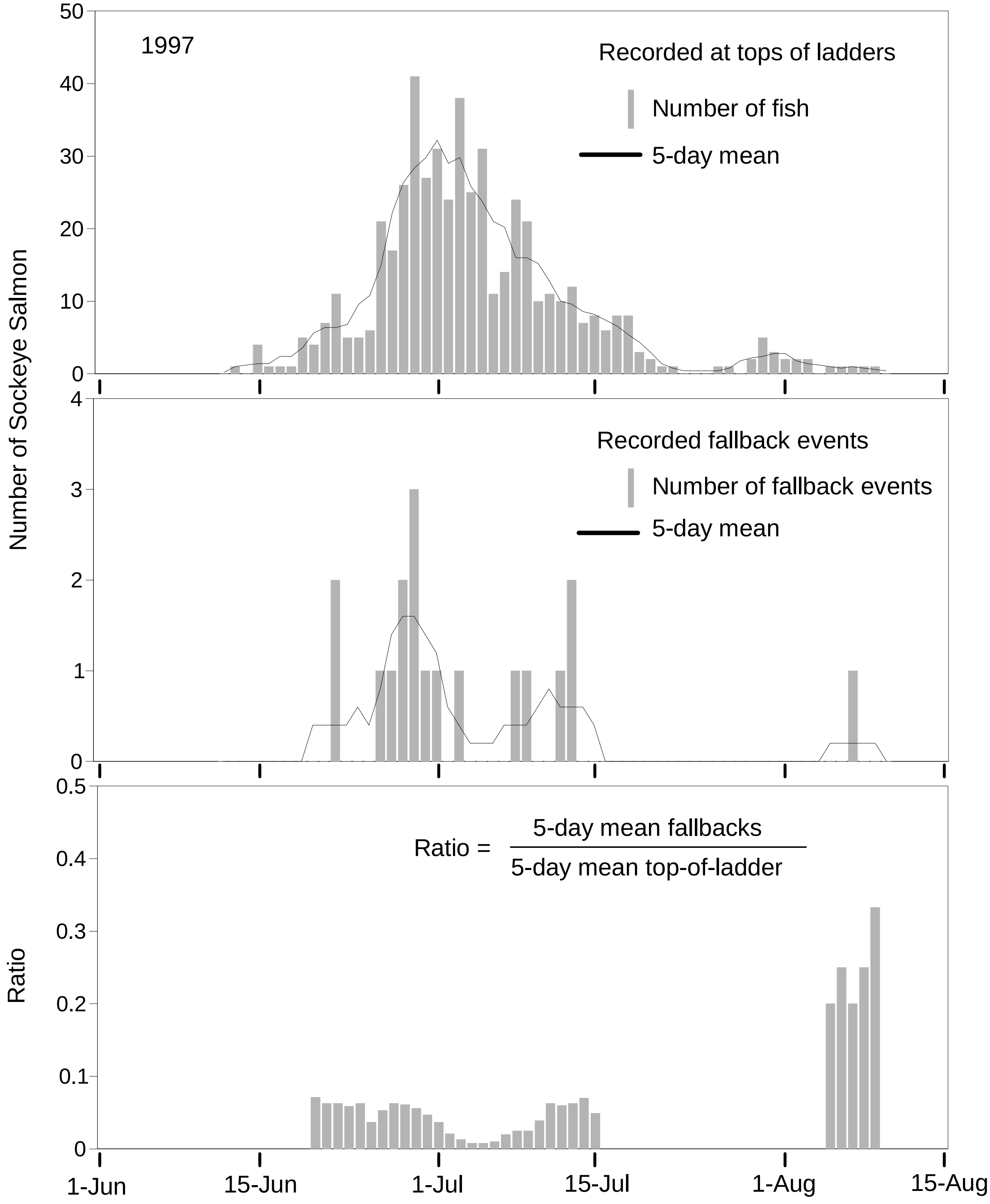

Figure 34. Daily number and 5-d moving average of recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d moving average fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for sockeye salmon with transmitters in 1997.

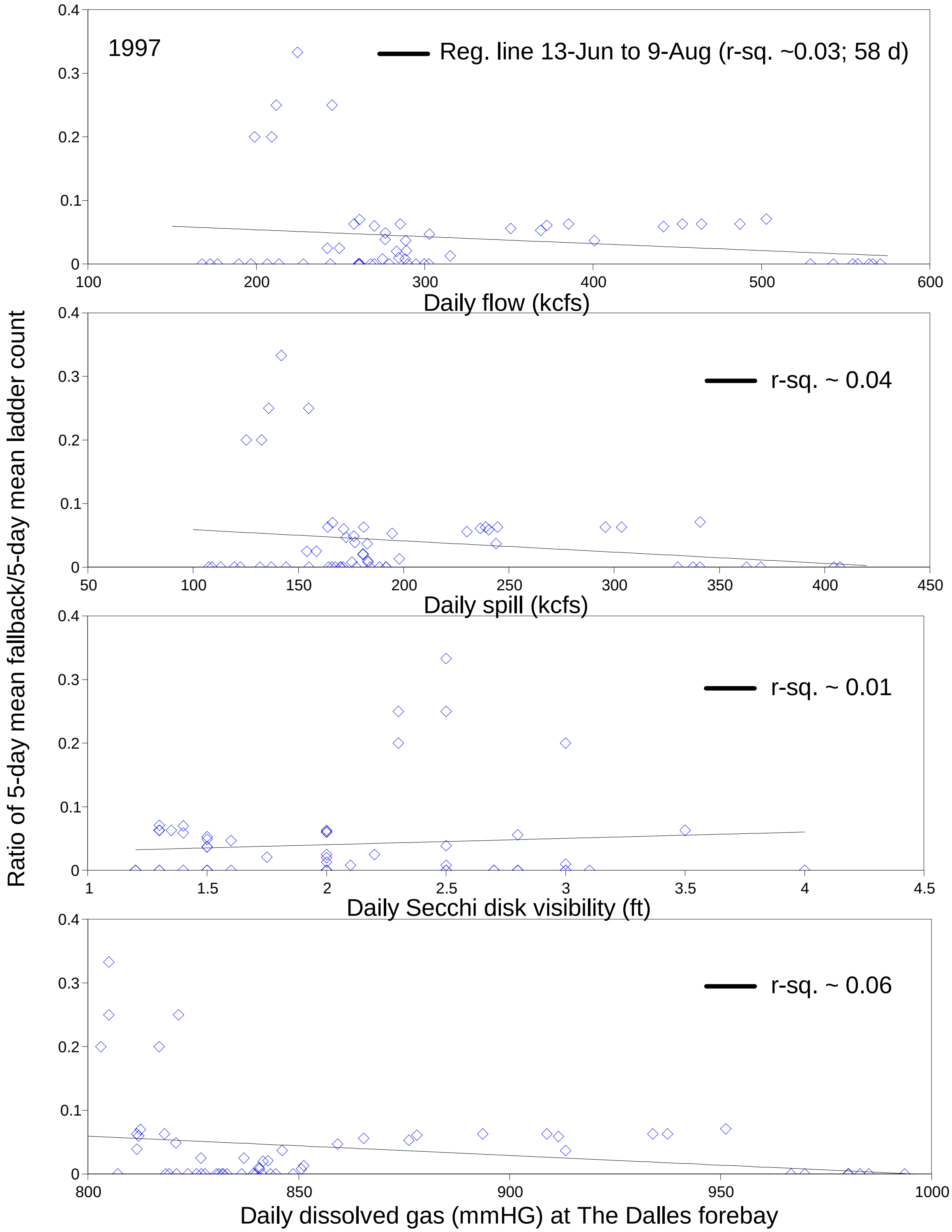

Figure 35. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for sockeye salmon with transmitters at The Dalles Dam in 1997. r-sq values approximate

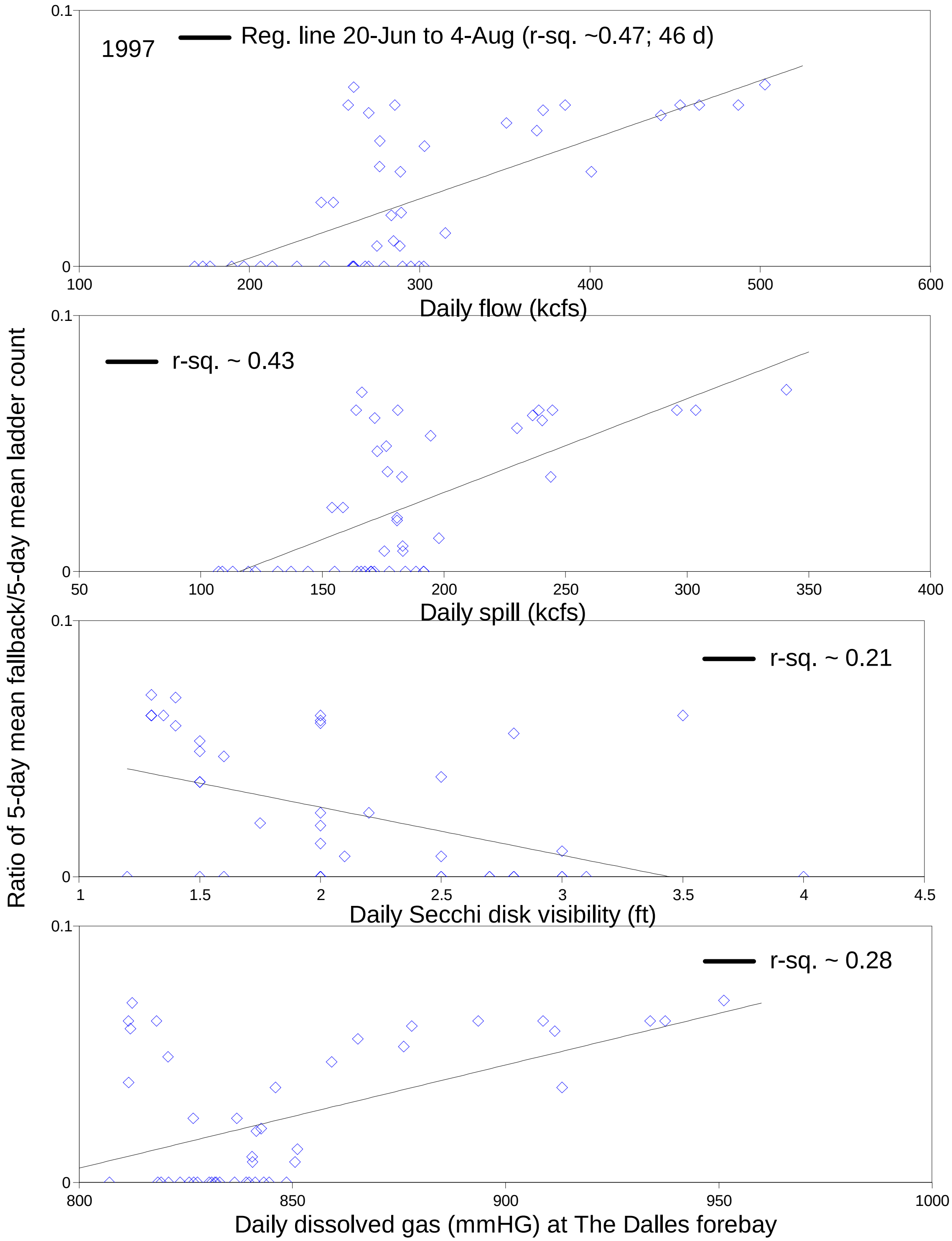

Figure 36. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for sockeye salmon with transmitters at The Dalles Dam from 20 June to 4 August, 1997. r-sq values approximate

19^{o} C, and moving-average ratios during that time were zero. When the fish that passed the dam between 20 June and 4 August were included, the correlation between water temperature and fallback ratios was strongly negative and the r^2 value was ~ 0.56 (Figure 37). From these results, we believe there was evidence that water temperatures above approximately 18^{o} C contributed to increased fallback by sockeye salmon at The Dalles Dam.

As with spring and summer chinook salmon we also used passage of sockeye salmon with transmitters and fallbacks within 24 h of passing The Dalles Dam, grouped the data in consecutive 5-d blocks, and calculated fallback ratios and mean values for the independent variables for each block. With this method, each fallback event affected only the ratio for the block in which it occurred. Consecutive 5-d blocks had dissimilar numbers of fish in each block and we ran analyses on the five possible block sequences over the date range that radio-tagged sockeye salmon were passing The Dalles Dam. Sequences started on consecutive days, and each had 9 to 10 blocks. We only used data between 20 June and 4 August (96.5% o fall passages) for the reasons described above.

Using the first sequence start date, which we believed was representative, fallback ratios were positively correlated with flow and spill (r^2 ~ 0.49; P ~ 0.04), and negatively correlated (r^2 ~ 0.20; P > 0.15) with Secchi visibility. Water temperature was also negatively correlated with fallback ratios, with r^2 = 0.60 (P = 0.01) for the unweighted model and r^2 = 0.38 (P = 0.08) for the weighted model. Logistic regression models that used maximum likelihood methods to account for variability in both the number of fallback events and the number of fish in each block produced similar results. However, 5-d blocks had widely divergent numbers of fish per block, ranging from ~ 4 fish to > 140 fish (std = 48 fish), and we believe grouping by days was therefore less appropriate for sockeye salmon than for spring and summer chinook salmon.

In another method, we grouped passage by sockeye salmon during consecutive days until at least 25 fish with transmitters had passed the dam. From 20 June to 4 August, this produced 15 bins, with an average of 31 fish/bin (median of 31 fish; std = 6). We then calculated mean flow, spill, Secchi disk visibility, and a fallback ratio for each bin, and tested logistic, weighted and unweighted linear regression models. Because there was relatively low variability in the number of fish/bin, weighting had limited impact on results. As with any grouping method, some variability and sensitivity was lost among independent variables by taking mean bin values.

Fallback ratios for variable-day bins were positively correlated with flow, spill, and dissolved gas, and negatively correlated with water temperature; we found almost no correlation with Secchi disk visibility (Figure 38). Weighted and unweighted r^2 values were 0.20 (P = 0.10) for flow and ~ 0.24 (P ~ 0.06) for spill with ratios increasing as flow and spill increased; logistic regressions using maximum likelihood methods produced similar trends with P = 0.13 for flow and P = 0.09 for spill. Models were less significant for dissolved gas, with P ~ 0.22 for the linear models and P = 0.25

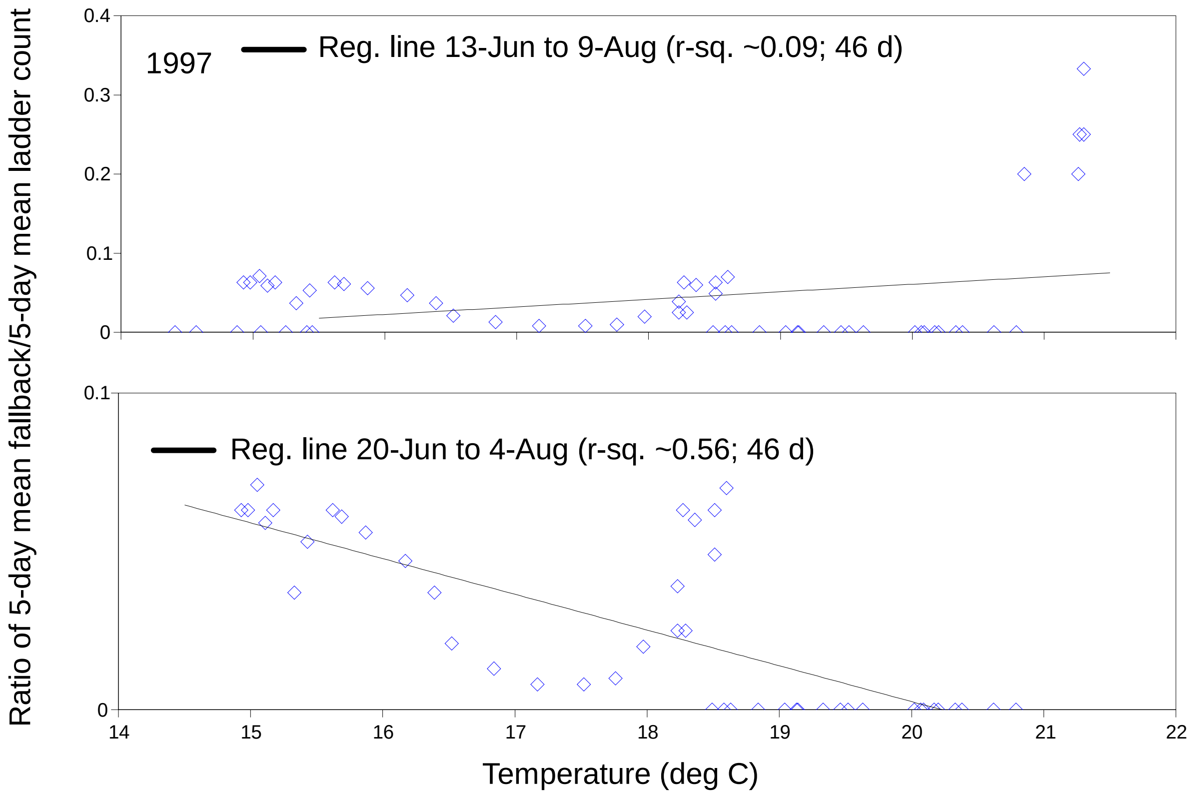

Figure 37. Regressions of daily mean water tenperature with 5-d moving average fallback ratios for sockeye salmon with transmitters at The Dalles Dam in 1997. r-sq values approximate

for the logistic model. No models were significant for Secchi visibility (P > 0.70). Fallback ratios decreased with water temperature, with r^2 values of ~ 0.12 (P ~ 0.22) for the linear models and P = 0.23 for the logistic model (Figure 38).

As with spring and summer chinook salmon, we grouped sockeye salmon by daily flow and spill conditions and calculated fallback ratios for each group. Given the wide range of flow and spill conditions and the relatively small number of fallbacks within 24 h of passage, variance in the number of fish/group and in ratio values was high.

In 1997, flow at The Dalles Dam during the passage of radio-tagged sockeye salmon ranged from about 160 kcfs to more than 570 kcfs. We grouped sockeye salmon based on mean daily flow increments of 10 kcfs. The 28 groups with fish (Table 13) had a mean of 17 sockeye salmon per group (median of 7); 86% of all passages occurred with mean daily flow between 240 and 390 kcfs. Fifty-three percent of 511 known-date

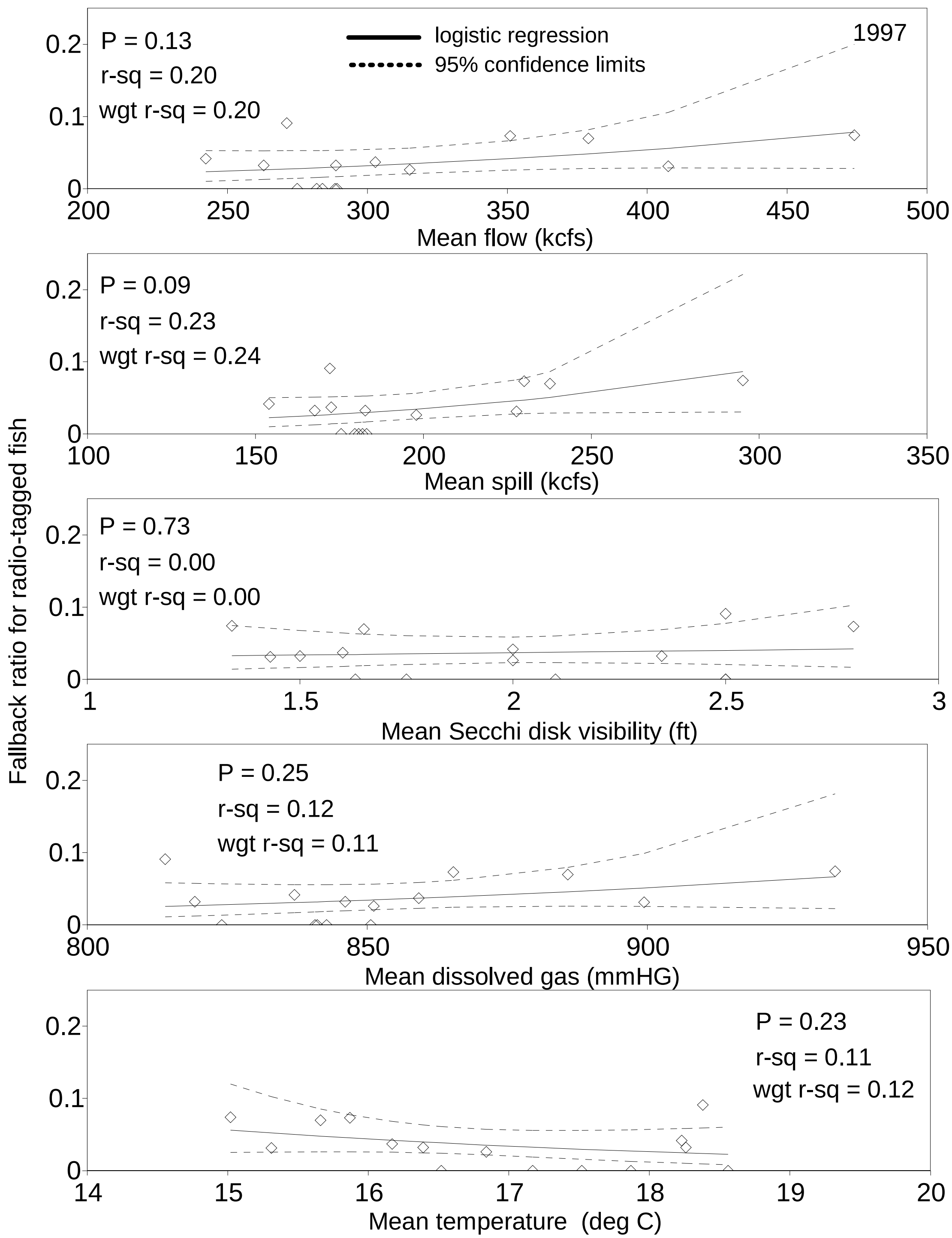

Figure 38. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of sockeye salmon fallbacks within 24 h at The Dalles Dam in 1997; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width time bins that included at least 25 fish.

passages of sockeye salmon at The Dalles Dam occurred at flows less than 290 kcfs, for which the aggregated fallback ratio was 0.026. Of all passages by radio-tagged sockeye salmon at The Dalles Dam, 240 (47%) occurred at flows greater than 290 kcfs. The aggregated fallback ratio for all passages when flows were 290 kcfs or more was 0.046.

Spill at The Dalles Dam during the passage of radio-tagged sockeye salmon in 1997 ranged from about 100 to 400 kcfs; 91% of the fish passed when mean daily spill was between 150 and 300 kcfs. Using 10-kcfs increments, 18 groups with fish were formed that had a mean of 28 fish per group (median of 8). As with flow at The Dalles Dam, we observed an increase in fallback ratios with increased spill (Table 13). For 306 (60%) passages by sockeye salmon when spill was less than 190 kcfs, 8 fallback events were recorded and the aggregated fallback ratio was 0.026. For 205 (40%) passages that occurred at spill of more than 190 kcfs the aggregated fallback ratio was 0.049 (Table 13).

Unweighted regression models using all groups and based on flow and spill were not significant ($P > 0.70$) with fallback ratio as the dependent value. Models weighted for the number of passages past the dam were also non-significant ($P > 0.50$). When we removed groups with fallback ratios equal to zero (16% of all passages for flow groups; 10% of all passages for spill groups), P values dropped, but no weighted or unweighted models were significant ($P > 0.15$).

We also created a binary data set that included every known-date passage of The Dalles Dam by sockeye salmon with transmitters in 1997. Fish that fell back within 24 h of passage were coded ‘1,’ and fish that did not fall back within 24 h were coded ‘0.’ We then tested whether fish that fell back passed the dam under significantly different environmental conditions than those that did not fall back. There were 494 known passages by sockeye salmon at The Dalles Dam between 20 June and 4 August, 1997. Following passage, 17 fell back within 24 h and 477 did not (Table 11). Although flow, spill, and dissolved gas levels were higher for fish that fell back within 24 h, differences were not significant at $P < 0.05$ for fish that fell back than for fish that did not fall back. Logistic regression models of the binary data set were also not significant.

Effects of Environmental Factors on Steelhead Fallbacks - 1996 and 1997

We limited fallback analyses related to environmental conditions for steelhead tagged in 1996 and 1997 primarily because relatively few steelhead fell back in either year, and only 8 fish in 1996 and 14 in 1997 fell back within 24 h of passage. In addition, about 60% of the steelhead tagged in 1996 that passed The Dalles Dam passed during the period of no spill that began on 5 September. For steelhead tagged in 1997, almost 80% of the tagged fish that passed the dam did so after 1 September when there was no spill. We also stopped radio-tagging steelhead at Bonneville Dam for almost 2 weeks in late July/early August when river temperatures exceeded 21 C in 1996, and for one week in July, 1997 due to high water temperatures. Interruptions in tagging created discontinuity in sampling and data collection.

Table 13. Known passages (past dam), fallbacks within 24 h of passage of the dam (24 h FB), and fallback ratios (FB/ recorded passages) by flow and spill at The Dalles Dam for sockeye salmon (SK) in 1997.

Sockeye Vs flow				Sockeye Vs spill			
Flow groups (kcfs)	Past dam	24 h FB	FB ratio	Spill groups (kcfs)	Past dam	24 h FB	FB ratio
160-169	2	0	0.00	100-109	4	0	0.00
170-179	2	0	0.00	110-119	3	0	0.00
180-189	3	0	0.00	120-129	3	0	0.00
190-199	3	0	0.00	130-139	8	1	0.13
200-209	6	1	0.17	140-149	3	0	0.00
210-219	2	0	0.00	150-159	46	2	0.04
220-229	3	0	0.00	160-169	21	2	0.10
230-239	--	--	--	170-179	83	2	0.02
240-249	46	2	0.04	180-189	135	1	0.01
250-259	12	2	0.17	190-199	70	2	0.03
260-269	10	0	0.00	200-209	--	--	--
270-279	55	1	0.02	210-219	--	--	--
280-289	127	1	0.01	220-229	--	--	--
290-299	16	0	0.00	230-239	84	6	0.07
300-309	30	1	0.03	240-249	16	0	0.00
310-319	38	1	0.03	250-259	--	--	--
320-329	--	--	--	260-269	--	--	--
330-339	--	--	--	270-279	--	--	--
340-349	--	--	--	280-289	--	--	--
350-359	41	3	0.07	290-299	11	2	0.18
360-369	21	1	0.05	300-309	7	0	0.00
370-379	26	2	0.08	310-319	--	--	--
380-389	17	1	0.06	320-329	--	--	--
390-399	--	--	--	330-339	6	0	0.00
400-409	6	0	0.00	340-349	5	0	0.00
410-419	--	--	--	350-359	--	--	--
420-429	--	--	--	360-369	1	0	0.00
430-439	--	--	--	370-379	--	--	--
440-449	5	0	0.00	380-389	--	--	--
450-459	5	0	0.00	390-399	--	--	--
460-469	11	2	0.18	400-409	5	0	0.00
470-479	--	--	--				
480-489	7	0	0.00				
490-499	--	--	--				
500-509	4	0	0.00				
510-519	--	--	--				
520-529	5	0	0.00				
530-539	--	--	--				
540-549	1	0	0.00				
>550	7	0	0.00				

* lines indicate midpoint of passage counts for radio-tagged sockeye salmon.

Steelhead were recorded falling back at The Dalles Dam throughout the steelhead migrations, with 63% of all fallback events in 1996 and 56% in 1997 before 1 November (Figure 39). Although we were not able to determine the exact time of all fallback events, we estimated that 45% of all fallbacks and 50% of fallback events within 24 h in 1996 occurred during spill. In 1997, we estimate that 23% of all fallback events and 43% of events within 24 h occurred during spill (Figure 39).

As with spring and summer chinook salmon and sockeye salmon, we calculated the 5-d moving average number of fallback events over 5 days and the number of steelhead with transmitters recorded at the tops of fishways over the same 5 days. Fallback events that occurred more than 24 h after a fish exited from the top of a fishway were not included in the analysis. We present this information to give a qualitative view of fallbacks at The Dalles Dam by steelhead. (See Bjornn et al., 2001 for complete migration history for steelhead tagged in 1996.)

In 1996, 8 steelhead with transmitters fell back within 24 h of passage at The Dalles Dam. Because sample size was small, we observed no clear patterns in the fallback ratios based on 5-d moving averages (Figure 40). Ratios were slightly higher late in October, but were inflated because one steelhead fell back within 24 h during that time when few fish with transmitters were passing the dam. Flows decreased from July through October, spill decreased until 1 September then ceased until spring, 1997. Water temperatures peaked in September, then decreased and Secchi disk visibility increased gradually during the fall and winter period of steelhead migration. We found little compelling evidence that environmental conditions other than spill at The Dalles Dam affected fallbacks within 24 h of passage in 1996.

Fourteen steelhead outfitted with transmitters in 1997 fell back within 24 h of passage at The Dalles Dam (12 fish before 31 October). As for the 1996-1997 run-year, the moving-average analysis was limited by small sample size. Peak fallback ratios occurred in July, and again in late October/early November when relatively few steelhead with transmitters were passing the dam (Figure 41). Six steelhead fell back within 24 h in July while there was spill at the dam as well as relatively low Secchi disk visibility, but correlations with fallback ratios were weak (approximate r^2 values < 0.05).

We also created a binary data set that included every known-date passage of The Dalles Dam by steelhead outfitted with transmitters in both 1996 and 1997. Fish that fell back within 24 h of passage were coded ‘1,’ and fish that did not fall back within 24 h were coded ‘0.’ We then tested whether fish that fell back passed the dam under significantly different environmental conditions than those that did not fall back. Again, tests were limited by the small number of steelhead that fell back within 24 h in each year. There were 615 known passages by steelhead at The Dalles Dam by fish tagged in 1996. Following passage, 8 fell back within 24 h and 607 did not (Table 11). We found no significant differences in flow, spill, Secchi visibility, or water temperature for fish that fell back within 24 h ($P > 0.45$). Sixteen fish fell back within 5 d of passage. Flow on the date of passage was 193 kcfs for fish that fell back and 158 for fish that did not fall back, a difference that was significant ($P = 0.007$). Spill was also higher on the date of passage for fish that fell back within 5 d (74 kcfs) than for fish that did not fall back (44 kcfs), and the difference neared significance ($P = 0.06$). We found no significant differences in water temperature ($P = 0.08$) or Secchi visibility ($P = 0.78$).

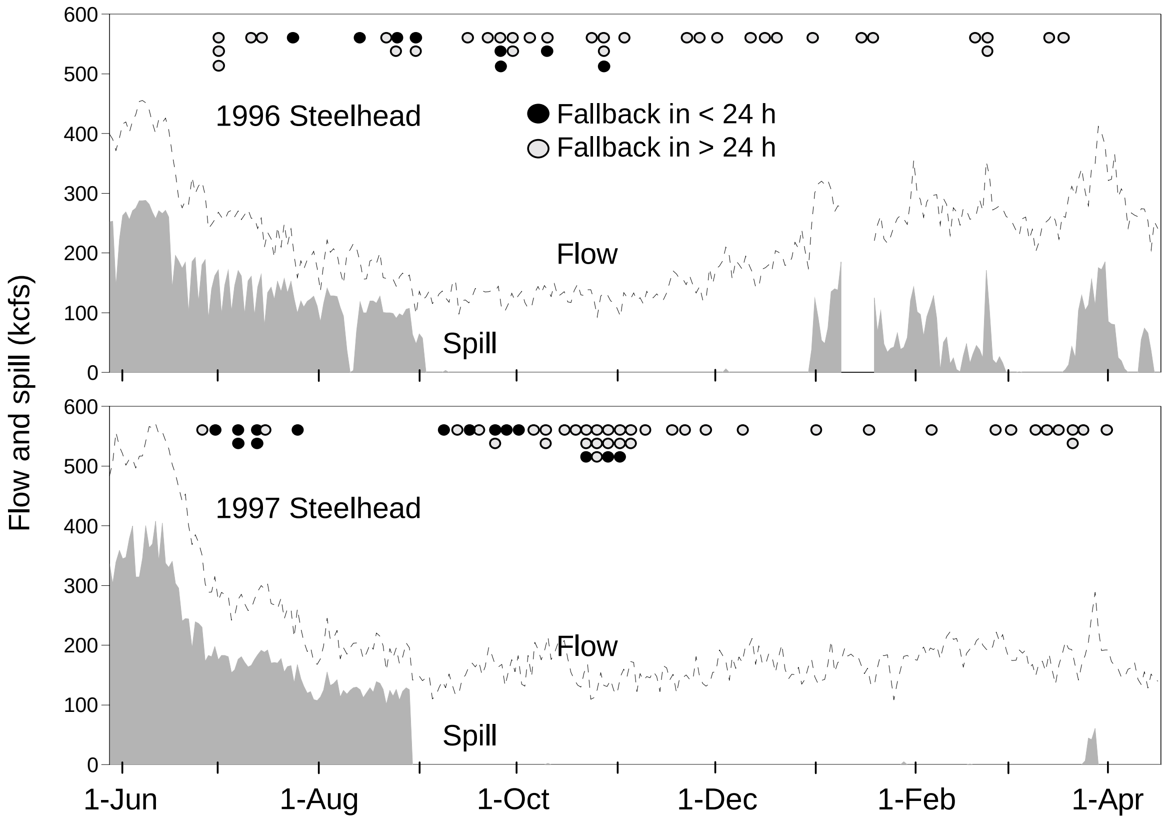

Figure 39. Flow, spill, and distribution of fallback events by steelhead with transmitters at The Dalles Dam in the run-years 1996-1997 and 1997-1998.

There were 718 known passages by steelhead tagged in 1997. Following passage, 14 fell back within 24 h and 704 did not (Table 11). Spill was significantly higher at the time of passage for fish that fell back (110 kcfs) than for fish that did not fall back (59 kcfs) (P = 0.03). Flow was also higher for fish that fell back (196 kcfs) than for fish that did not fall back (177 kcfs), but the difference was not significant (P = 0.17). We had insufficient Secchi visibility, dissolved gas, and temperature data for meaningful comparisons in 1997-1998 (Table 11). Twenty-two fish fell back within 5 d of passage (Table 12). Flow on the date of passage was 204 kcfs for fish that fell back and 177 for fish that did not fall back, a difference that was significant (P = 0.02). Spill was also significantly higher on the date of passage for fish that fell back within 5 d (71 kcfs) than for fish that did not fall back (32 kcfs) (P = 0.01).

Effects of Environmental Factors on Fall Chinook Salmon Fallbacks - 1998

We limited fallback analyses related to environmental conditions for fall chinook salmon tagged in 1998 primarily because we did not sample from the August portion of the run while spill was occurring, because environmental data was limited, and because only 9 fish fell back within 24 h of passage. All radio-tagged fish passed

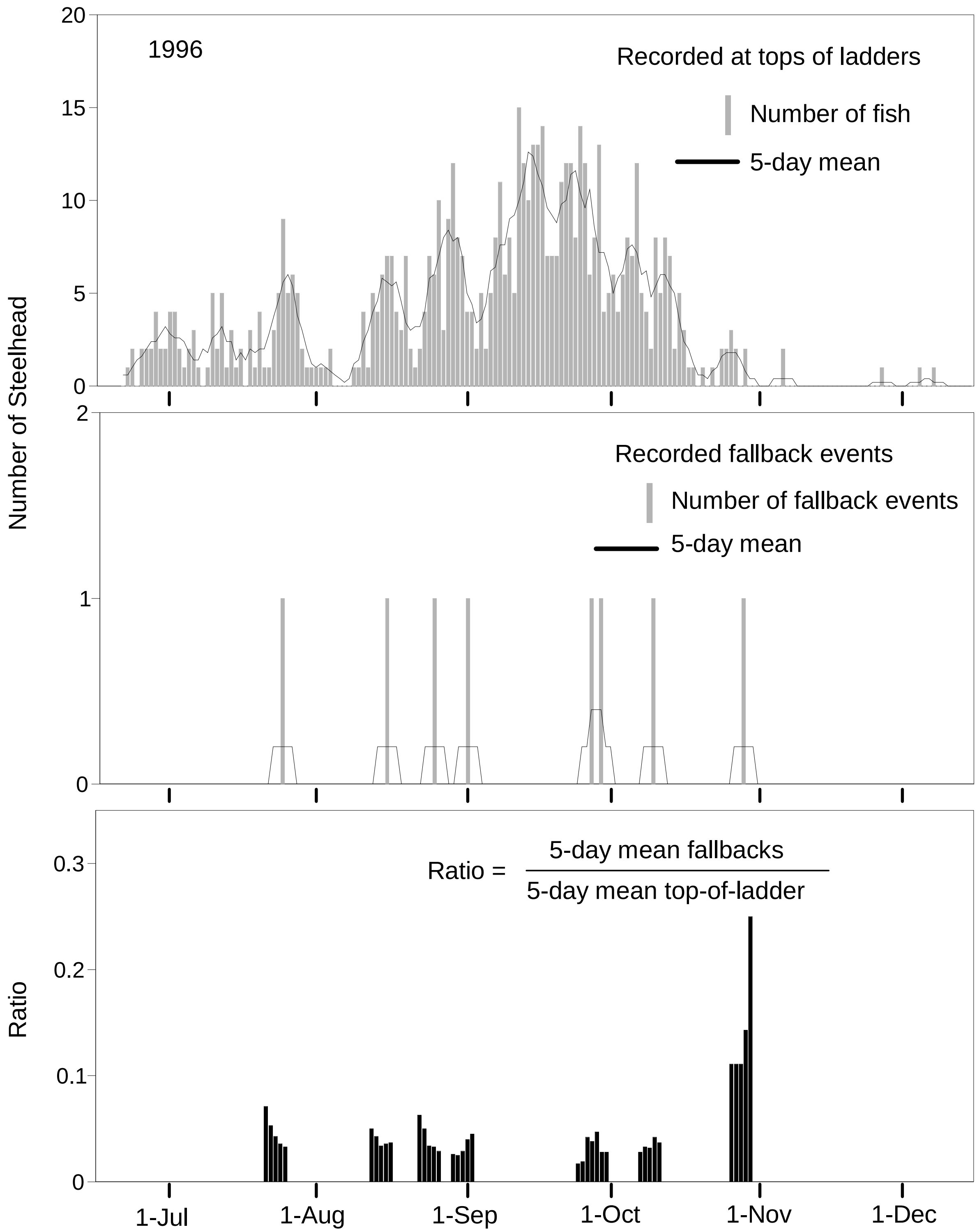

Figure 40. Daily number and 5-d moving average of recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for steelhead outfitted with transmitters in 1996.

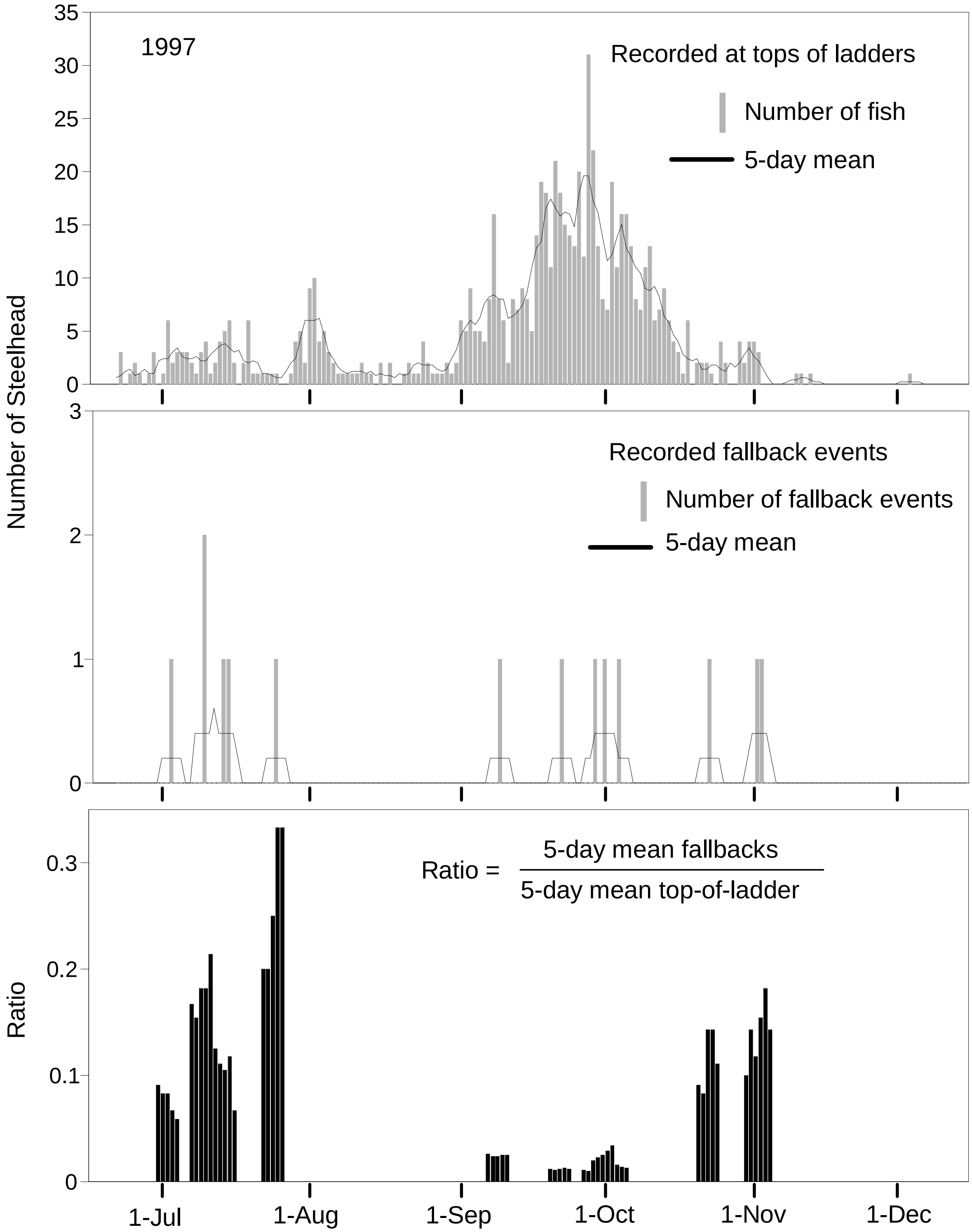

Figure 41. Daily number and 5-d moving average of recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for steelhead outfitted with transmitters in 1997.

The Dalles Dam after 1 September, during the period of no spill.

Fall chinook salmon were recorded falling back at The Dalles Dam starting in the second week of September and in every week of the migration thereafter (Figure 42). A relatively high number of fallback events occurred in October after the number of radio- tagged fish passing the dam decreased.

As with other species, we calculated the 5-d moving average number of fallback events over 5 days and the number of fall chinook salmon with transmitters recorded at the tops of fishways over the same 5 days. Fallback events that occurred more than 24 h after a fish exited from the top of a fishway were not included in the analysis. We present this information to give a qualitative view of fallbacks at The Dalles Dam by fall chinook salmon tagged in 1998.

Nine fall chinook salmon with transmitters fell back within 24 h of passage at The Dalles Dam in 1998. We observed no clear patterns in the fallback ratios based on 5-d moving averages (Figure 43). Ratios spiked late in October, but were inflated because only one fall chinook salmon fell back within 24 h during that time when few fish with transmitters were passing the dam. When we excluded the late fallback event, fallback ratios were positively correlated with flow at the dam with an approximate r^2 of 0.17, and were positively correlated with water temperature ($r^2 \sim 0.11$).

Thirty-five fall chinook salmon fell back within 5 d of passage at The Dalles Dam. A moving-average analysis similar to that for fallbacks within 24 h showed increasing fallback ratios through October, with a similar spike in ratios due to one fallback event at the end of the migration (Figure 44). Excluding the last event, fallback ratios had a weak negative correlation with flow ($r^2 \sim 0.05$) and a strong negative correlation with water temperature ($r^2 \sim 0.56$).

We also created a binary data set that included every known-date passage of The Dalles Dam by fall chinook salmon with transmitters in 1998. Fish that fell back within 24 h of passage were coded '1,' and fish that did not fall back within 24 h were coded '0.' We then tested whether fish that fell back passed the dam under significantly different environmental conditions than those that did not fall back. Tests were limited by the small number of fall chinook salmon that fell back within 24 h in each year. There were 651 known passages by fall chinook salmon at The Dalles Dam by fish tagged in 1998. Following passage, 9 fell back within 24 h and 642 did not (Table 11). We found no significant differences in flow, spill, Secchi visibility, or water temperature for fish that fell back within 24 h ($P > 0.35$). Thirty-five fish fell back within 5 d of passage. We found little difference in flow, spill, Secchi visibility, or water temperature for on the date of passage for fish that fell back ($P > 0.30$) (Table 12).

Multiple Regression Analyses: Environmental Variables and Fallback Ratios

We ran stepwise regression models for spring and summer chinook salmon and sockeye salmon using fallback ratio

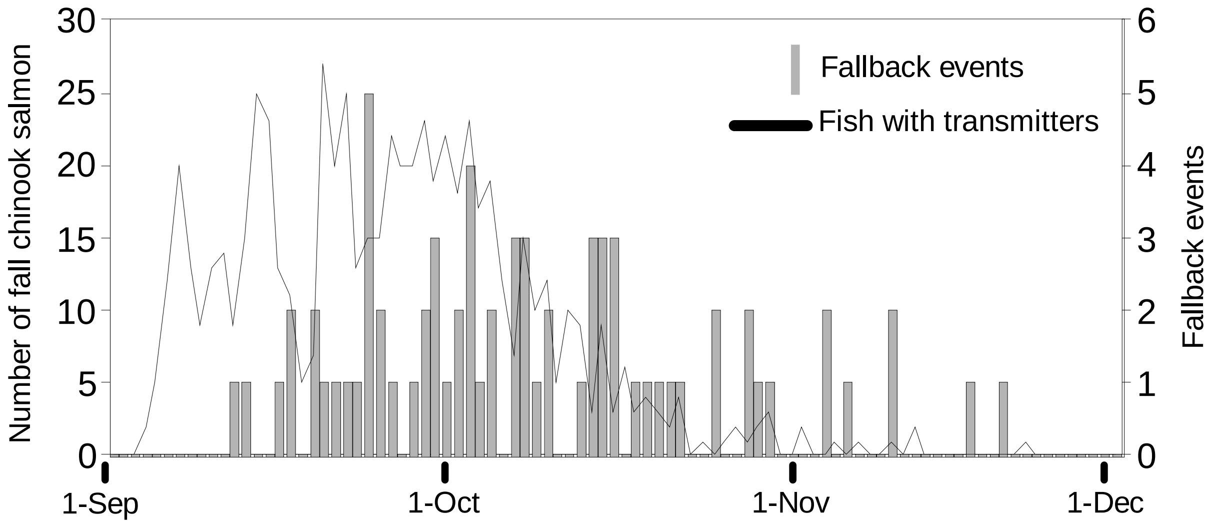

Figure 42. Number of fall chinook salmon with transmitters recorded passing The Dalles Dam in 1998, and the number of fish that fell back at the dam; date of fallback event is shown, not date of passage.

data from the variable-day-bin and 5-d block methods described previously. Although there was considerable covariance among some environmental variables related to fallback of radio-tagged fish at The Dalles Dam, we initially included flow, spill, Secchi disk visibility, dissolved gas levels, and water temperature, a surrogate for passage date, as independent variables in all models.

During the 1996 spring and summer chinook salmon migration, flow, spill, and dissolved gas were highly correlated ($r > 0.72$) (Figure 45). Secchi disk visibility was weakly correlated with other variables ($r < 0.26$). Water temperatures had a parabolic relationship with flow and spill: peak flow and spill were coincident with intermediate temperatures, while peak temperatures late in the migration and low temperatures early in the season were associated with lower flow and spill conditions (Figure 45).

With all 1996 variables in the first stepwise regression model, and spring and summer chinook salmon fallback ratios from the variable-day-bin method as the dependent variable, Secchi disk depth was the first and only variable selected with an r^2 value of 0.43 (Table 14). When we used the fallback ratios from the consecutive 5-d-block method as the dependent variable, Secchi depth was again the first and only variable selected ($r^2 = 0.22$) (Table 14). In both models, no additional variables met the 0.10 significance level for inclusion in the stepwise models. When we removed Secchi visibility from the models, no variables were selected.

We tested multiple regression models on two versions of the 1997 spring and

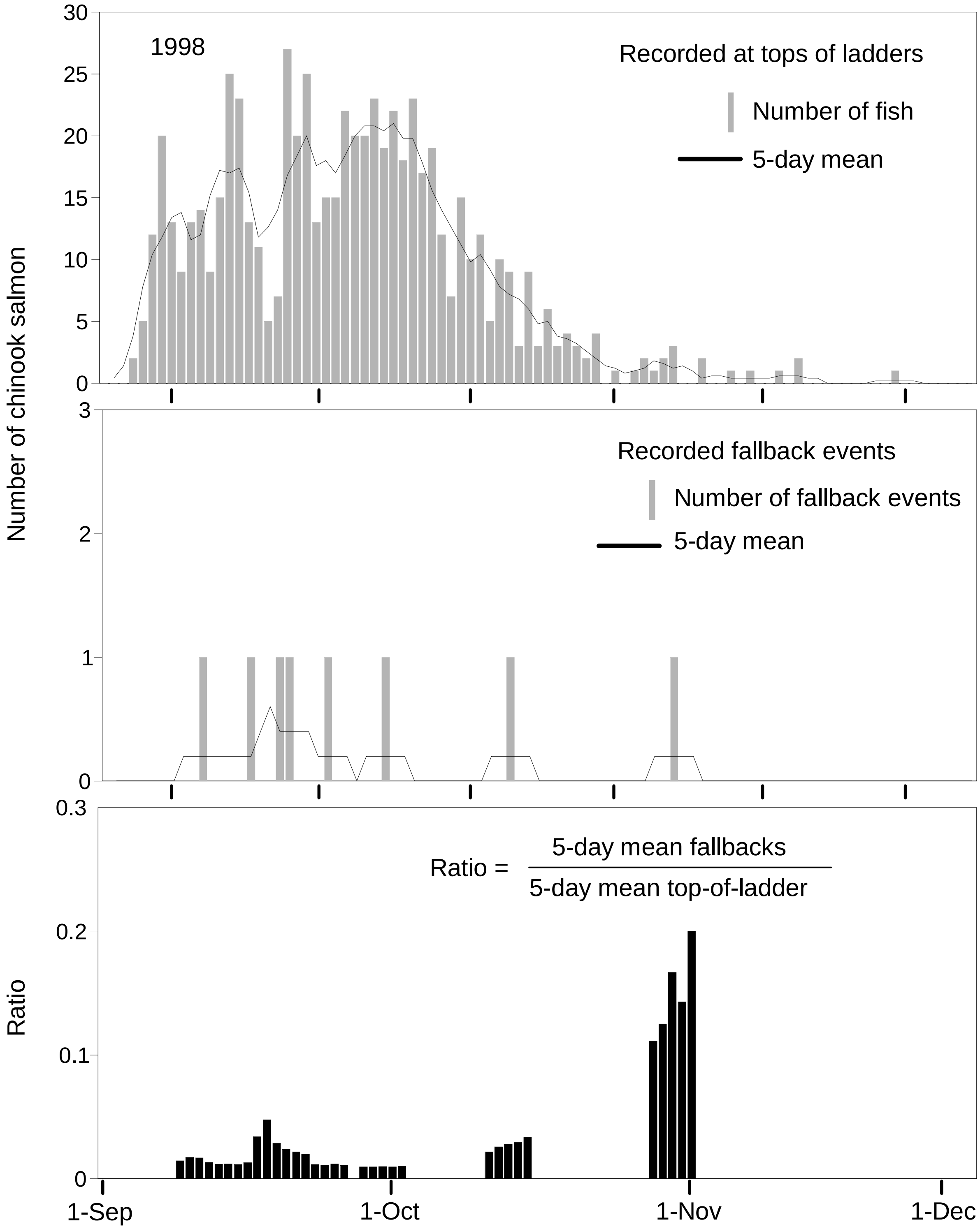

Figure 43. Daily number and 5-d moving average of recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for fall chinook salmon outfitted with transmitters in 1998.

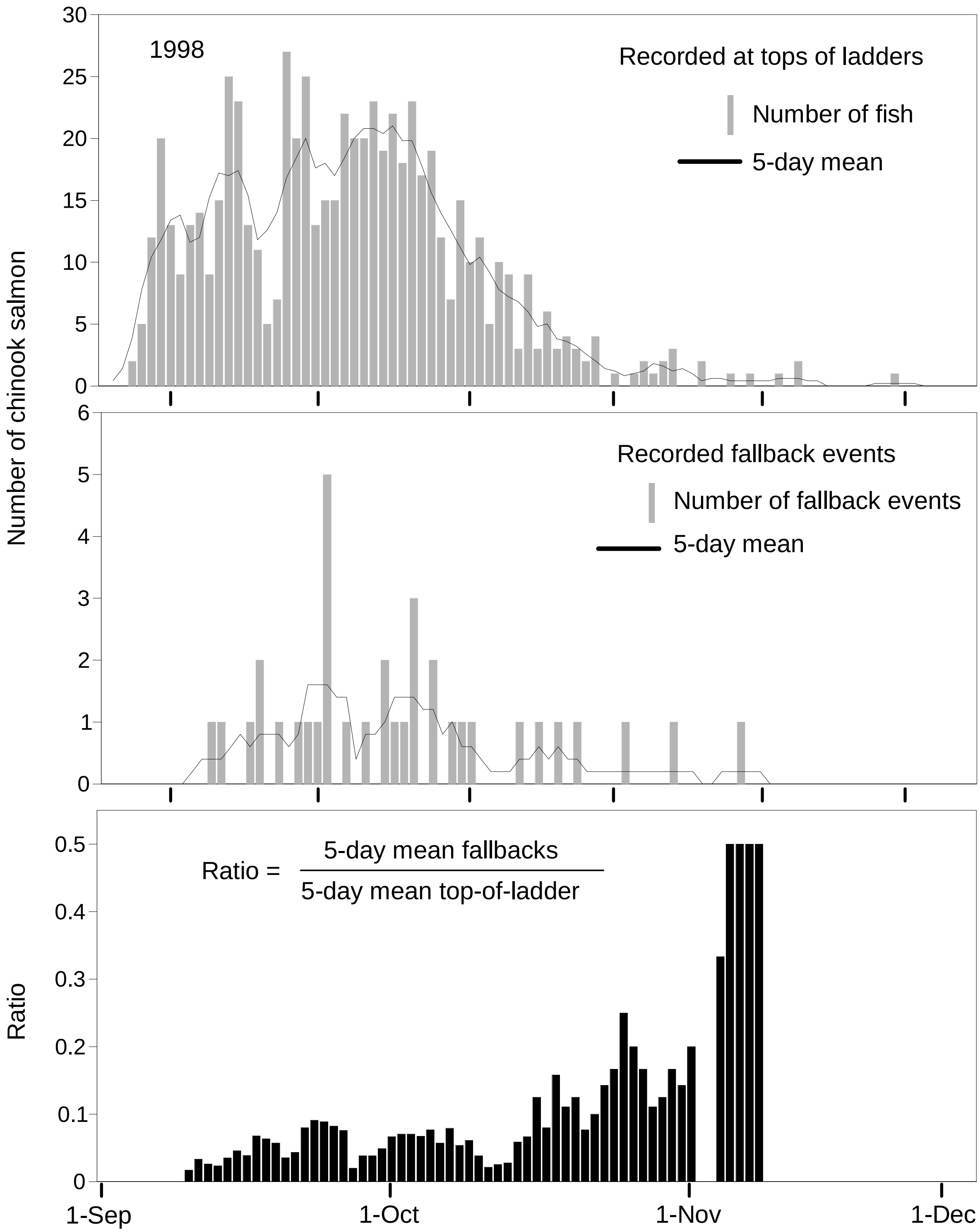

Figure 44. Daily number and 5-d moving average of recorded passages at tops of the fishways at The Dalles Dam, daily number and 5-d mean fallbacks within 5 d of passage, and the 5-d moving average ratio of fallbacks to passages for fall chinook salmon outfitted with transmitters in 1998.

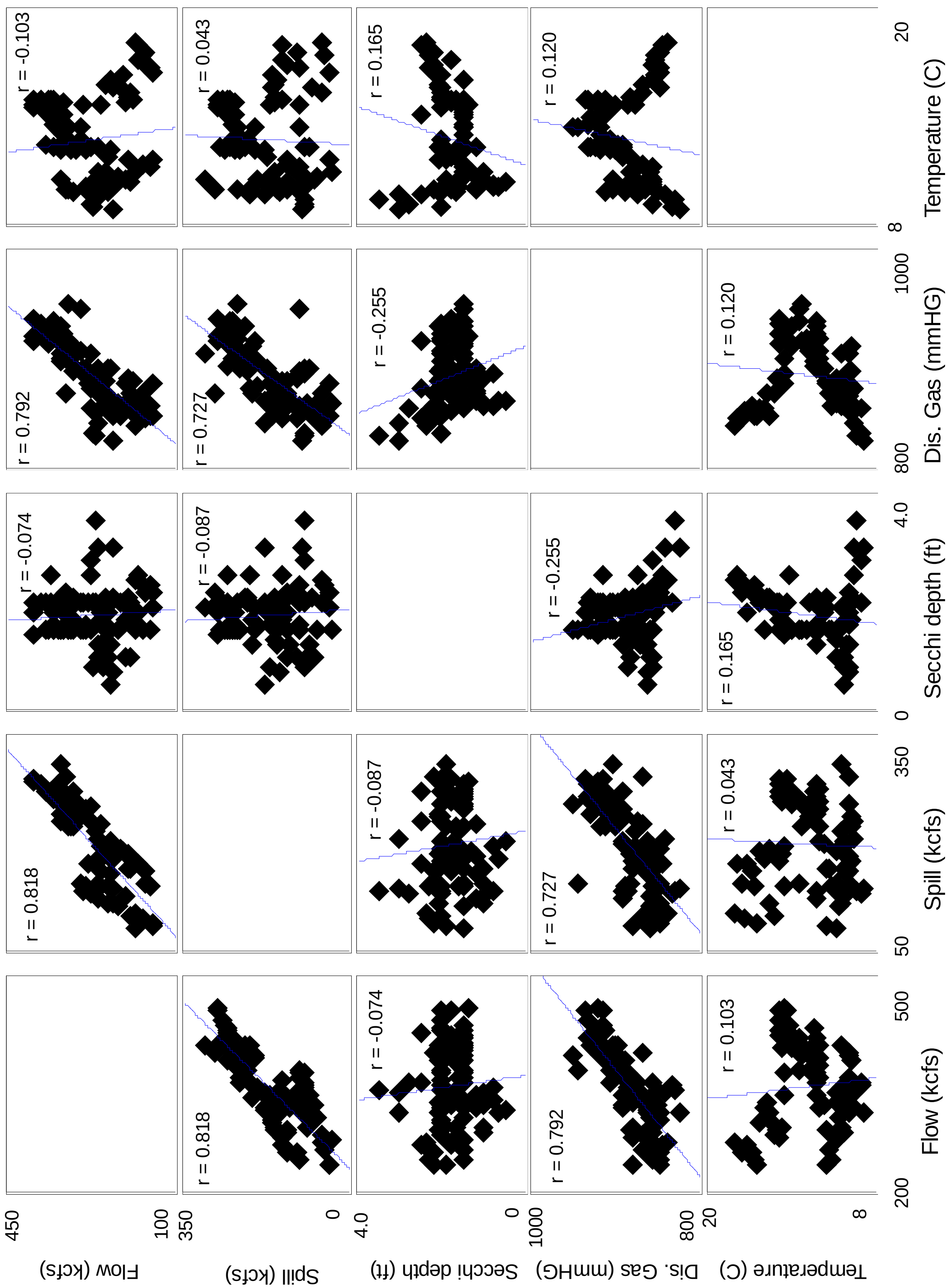

Figure 45. Scatter plots and correlation coefficients for environmental variables used in multiple regression models, based on daily mean values during the spring and summer chinook salmon migration in 1996.

Table 14. Stepwise multiple regression model outputs for 1996 including models run, variables retained, and standard procedure outputs. All models have spring and summer chinook salmon fallback ratios as the dependent variable.

Models run	Variables retained	Variables removed	r^2	Partial r^2	F	Prob. > F
Model 1, Variable-day-bin model with all variables included from 10 April to 4 July						
	a. Secchi disk visibility		0.4297	0.4297	12.06	0.0031
Model 2, Consecutive 5-d block model with all variables included from 10 April to 3 July						
	a. Secchi disk visibility		0.2211	0.2211	4.26	0.0568

summer chinook salmon fallback data at The Dalles Dam. The first set included the entire range of dates that chinook salmon with transmitters were passing the dam (9 April to 25 July); the second set included about 76% of all passages (9 April to 2 July) and did not include the tail end of the migration when ratio values appeared to be distorted by a small number of fallback events and few tagged fish passing the dam.

Over the entire date range, flow, spill, and dissolved gas were highly correlated (r ~ 0.90) (Figure 46). Secchi disk depth was negatively correlated with flow, spill, and dissolved gas levels (r ~ 0.4 to 0.6) and water temperature had parabolic relationships with the other variables (Figure 46). In general, correlations among environmental variables in the truncated data set (9 April to approximately 2 July) were similar to or higher than those for the entire date range.

With the entire 1997 spring and summer chinook salmon data set, no variables met the 0.10 selection criteria for inclusion in the stepwise models using either the variable-day-bin or 5-d-block data (Table 15). With the truncated data set (through 2 July), dissolved gas was first selected in the variable-day-bin (r^2 = 0.32) and 5-d block (r^2 = 0.19) models. No additional variables met the 0.10 selection criteria for inclusion in the models. When we removed dissolved gas from the models, spill was the first and only variable selected using the variable-day-bin method (r^2 = 0.24; P = 0.02) and Secchi visibility was the first and only variable selected using the 5-d block method (r^2 = 0.18; P = 0.19).

During the 1998 chinook salmon migration, flow, spill, and dissolved gas were highly correlated (r > 0.78) (Figure 47). Secchi disk visibility was more correlated (r > -0.6) with flow, spill, and dissolved gas levels than in 1996 or 1997. Water temperature was only weakly correlated with other variables, although temperatures had the characteristic parabolic relationships with flow, spill, and dissolved gas we observed in previous years (Figure 47).

With the entire 1998 spring and summer chinook salmon data set, no variables met the 0.10 selection criteria for inclusion in the stepwise models using either the variable-day-bin or 5-d-block data (Table 16). Truncating the data to only include data through ~ 28 June (81% of all passages) did not result in model fit.

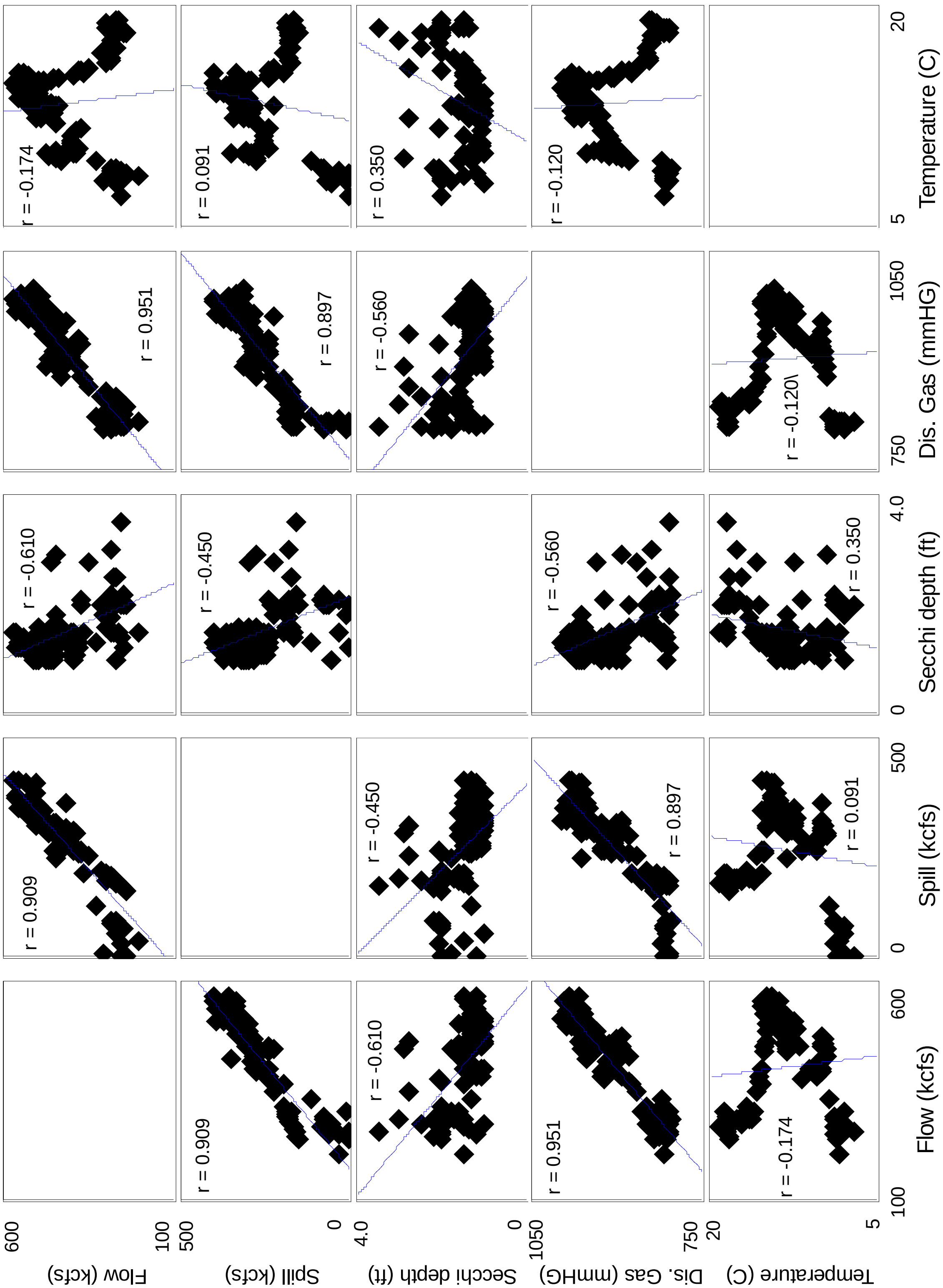

Figure 46. Scatter plots and correlation coefficients for environmental variables used in multiple regression models, based on daily mean values during the spring and summer chinook salmon migration in 1997.

Table 15. Stepwise multiple regression model outputs for 1997 including models run, variables retained, and standard procedure outputs. All models have spring and summer chinook salmon fallback ratios as the dependent variable.

Models run	Variables retained	Variables removed	r^2	Partial r^2	F	Prob. > F
Model 1, Variable-day-bin model with all variables included from 9 April to 25 July						
	a. No variables selected					
Model 2, Variable-day-bin model with all variables included from 9 April to 2 July						
	a. Dissolved gas		0.3227	0.3227	9.05	0.0072
Model 3, Consecutive 5-d block model with all variables included from 9 April to 25 July						
	a. No variables selected					
Model 2, Consecutive 5-d block model with all variables included from 9 April to 2 July						
	a. Dissolved gas		0.1927	0.1927	3.58	0.0779

Table 16. Stepwise multiple regression model outputs for 1998 including models run, variables retained, and standard procedure outputs. All models have spring and summer chinook salmon fallback ratios as the dependent variable.

Models run	Variables retained	Variables removed	r^2	Partial r^2	F	Prob. > F
Model 1, Variable-day-bin model with all variables included from 5 April to 19 July						
	a. No variables selected					
Model 2, Consecutive 5-d block model with all variables included from 10 April to 3 July						
	a. No variables selected					

Table 17. Correlation coefficients in matrix for daily mean flow, spill, Secchi disk visibility, dissolved gas, and water temperature during the sockeye salmon migration at The Dalles Dam from 13 June to 4 August, 1997.

	Water temp	Flow	Spill	Secchi disk	Dissolved gas
Water temp	---	-0.893	-0.842	0.683	-0.823
Flow	-0.893	---	0.982	-0.677	0.959
Spill	-0.842	0.982	---	-0.633	0.948
Secchi	0.683	-0.677	-0.633	---	-0.618
Gas	-0.823	0.959	0.948	-0.618	---

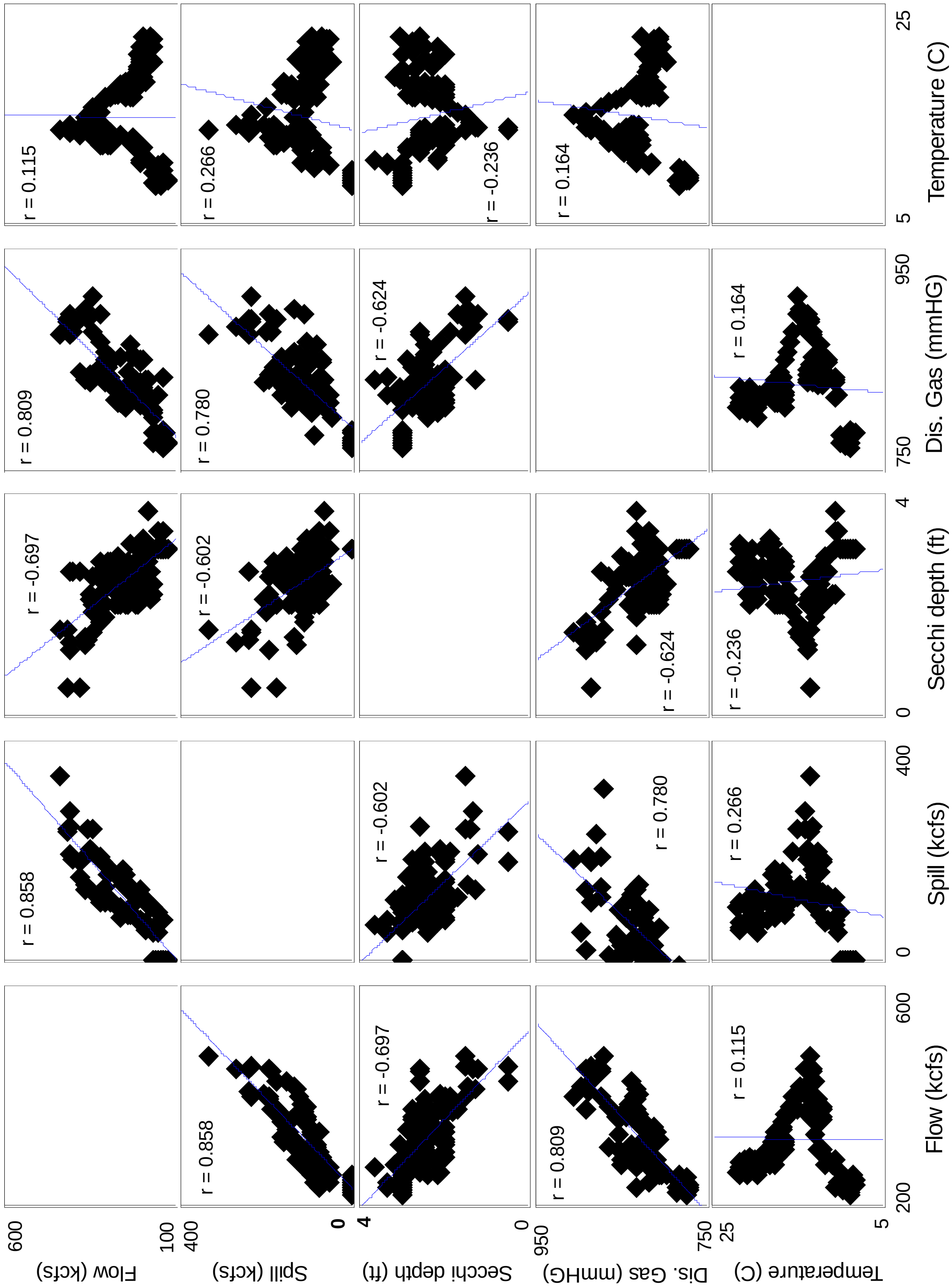

Figure 47. Scatter plots and correlation coefficients for environmental variables used in multiple regression models, based on daily mean values during the spring and summer chinook salmon migration in 1998.

During the 1997 sockeye salmon migration from 13 June through 4 August, flow and spill were highly correlated (r = 0.982), as were flow and dissolved gas (r = 0.959), and spill and dissolved gas (r = 0.948) (Table 17). (Also see Figure 46 for 1997 coefficients.) Secchi disk visibility was negatively correlated with flow, spill, and dissolved gas (r about -0.65) and positively correlated with water temperature (Table 17).

We limited fallback data included in stepwise models to between 20 June and 4 August (see previous comments for explanation). With all environmental variables included and the variable-day-bin fallback ratio as the dependent variable for 1997 sockeye salmon, spill was first selected in the stepwise procedure with an r^2 value of 0.23 (Table 18). No additional variables met the P = 0.10 selection criteria for inclusion in the model. When we removed spill from the model, flow was the first and only variable selected with an r^2 of 0.20 (Table 18). Water temperature was the first and only variable selected using the consecutive 5-d block model, with an r^2 of 0.60 (Table 18). When we removed water temperature from the model, flow was the first and only variable selected with an r^2 of 0.51.

Table 18. Stepwise multiple regression model outputs for 1997 including models run, variables retained, and standard procedure outputs. All models have sockeye salmon fallback ratios as the dependent variable.

Models run	Variables retained	Variables removed	r^2	Partial r^2	F	Prob. > F
Model 1, Variable-day-bin model with all variables included from 20 June to 4 August						
	a. Spill		0.2322	0.2322	3.93	0.0690
Model 2, Variable-day-bin model; all variables except spill: 20 June to 4 August						
	a. Flow		0.1990	0.1990	3.23	0.0956
Model 3, Consecutive 5-d block model with all var. included from 20 June to 3 August						
	a. Water temperature		0.6032	0.6032	10.64	0.0138
Model 4, Consecutive 5-d block model; all variables except temp: 20 June to 3 August						
	a. Flow		0.5136	0.5136	7.39	0.0298

Final Distribution of Fish that Fell Back at The Dalles Dam

We coded all migration data for salmon and steelhead outfitted with transmitters in 1996, 1997, and 1998, including telemetry records at dams and monitored tributaries, recapture records, and mobile track data. We used general migration data to identify final distribution for all fish that fell back at The Dalles Dam and to estimate survival through the lower Columbia and Snake Rivers to tributaries. We designated as survived those fish that remained in tributaries long enough to potentially spawn; fish that drifted to mainstem sites after potential spawning were included in tributary counts. We also considered fish that passed the uppermost monitored sites (i.e. the top of Priest Rapids Dam in 1996, Wells Dam in 1997 and 1998, the Snake River site near Asotin in all years) to have survived. Fish recaptured at the Lower Granite Trap without transmitters, or transported from the trap to hatcheries were also designated as survived, as were fish recaptured at or near Ringold Trap.

Survival to tributaries, hatcheries, or past the uppermost monitored sites for spring and summer chinook salmon that fell back at The Dalles Dam was 75.8% in 1996, 74.3% in 1997, and 61.9% in 1998 (Table 19). Steelhead survival was 57.1% for fish tagged in 1996 and 46.7% for fish tagged in 1997. About 67% of sockeye salmon and 62% of fall chinook salmon that fell back at The Dalles Dam survived using our limited criteria (Table 19).

Of 66 spring and summer chinook salmon that fell back at The Dalles Dam in 1996, 3 (5%) were later recorded in tributaries downstream from Bonneville Dam, 14 (21%) were in tributaries between Bonneville and The Dalles dams, 7 (11%) were in the Deschutes or John Day rivers, 3 (5%) were in the Umatilla River, 2 (3%) were in the Tucannon River, and 17 (26%) were in Snake River tributaries upriver from Lower Granite Dam or in the Lower Granite Trap, (Table 19). Four (6%) were last recorded at the top of Priest Rapids Dam. Sixteen fish (25%) fell back and were not recorded in tributaries or the top of Priest Rapids Dam, of which 13 were last recorded in the Bonneville Dam pool or at The Dalles Dam. Thirty of 66 fish that fell back did not reascend, of which 17 (57%) were recorded entering downstream tributaries (Table 20).

Of 101 spring and summer chinook salmon that fell back at The Dalles Dam in 1997, 20 (20%) were later recorded in tributaries between Bonneville and The Dalles dams, 10 (10%) were in the Deschutes River, 1 (1%) was in the John Day River, 3 (3%) were in the Wenatchee River, 3 (3%) were in the Icicle or Similkameen rivers, 3 (3%) were at Wells Dam or trap, 2 were in the Tucannon River, and 32 (32%) were in Snake River tributaries upriver from Lower Granite Dam (Table 19). Twenty-six fish (26%) fell back and were not recorded in tributaries or at Wells Dam, of which 11 were last recorded in the Bonneville Dam pool or at The Dalles Dam. Thirty-two of 101 fish that fell back did not reascend, of which 20 (63%) were recorded entering downstream tributaries (Table 20).

Of 84 spring and summer chinook salmon that fell back at The Dalles Dam in 1998, 1 (1%) was later recorded in the Sandy River downstream from Bonneville Dam, 14 (17%) were in tributaries between Bonneville and The Dalles dams, 5 (6%) were in the Deschutes or John Day rivers, 2 (2%) were in the Wenatchee River, and 29 (35%) were in Snake River tributaries upriver from Lower Granite Dam or in the Lower Granite Trap (Table 19). Thirty-two fish (38%) fell back and were not recorded in tributaries, of which 10 were last recorded in the Bonneville Dam pool or at The Dalles Dam. Thirty of 84 fish that fell back did not reascend, of which 15 (50%) were recorded entering downstream tributaries (Table 20).

Of 35 steelhead tagged in 1996 that fell back at The Dalles Dam, 4 (11%) were later recorded in tributaries between Bonneville and The Dalles dams, 6 (17%) were in the Deschutes or John Day rivers, 1 (3%) was in the Walla Walla River,

Table 19. Final recorded location of spring and summer chinook salmon (CK), steelhead (SH), sockeye salmon (SK), and fall chinook salmon (FCK) with transmitters that fell back at The Dalles Dam in 1996 to 1998 and percent that survived to tributaries. Fish that reached tributary sites during spawning times and then returned to mainstem areas (i.e steelhead kelts) were included in tributary counts.

	1996 CK	1997 CK	1998 CK	1996 SH	1997 SH	1997 SK	1998 FCK
Number of fallback fish	**66**	**101**	**84**	**35**	**45**	**24**	**65**
Final location							
Cowlitz River	1						
Santiam River	1						
Sandy River	1		1				
Wind River	4	2	2				1
Little White Salmon River	3	2		1			5
White Salmon River	1	3				2	10
Spring Creek Hatchery							3
Hood River	1	3	2				1
Klickitat River	5	10	10	3		1	10
Deschutes River	5	10	4	3	5		4
John Day River	2	1	1	3	3		
Umatilla River	3						
Walla Walla River				1			
Hanford Reach							5
Wenatchee/Tumwater Dam		3	2			7	
Okanogan River						6	
Icicle River		2					
Similkameen River		1					
Lyons Ferry Hatchery					1		1
Tucannon River	2	2			1		
Clearwater River	6	17	10	2	6		
Snake River above Asotin	3	1		1	1		
Grande Ronde River		1	1	1			
Imnaha River			2				
Salmon River	3	13	14	4	1		
Total:	**41**	**71**	**49**	**19**	**18**	**16**	**40**
Percent that survived to tributaries:	**62.1**	**70.3**	**58.3**	**54.3**	**40.0**	**66.7**	**61.5**
Additional fish that survived to relevant non-tributary sites:							
L. Granite trap: to hatchery	4		2				
L. Granite trap, no trans.	1				1		
At/Near Ringold trap		1	1	1	2		
Top of Pr. Rapids Dam[a]	4						
At Wells Dam/trap		3					
Percent that survived to tributaries, traps, top of Pr. Rapids (1996) or Wells dams:	**75.8**	**74.3**	**61.9**	**57.1**	**46.7**	**66.7**	**61.5**

[a] 1996 only

and 8 (23%) were in Snake River tributaries upriver from Lower Granite Dam (Table 19). Fifteen fish (43%) fell back and were not recorded in tributaries, of which 11 were last recorded at lower Columbia River dams or in their reservoirs. Eight of 35 fish that fell back did not reascend, of which 4 (50%) were recorded entering downstream tributaries (Table 20).

Of 45 steelhead tagged in 1997 that fell back at The Dalles Dam, 8 (18%) were later recorded in the Deschutes or John Day rivers, 1 (2%) was in the Tucannon River, 1 (2%) was at Lyons Ferry Hatchery, and 9 (20%) were in Snake River tributaries upriver from Lower Granite Dam or in the Lower Granite Trap (Table 19). Twenty-four fish (53%) fell back and were not recorded in tributaries, of which 11 were last recorded in the Bonneville Dam pool or at The Dalles Dam, and 10 were last recorded at other lower Columbia River dams or in their reservoirs. Eleven of 45 fish that fell back did not reascend; none were recorded entering downstream tributaries (Table 20).

Of 24 sockeye salmon that fell back at The Dalles Dam in 1997, 2 (8%) were later recorded in the White Salmon River, 1 (4%) was in the Klickitat River, 7 (29%) were in the Wenatchee River, and 6 (25%) were in the Okanogan River (Table 19). Eight fish (33%) fell back and were not recorded in tributaries, of which 6 were last recorded at lower Columbia River dams or in their reservoirs. Six of 24 fish that fell back did not reascend, of which 3 (50%) were recorded entering downstream tributaries (Table 20).

Of 65 fall chinook salmon that fell back at The Dalles Dam in 1998, 30 (46%) were later recorded in tributaries or at hatcheries between Bonneville and The Dalles dams, 4 (6%) were in the Deschutes River, 5 (8%) were in the Hanford Reach of the Columbia River, and 1 (2%) was at Lyons Ferry Hatchery (Table 19). Twenty-five fish (38%) fell back and were not recorded in tributaries, of which 18 were last recorded in the Bonneville Dam pool or at The Dalles Dam, and 3 were downstream from Bonneville Dam. Fifty of 65 fish that fell back did not reascend, of which 29 (58%) were recorded entering downstream tributaries (Table 20).

With the exception of steelhead tagged in 1997, between 50% and 63% of radio-tagged fish that fell back at The Dalles Dam and did not reascend entered downstream tributaries (Table 20). Results suggest that many fallbacks at the dam may be attributable to migration behavior, including wandering, temporary straying, or overshoot of natal tributaries. For most stocks, the highest number of overshoot fallback fish eventually entered the Klickitat River.

Discussion

We monitored fallback behavior for more than 4,200 adult salmon and steelhead at The Dalles Dam using radio-telemetry equipment during the years 1996 to 1998. Significant proportions of the radio-tagged spring and summer chinook salmon and fall chinook salmon fell back in each year they were monitored; fallback proportions for steelhead in 1996 and

Table 20. Number of spring and summer chinook salmon (CK), steelhead (SH), sockeye salmon (SK), and fall chinook salmon (FCK) with transmitters that fell back at The Dalles Dam in 1996 to 1998 that did not reascend The Dalles Dam after falling back, and did or did not enter downstream tributaries after falling back in 1996.

	Fell back and did not reascend	Did not enter tributary	Entered downstream tributary	Final distribution (river entered)
1996 CK	30	13	17 (57%)	Klickitat (5), Wind (4), Little White Salmon (3), Cowlitz (1), Santiam (1), Sandy (1), White Salmon (1), Hood (1),
1997 CK	32	12	20 (63%)	Klickitat (10), White Salmon (3), Hood (3), Wind (2), Little White Salmon (2)
1998 CK	30	15	15 (50%)	Klickitat (10), Hood (2), Wind (2), Sandy (1)
1996 SH	8	4	4 (50%)	Klickitat (3), Little White Salmon (1)
1997 SH	11	11	0 (0%)	(none)
1997 SK	6	3	3 (50%)	White Salmon (2), Klickitat (1)
1998 FCK	50	21	29 (58%)	Klickitat (10), White Salmon (10), Little White Salmon (5), Spring Creek Hatchery (3), Wind (1)
All species combined	167	79	88 (53%)	Klickitat (39), White Salmon (16), Little White Salmon (11), Wind (9), Hood (6), Spring Creek Hatchery (3), Sandy (2), Santiam (1), Cowlitz (1)

1997 and sockeye salmon in 1997 were relatively low compared to proportions for chinook salmon.

The percentage of spring and summer chinook salmon (11.0% to 14.2%) that fell back over the dam and fallback rates (13.8% to 18.4%) were highest in 1997 and lowest in 1998. Fallback percentages were 4.9% for sockeye salmon, between 6% and 7% for steelhead, and 10.4% for fall chinook salmon. Fallback rates were 5.1% for sockeye salmon, 6.8% to 7.7% for steelhead, and 11.8% for fall chinook salmon. Percentages and rates were less than 4.5% for steelhead when we only included data through 31 October of the year they were tagged, the date when most steelhead had passed the dam. For all three years, the percentage of spring and summer chinook salmon that fell back and fallback rates were related to overall flow and spill conditions. In 1997, a relatively high-flow year, fallback rates and percentages were highest. Proportionately fewer chinook salmon fell back in 1996 and 1998, lower flow years than 1997.

In contrast to fallback behavior at Bonneville Dam, relatively few radio-tagged chinook salmon or steelhead fell back within 24 h of passage (see Bjornn et al. 2000b). Less than a third of spring and summer chinook salmon, steelhead, and fall chinook salmon fell back within 24 h of passage. Sixty percent of spring and summer chinook salmon, 67% of steelhead, and 85% of fall chinook salmon were recorded at upstream sites (mostly at John Day Dam or in the Deschutes River) before they fell back at The Dalles Dam. For this reason, we believe that environmental conditions at the dam when fish were passing were not the primary cause of most fallback behavior at The Dalles Dam.

In 1996 and 1997, 24 h fallback ratios (the number that fell back divided by the number that passed) for spring and summer chinook salmon increased with flow, spill, and dissolved gas levels and decreased with lower turbidity levels. Similar trends were observed for 1997 sockeye salmon during all but the very beginning and tail end of the migration. High water temperatures were associated with higher fallback ratios for spring and summer chinook salmon and sockeye salmon in 1997. We found little correlation between 24 h fallback ratios and environmental conditions for steelhead or fall chinook salmon.

T-tests and logistic regressions using binary datasets (fallback or no fallback within 24 h of passage) showed few significant differences in environmental conditions for fallback fish. Flow and spill at the time of passage were higher for spring and summer chinook salmon in 1996 and 1997, sockeye salmon in 1997, and fall chinook salmon in 1998 that fell back within 24 h, but differences were not significant at ($P < 0.05$). Spill was significantly higher for steelhead that fell back within 24 h in 1997 ($P < 0.05$) and Secchi visibility was significantly lower for spring and summer chinook salmon that fell back in 1996 ($P < 0.005$).

Multiple regression models with fallback ratios as the dependent variable and environmental conditions as the independent variables produced results that were similar to univariate models for spring and summer chinook salmon and sockeye salmon. Secchi disk visibility was the most significant predictor of fallback ratios for 1996 spring and summer chinook salmon, dissolved gas or spill were the most significant predictors for 1997 spring and summer chinook salmon, and no variables were selected for 1998 spring and summer chinook salmon. Flow and/or spill were identified as the most significant variables for predicting fallbacks by sockeye salmon, with fallback ratios increasing with flow and spill. One model also identified water temperature as a significant predictor of sockeye salmon fallback ratios. High correlations between flow, spill, and dissolved gas in all years made it difficult to separate effects.

We believe most spring and summer chinook salmon and sockeye salmon that fell back at The Dalles Dam did so via the spillway. Between 94% and 100% of fallbacks by spring and summer chinook salmon and sockeye salmon occurred on days with forced spill. About 57% of fallbacks by steelhead tagged in 1996, 71% of fallbacks by steelhead tagged in 1997, and 100% of fall chinook salmon in 1998 fell back on days with no spill. Radio-tagged fall chinook salmon did not begin passing the dam until after the period of no-spill began on 1 September. Based on our observations at Bonneville and McNary dams, we believe some fish also likely fell back through the navigation lock, via an ice and trash sluiceway, or though the juvenile bypass; we believe relatively few fish fell back through powerhouses, but no potential fallback routes were monitored at The Dalles Dam in any year. For comparison, 63% of fall chinook salmon fallbacks at Bonneville Dam and 78% at McNary Dam were via the navigation lock; the remaining 22% at McNary Dam fell back via the juvenile bypass. About half of all steelhead fallbacks during no-spill conditions at Bonneville Dam in 1997 were through the navigation lock or through ice and trash sluiceways (the juvenile bypass was not monitored at Bonneville Dam). At McNary Dam, 72% of fallbacks by steelhead during no-spill conditions in 1997 were via the juvenile bypass and 3% were via the navigation lock.

We did not observe a pattern of higher fallbacks associated with either ladder for spring and summer or fall chinook salmon. Sockeye salmon that passed over the Washington-shore ladder fell back at significantly higher rates than those that passed the Oregon-shore ladder. Most steelhead that fell back within 24 h of passage had passed the dam via the Oregon-shore fishway.

A high percentage of the fish that fell back at The Dalles Dam reascended the dam (55-68% of the spring and summer chinook salmon, about 75% of sockeye salmon and steelhead, 23% of the fall chinook salmon) and those extra passages at the dam (more than once for some fish) caused the counts of fish at the fishway counting windows to have a positive bias (more fish reported passing the dam than actually passed). We calculated ladder count adjustment factors based on all passages, fallbacks, and reascensions for each year and species. Pooled adjustment factors, using all data for spring and summer chinook salmon were 0.840 in 1996, 0.839 in 1997, and 0.875 in 1998. The pooled adjustment factor was 0.951 for sockeye salmon in 1997, 0.937 for steelhead in 1996, 0.926 for steelhead in 1997, and 0.888 for fall chinook salmon in 1998. Positive biases due to fallback and reascenion by spring and summer chinook salmon were about 5,900 in 1996, 14,400 in 1997, and 5,100 in 1998. Positive biases were about 1,600 sockeye salmon in 1997, and about 10,200 steelhead in 1996, 12,200 steelhead in 1997, and 10,400 fall chinook salmon in 1998. Adjustments based on data weighted by total counts of fish passing via ladder were similar to pooled adjustments for spring and summer chinook salmon and sockeye salmon, and were slightly higher for steelhead and fall chinook salmon. Pooled adjustment factors indicated higher positive bias for steelhead because a relatively high number of radio-tagged steelhead fell back at The Dalles Dam early and late in migrations when relatively few fish were passing the dam.

Based on complete migration summaries, 62% to 76% of spring and summer chinook salmon, 47% to 57% of steelhead, 67% of sockeye salmon, and 62% of fall chinook salmon that fell back at The Dalles Dam were subsequently recorded at tributary locations or the uppermost monitoring sites and potentially spawned or were transported from adult traps to hatcheries. Migration behavior appeared to have contributed to many fallback events at the dam: 15% to 26% of spring and summer chinook salmon, 13% of sockeye salmon, 11% of steelhead in 1996 (0% of 1997 steelhead), and 46% of fall chinook salmon entered tributaries downstream from The Dalles Dam after falling back. Fish that fell back and subsequently entered downstream tributaries mostly entered the Klickitat River (49%), the White Salmon River (20%), and the Little White Salmon River (11%). Five percent entered tributaries downstream from Bonneville Dam. The relatively high incidence of entering downstream tributaries after falling back indicated some fallbacks were likely caused by fish wandering and overshooting their home stream, or other migration factors.

From 24% to 35% of spring and summer chinook salmon and 18% to 20% of steelhead that fell back were recorded in tributaries upriver from Lower Granite Dam or were transported from the adult trap at Lower Granite Dam to hatcheries. About 54% of the sockeye salmon that fell back at The Dalles Dam were last recorded at tributaries to the upper Columbia, mostly in the Wenatchee and Okanogan rivers.

Fish that fell back and were not recorded in tributaries or the uppermost monitoring sites (24% to 38% of spring and summer chinook salmon, sockeye salmon, and fall chinook salmon, 43% to 53% of steelhead) were last detected primarily at dam sites or in reservoirs throughout the lower-Columbia River/Snake River hydrosystem. Fish unaccounted for in tributaries or hatcheries may have died or regurgitated transmitters before reaching spawning grounds, may have been recaptured but not reported, may have entered tributaries undetected, or may have entered small, unmonitored tributaries. Additional migration information for fish that did or did not fall back at The Dalles Dam will be reported in specific general migration reports for each species, the first of which are for spring and summer chinook salmon and steelhead tagged in 1996 (Bjornn et al. 2000a; 2001).

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