Technical Report 2000-3

IDAHO COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT

ADULT CHINOOK AND SOCKEYE SALMON, AND STEELHEAD FALLBACK RATES AT JOHN DAY DAM - 1996, 1997, AND 1998

A report for Project MPE-P-95-1

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for

U.S. Army Corps of Engineers
Portland and Walla Walla Districts

and

Bonneville Power Administration
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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 John Day 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, Michael Jepson, 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, 1,564 spring and summer chinook salmon, 410 fall chinook salmon, 430 sockeye salmon, and 1,024 steelhead retained transmitters and were recorded passing John Day Dam via fishways. An additional 19 to 45 spring and summer chinook salmon, 71 fall chinook salmon, 38 sockeye salmon, and 17 to 23 steelhead were known to pass the dam, either via the navigation lock, during fishway antenna outages, or with malfunctioning or lost transmitters. We monitored passage and fallbacks at John Day 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 9.4% to 12.3% and were highest in 1996. Fallback percentages were 3.8% for sockeye salmon, 10.0% for steelhead tagged in 1996, 7.9% for steelhead tagged in 1997, and 4.0% for fall chinook salmon in 1998. Fallback rates for spring and summer chinook salmon ranged from 11.4% to 14.4% and were also highest in 1996. Fallback rates were 4.1% for sockeye salmon, 9.0% to 11.1% for steelhead, and 4.0% for fall chinook salmon. Percentages and rates were < 6.7% 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 60% and 82% of spring and summer chinook salmon that fell back eventually reascended the dam and were last recorded at upstream sites. About 46% of steelhead tagged in 1996, 75% of steelhead tagged in 1997, and 89% of sockeye salmon eventually reascended; 5% of fall chinook salmon reascended after fallback.

With the exception of sockeye salmon (95%), less than 40% of the fish that fell back did so within 24 h of passing the dam. Between 33% and 46% of spring and summer chinook salmon, 5% of sockeye salmon, 25% of steelhead, and 42% of fall chinook salmon were recorded at upstream sites before falling back. We did not observe a pattern of higher fallbacks associated with either ladder for spring and summer chinook salmon, fall chinook salmon, sockeye salmon, or steelhead.

Ladder count adjustment factors based on pooled data for spring and summer chinook salmon were 0.871 in 1996, 0.889 in 1997, and 0.894 in 1998. Using pooled correction factors, positive biases due to fallbacks in counts of spring and summer chinook salmon passing ladders at John Day Dam were about 3,900 fish in 1996, 9,200 fish in 1997, and 4,000 fish in 1998. The adjustment factor for sockeye salmon in 1997 using pooled data was 0.961, and the positive bias was about 1,400 fish. For steelhead tagged in 1996, the pooled correction factor was 0.895 and the positive bias was about 16,500 fish. The pooled correction factor was 0.916 for steelhead tagged in 1997, with a positive bias of about 13,400 fish. The pooled correction factor was 0.961 for fall chinook salmon, with a positive bias of about 3,100 fish. Weighted correction factors were similar to pooled values for spring, summer, and fall chinook salmon and sockeye salmon, and were slightly higher for steelhead. Escapement adjustments based on values weighted by total counts of fish passing via ladders were generally similar to adjustments based on pooled data, but tended to be slightly lower than adjustments based on pooled data for all species except fall chinook salmon. Positive biases further decreased when we included estimated passage through the navigation lock, which compensated for bias in counts in ladders.

Limited antenna coverage at John Day 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. All fallbacks by spring and summer chinook salmon and sockeye salmon occurred on days with forced spill. About 76% of fallbacks by steelhead tagged in 1996 and 46% of fallback by steelhead tagged in 1997 fell back on days with spill. A small number of fish may have fallen back through the navigation lock, via the ice and trash sluiceway, or via the juvenile bypass in all years, but we did not monitor those routes (except juvenile bypass in 1998). Radio-tagged fall chinook salmon did not begin passing the dam until after the period of no-spill began on 1 September in 1998, and we suspect most fall chinook salmon fell back via the unmonitored navigation lock based on evidence from Bonneville and McNary dams. It was not clear how many fish fell back through powerhouses, as routes through turbine intakes also were not monitored, but based on high reascension rates for most species, we believe few fish fell back via turbines.

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 and spill, and decrease with increased turbidity for spring and summer chinook salmon in all years and sockeye salmon in 1997. Some linear and logistic regression models were significant, but most r^2 values were < 0.20. Fallback ratios for spring and summer chinook salmon and sockeye salmon also tended to increase with increased dissolved gas in 1996 and 1997. Ratios tended to decrease with increased water temperature for spring and summer chinook salmon and sockeye salmon, except that ratios spiked in some years when temperatures exceeded 18^o C. Few steelhead or fall chinook salmon fell back within 24 h in any year, particularly during zero spill conditions.

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 steelhead in 1996 and 1997 that fell back within 24 h, but differences were not significant at ($P < 0.05$), except for steelhead tagged in 1997 ($P = 0.03$ for flow, $P < 0.001$ for spill). We found that water temperature, dissolved gas, and Secchi visibility did not significantly ($P < 0.05$) affect fallback by salmon or steelhead. However, we did observe fallback ratios for some sockeye salmon, steelhead, and fall chinook salmon spiked higher at approximately 18º C.

Spring and summer chinook salmon that fell back within 5 d of passage passed the dam under significantly higher flow and spill conditions in both 1997 and 1998, as did steelhead tagged in 1997 ($P < 0.005$). Dissolved gas levels were also higher for fallback spring and summer chinook salmon in 1997 ($P < 0.005$), and water temperatures were significantly lower for fallback spring and summer chinook salmon in 1996 and 1997 ($P < 0.05$). Secchi visibility was significantly lower ($P < 0.005$) for fall chinook salmon that fell back within 5 d of passage.

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 John Day Dam. Approximately 72% to 83% of spring and summer chinook salmon, 57% (1996) and 64% (1997) of steelhead, 78% of sockeye salmon, and 53% of fall chinook salmon that fell back at John Day 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 19% to 24% of spring and summer chinook salmon, 14% to 28% of steelhead tagged, 6% of sockeye salmon, and 47% of fall chinook salmon entered tributaries down river from John Day Dam, indicating some fallbacks were likely caused by wandering, overshoot behavior, or other migration factors. From 31% to 38% of spring and summer chinook salmon and 17% to 36% 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 67% of the sockeye salmon that fell back at John Day Dam were last recorded in tributaries to the upper Columbia River, mostly in the Wenatchee and Okanogan rivers. Most fall chinook salmon that fell back were last recorded downstream from John Day Dam. Fish not recorded in tributaries or the uppermost monitoring sites (17% to 28% of spring and summer chinook salmon and sockeye salmon, 36% to 44% of steelhead, 47% of fall chinook salmon) 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 John Day 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 John Day Dam had been identified (Monan and Liscom 1974; 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 John Day 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 John Day 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 The Dalles 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 John Day 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 and the first part of the fall chinook salmon run 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

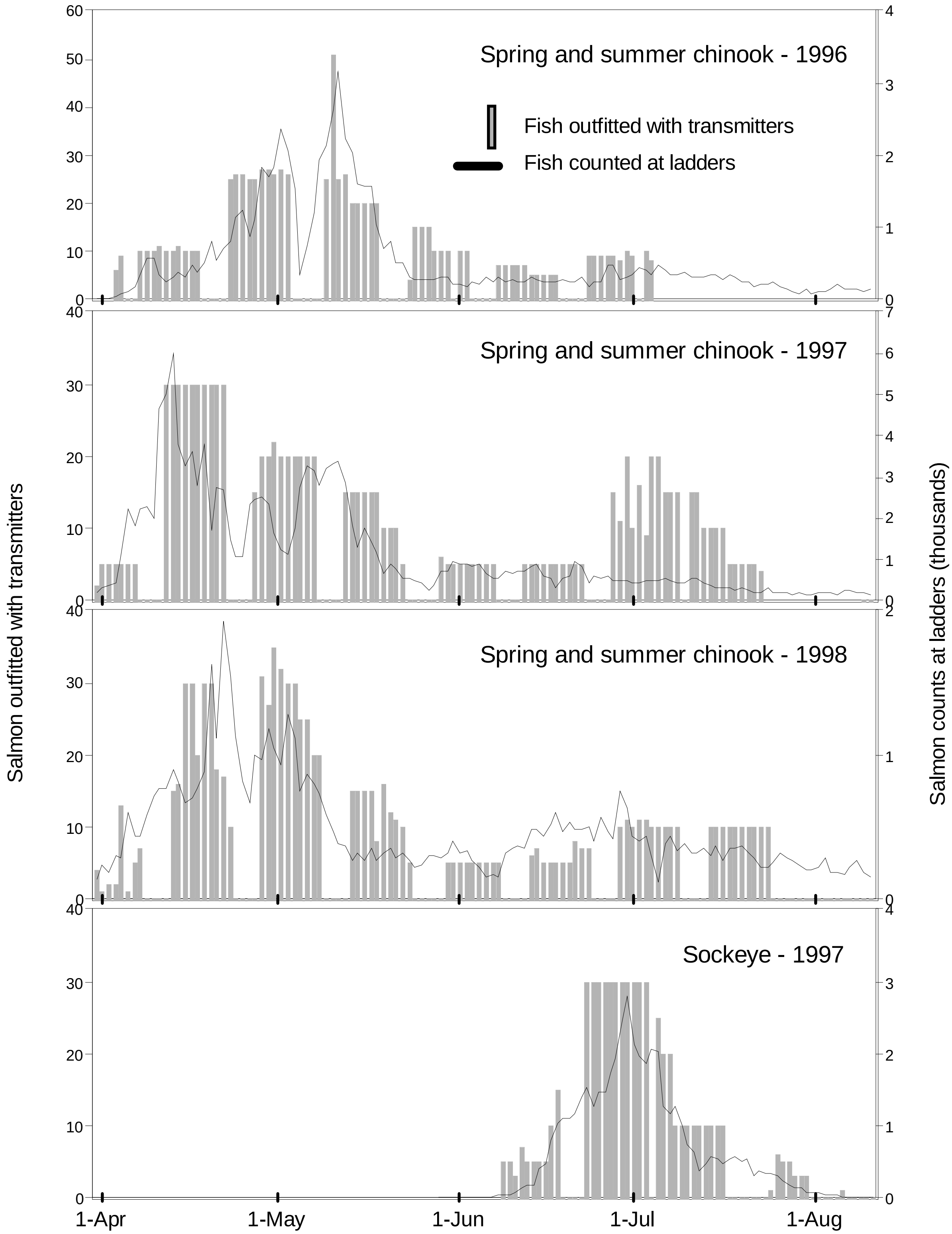

Figure 1. Daily spring and summer chinook salmon and sockeye counts at Bonneville Dam and the number of salmon outfitted with transmitters in 1996, 1997, and 1998.

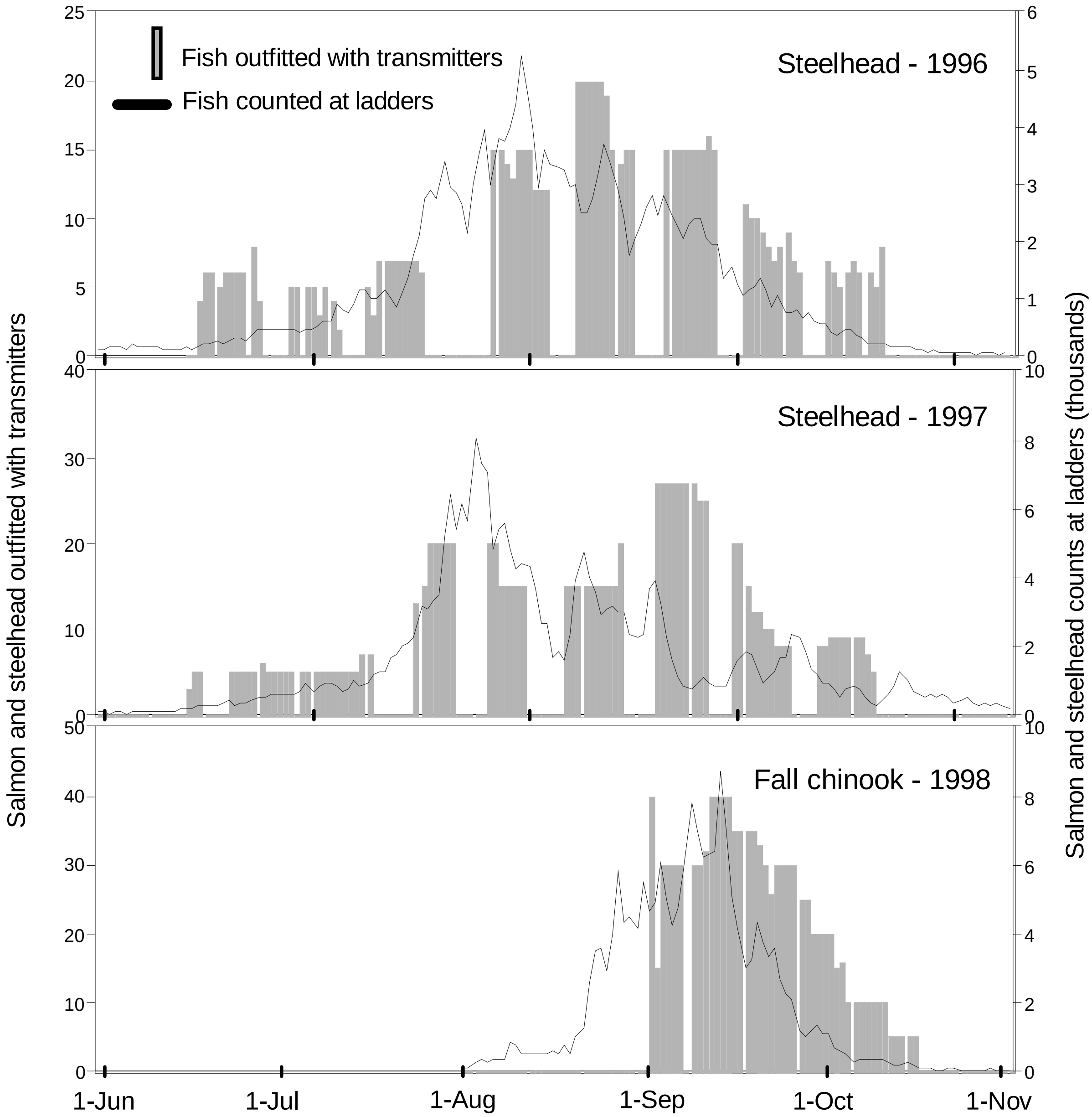

Figure 2. Daily steelhead and fall chinook salmon counts at Bonneville Dam and the number of steelhead and salmon outfitted with transmitters in 1996, 1997, and 1998 .

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 or different passage routes. Relatively high proportions of radio-tagged sockeye salmon (9% at Bonneville and 14% at McNary

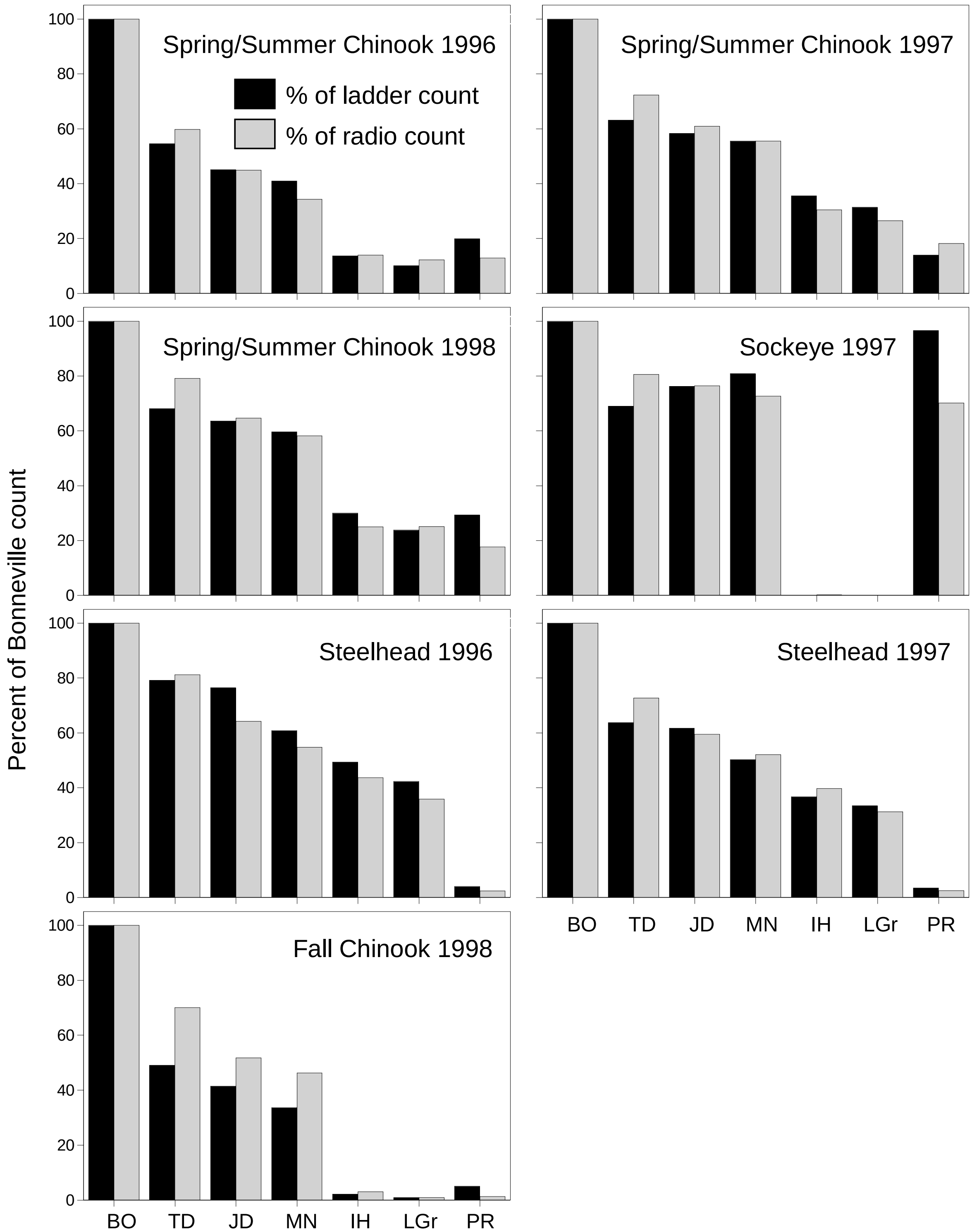

Figure 3. Percent of chinook and sockeye salmon and steelhead counted at Bonneville Dam and radio-tagged salmon and steelhead recorded at Bonneville Dam that were recorded upstream at other Columbia and Snake River dams in 1996, 1997, and 1998. Counts not adjusted for fallback and reascension or navigation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

Dam) pass via navigation locks, suggesting that USACE ladder counts were likely underestimates of escapement at some dams, and navigation lock passage may also have contributed to differences in proportions of tagged and counted fish. 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 John Day Dam via ladders made up 1.3% of those counted at the dam in 1996, 0.8% in 1997, and 2.1% in 1998. Radio-tagged sockeye salmon made up 1.3% of those counted at the dam in 1997, tagged steelhead made up 0.30% of the 1996 count and 0.36% 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 0.04 (4% 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 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 early passage at John Day Dam when 16 salmon with transmitters passed the dam over a 7-d period and the ladder count of salmon was more than 8,200 fish (sampling rate ~ 0.001).

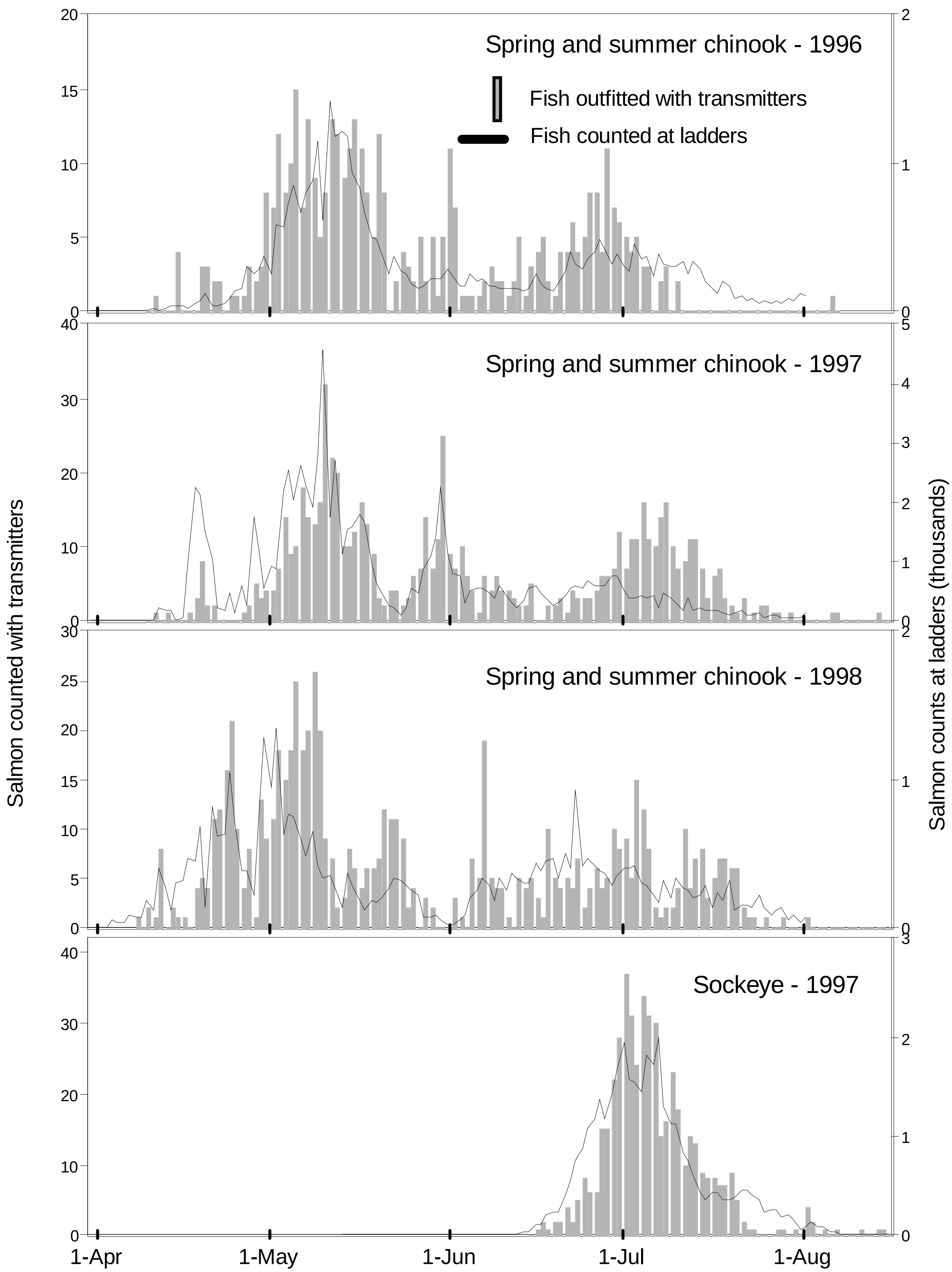

Figure 4. Daily spring and summer chinook salmon and sockeye salmon counts at John Day Dam and the number of salmon with transmitters that passed the dam in 1996, 1997, and 1998.

Most sockeye salmon passed John Day Dam between 17 June and 23 July in 1997 (Figure 4), and tagged fish made up 1-2% of the run during that time. Most steelhead passed John Day Dam from late June through October in both 1996 and 1997, and during most of the migration radio-tagged fish made up 0.1 to 0.7% of the fish passing the dam (Figure 6). Radio-tagged steelhead made up a higher percentage of the fish passing the dam early and late in the migration than during the main period of passage.

Environmental conditions at John Day 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 and June (Figure 10.) The 1998 means were the lowest for flow in all months compared and the lowest for spill for April and July. The 1998 mean monthly Secchi depths were highest for all years and 1998 water temperatures were highest in all months except April (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 John Day 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 (1984 to 1998) at John Day Dam and peaked about two weeks later than average (Figure 11). The 1997 chinook salmon run was larger than average and the run was trimodally distributed, with peaks in mid April, early May, and late May. The nadir in the 1997 run of chinook salmon in late April coincided with high turbidity (Secchi disk visibility about 1.5 feet) and a spike in flow and spill (Figures 8 and 9). The 1998 run was somewhat smaller than average, but passage distribution was similar to average. Timing of sockeye salmon passage in 1997 and steelhead passage in 1996 and 1997 were generally similar to 15-year averages. The 1997 sockeye run was smaller than the 15-year average and peak counts were slightly later than average. Passage of 1996 steelhead was higher than average through August, but the run overall was close to average. Passage of 1996 steelhead was slightly lower than average in August, but counts were about average later in the migration (Figure 11).

Passage of 1997 steelhead was generally similar to average over most of the migration (Figure 11). Fall chinook salmon counts in 1998 were lower than the 15-year average, particularly during traditional peak counts in mid-September. The 1998 fall chinook salmon run also had two somewhat atypical nadirs in counts in mid-September (Figure 11).

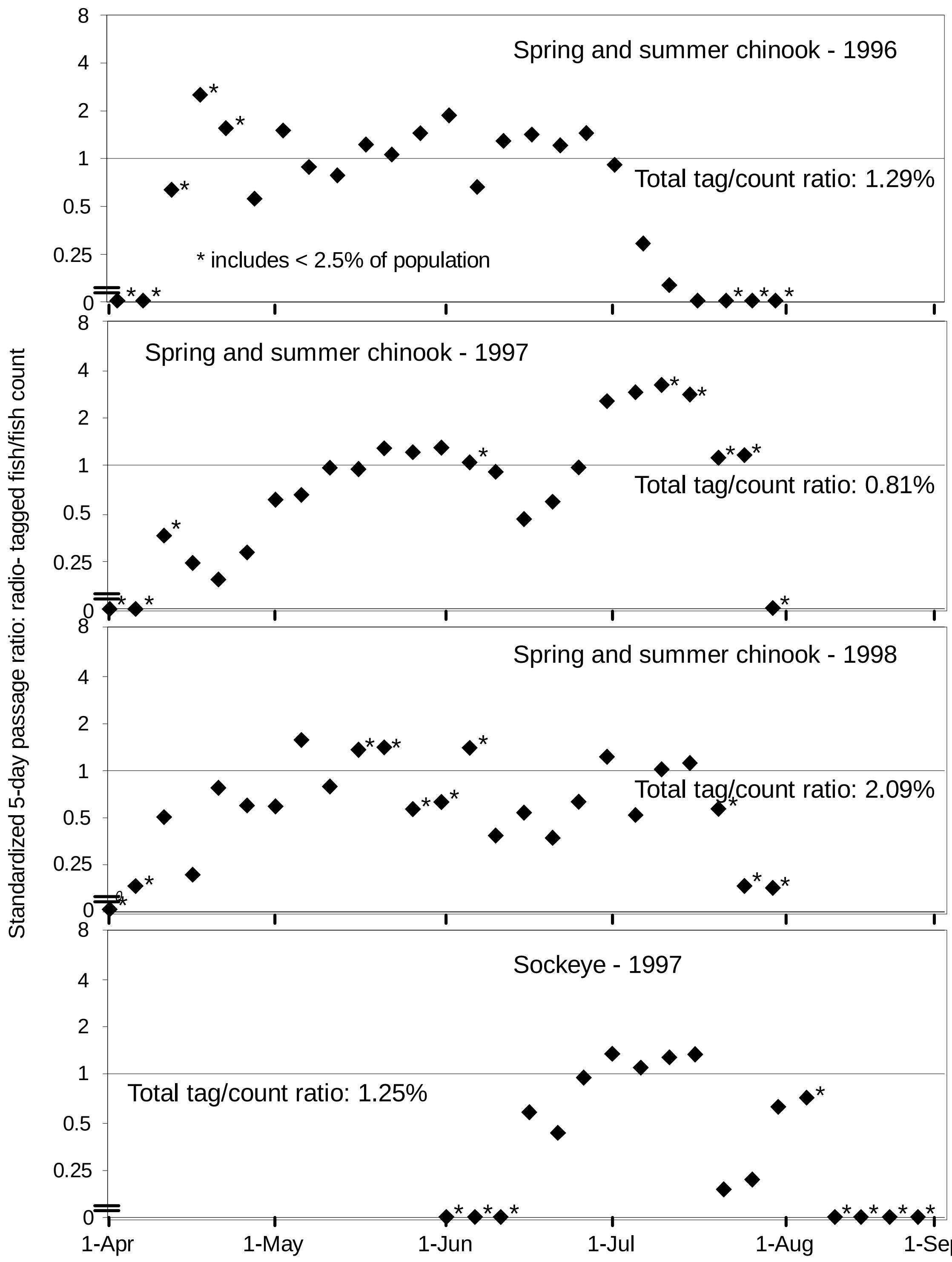

Figure 5. Standardized proportions of radio-tagged spring and summer chinook salmon and sockeye salmon passing John Day Dam to the total counts at the dam during 5-d blocks in 1996, 1997, and 1998. Blocks that include less than 2.5% of the total run noted with an asterisk. Log (~base 2) scale used to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

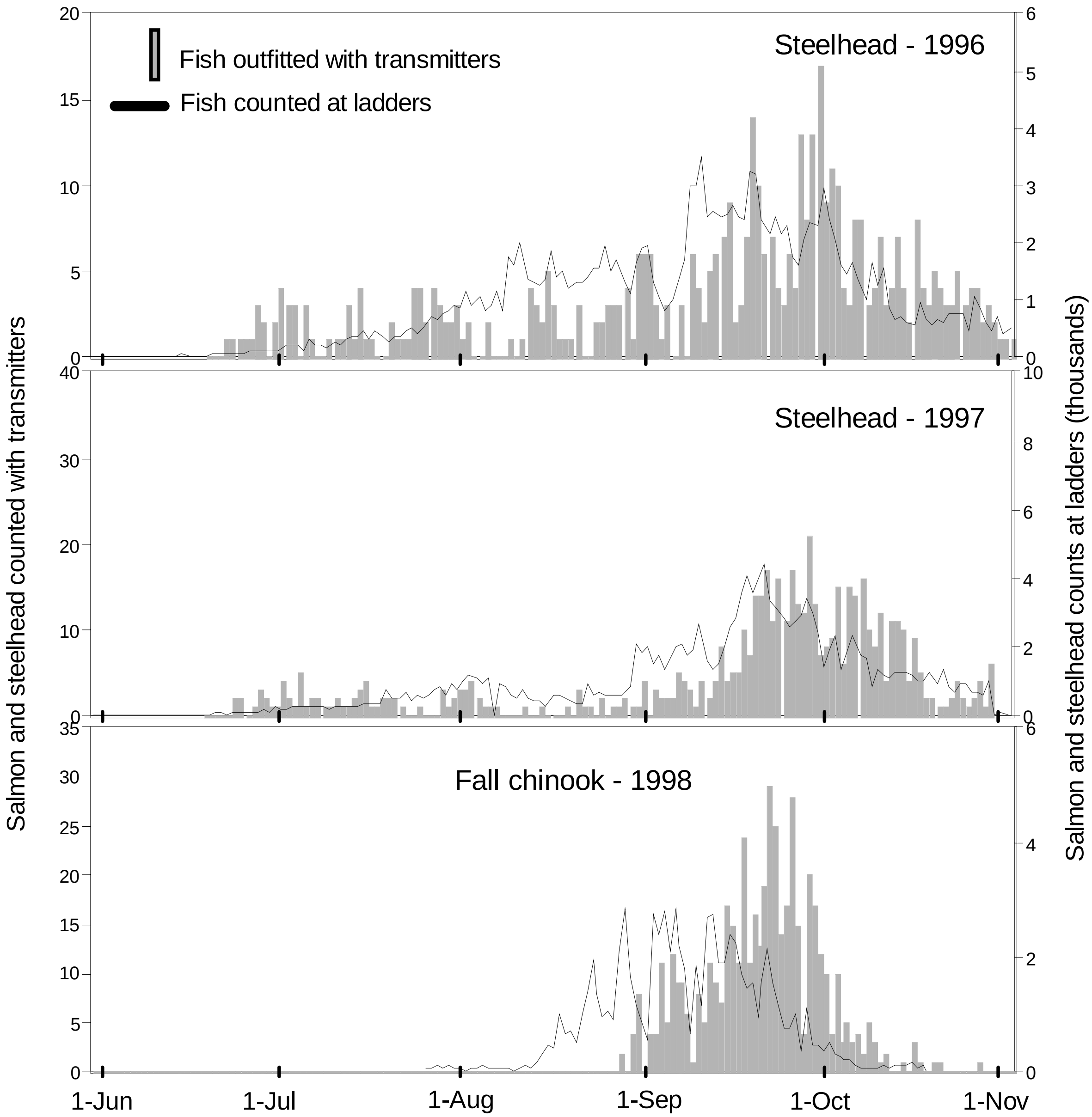

Figure 6. Daily steelhead and fall chinook salmon counts at John Day Dam and the number of steelhead and salmon with transmitters that passed the dam in 1996, 1997, and 1998.

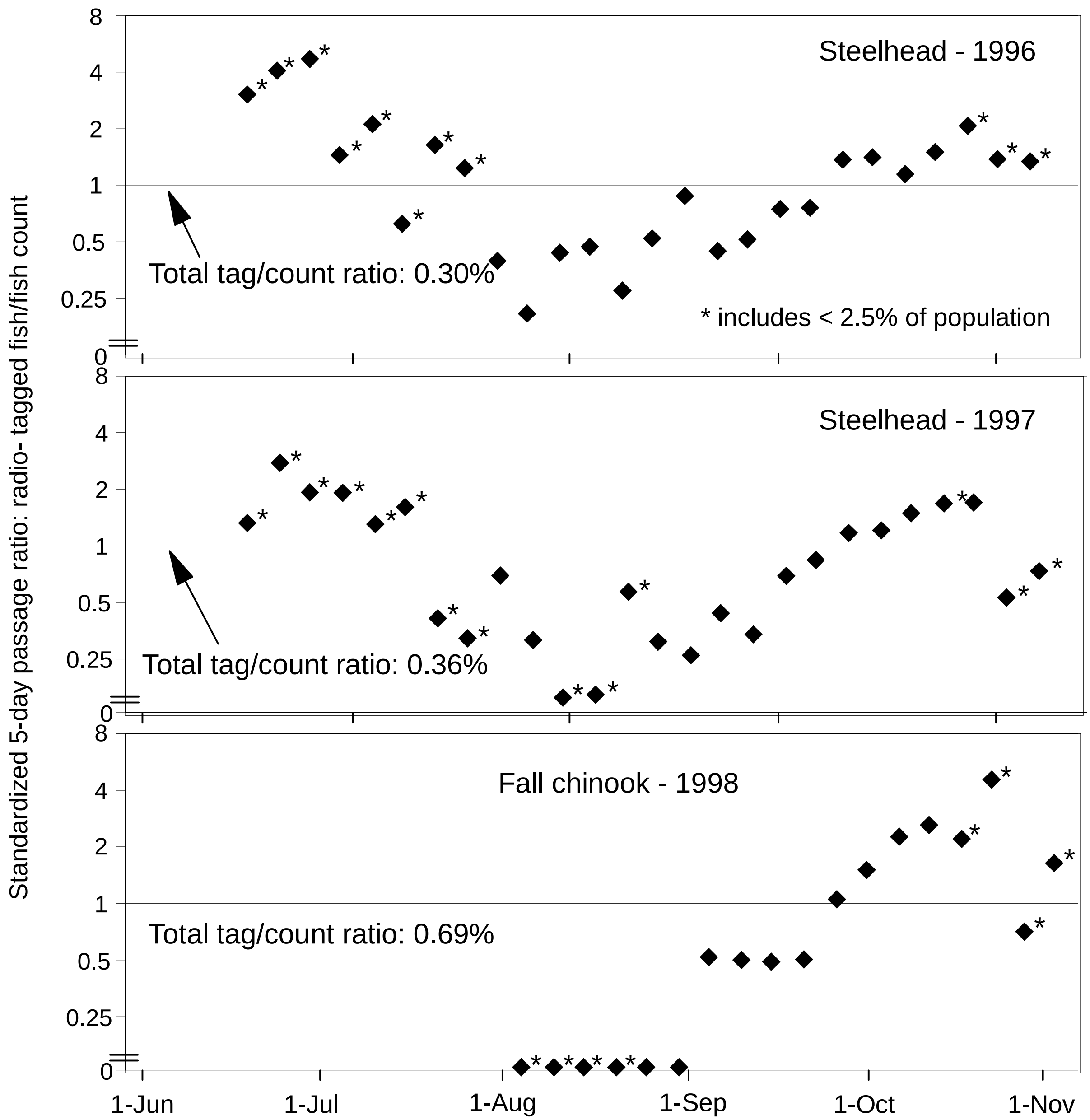

Figure 7. Standardized proportions of radio-tagged steelhead and fall chinook salmon passing John Day Dam to the total counts at the dam during 5-d blocks in 1996, 1997, and 1998. Blocks that include less than 2.5% of the total run noted with an asterisk. Log (~base 2) scale used to show relative distance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

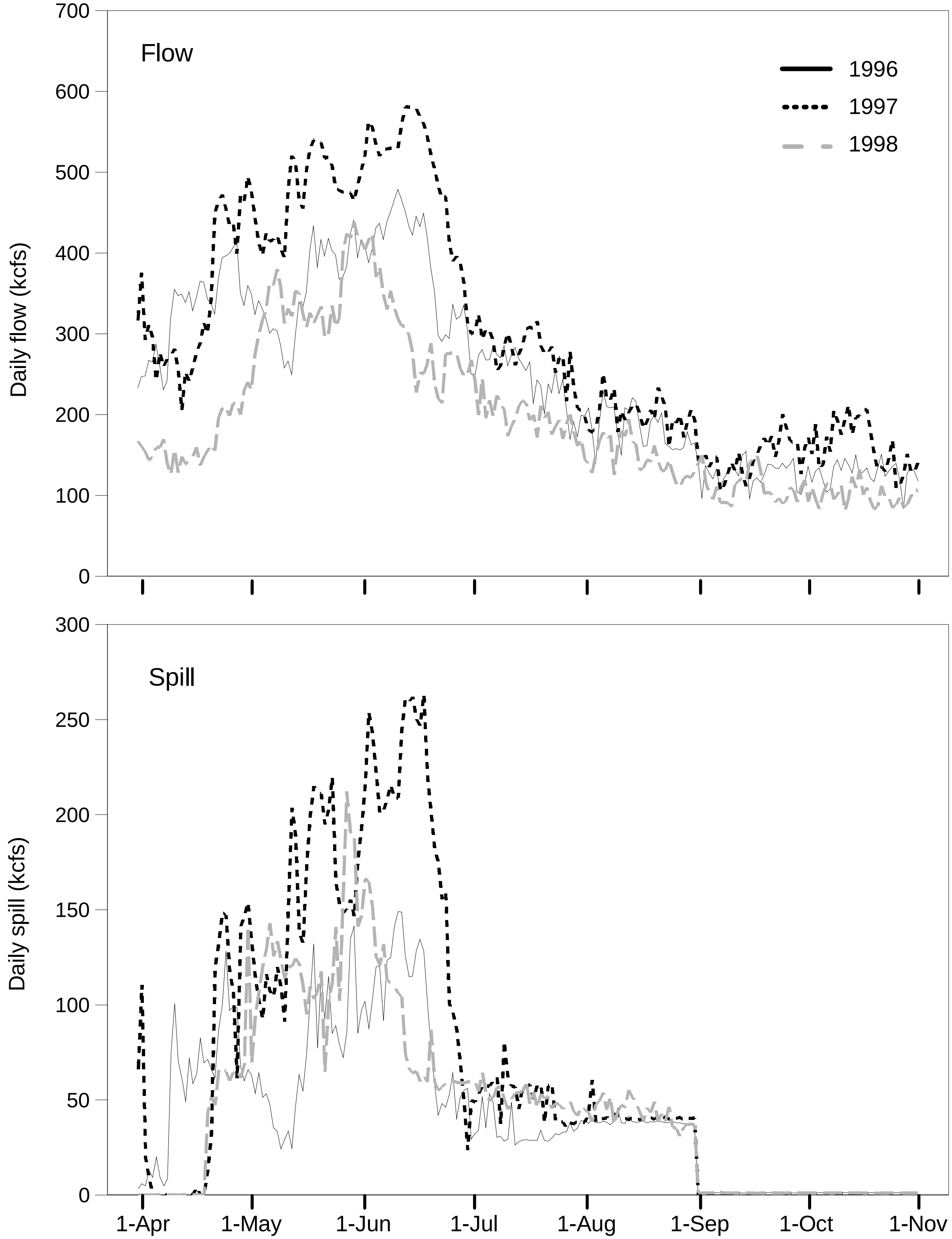

Figure 8. Daily flow and spill at John Day Dam in 1996, 1997, and 1998.

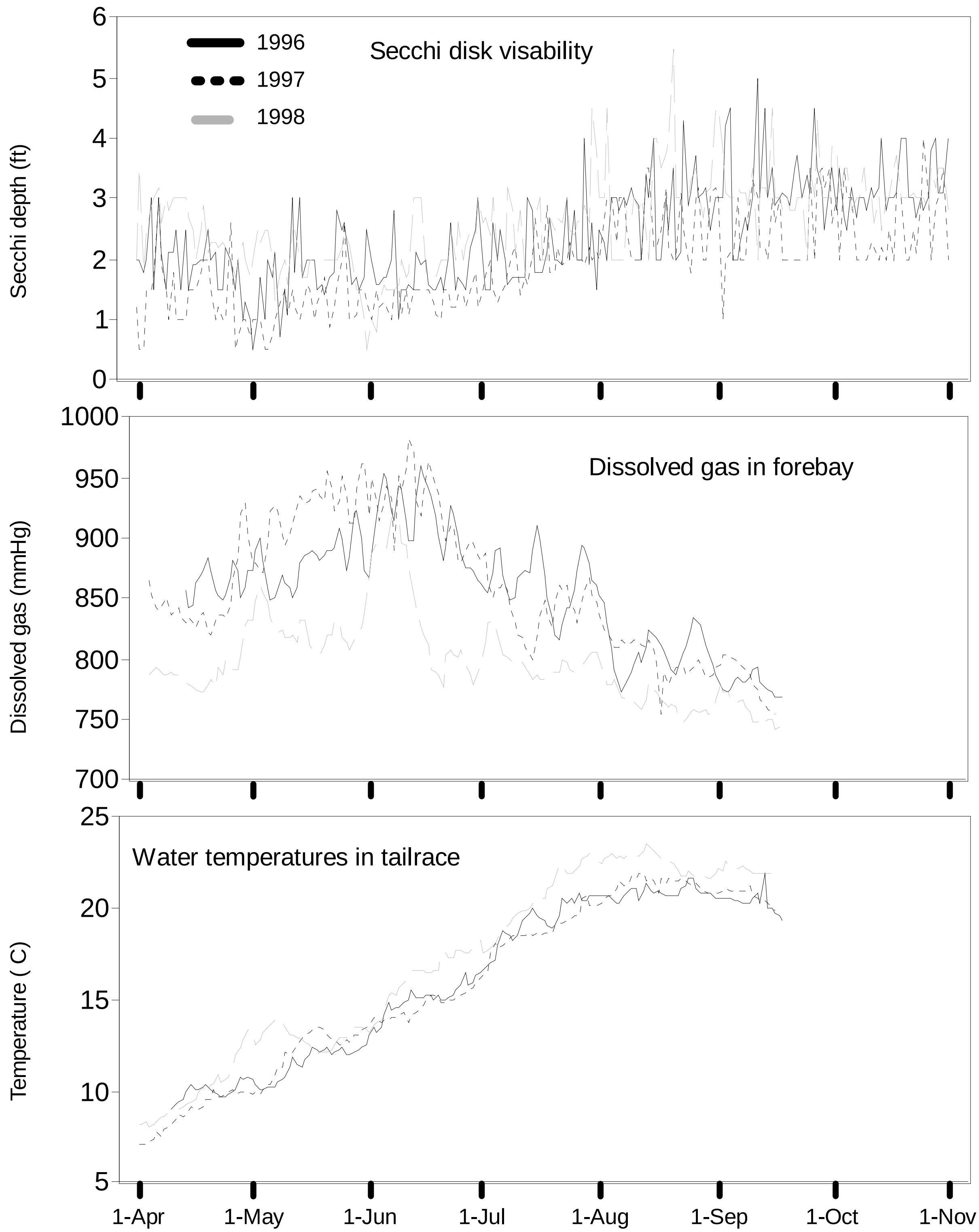

Figure 9. Daily Secchi disk visibility in the forebay, dissolved gas levels in the forebay, and water temperature in the tailrace at John Day Dam in 1996, 1997, and 1998.

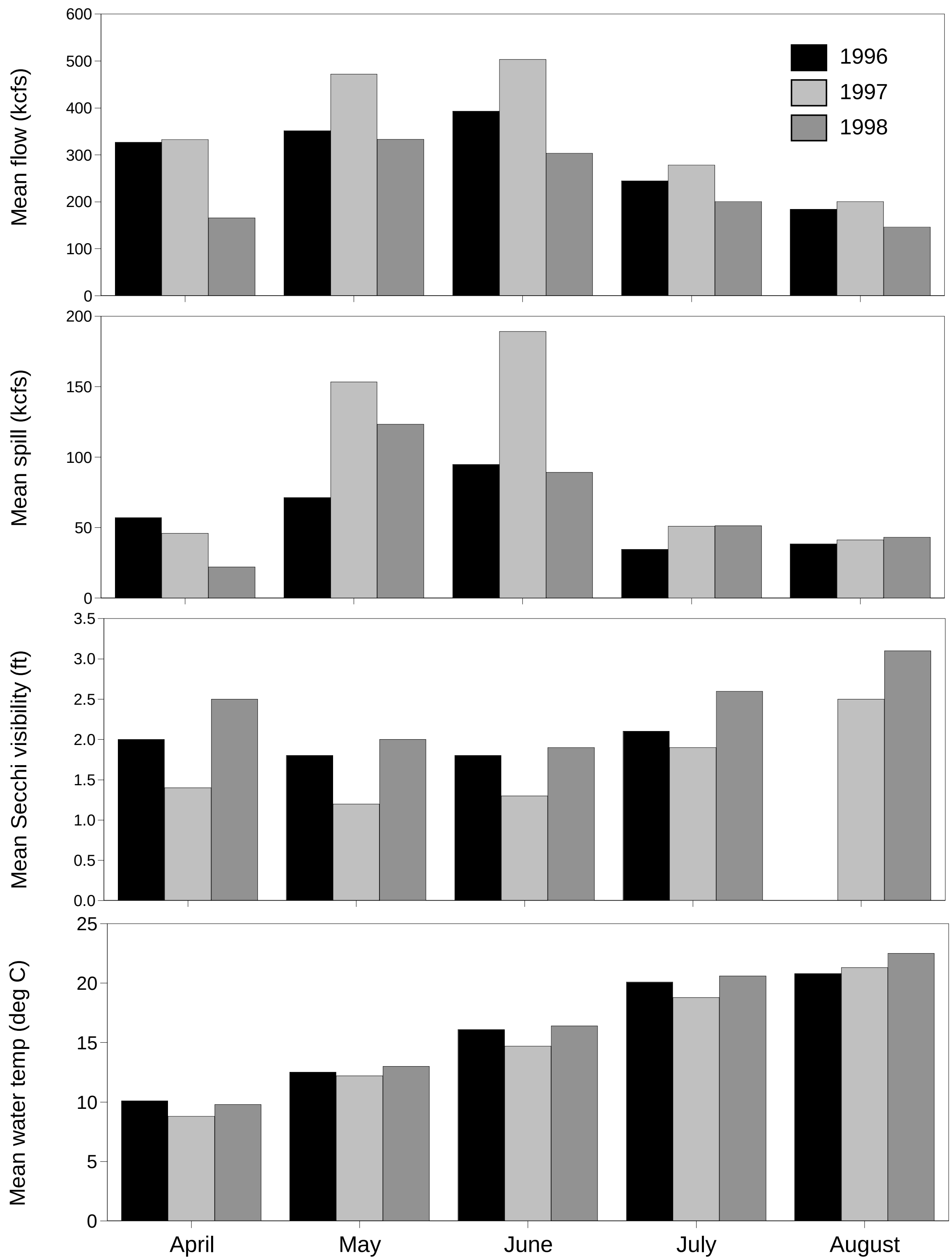

Figure 10. Monthly mean values for flow, spill, Secchi disk visibility, and water temperature in the forebay at John Day Dam in 1996, 1997, and 1998.

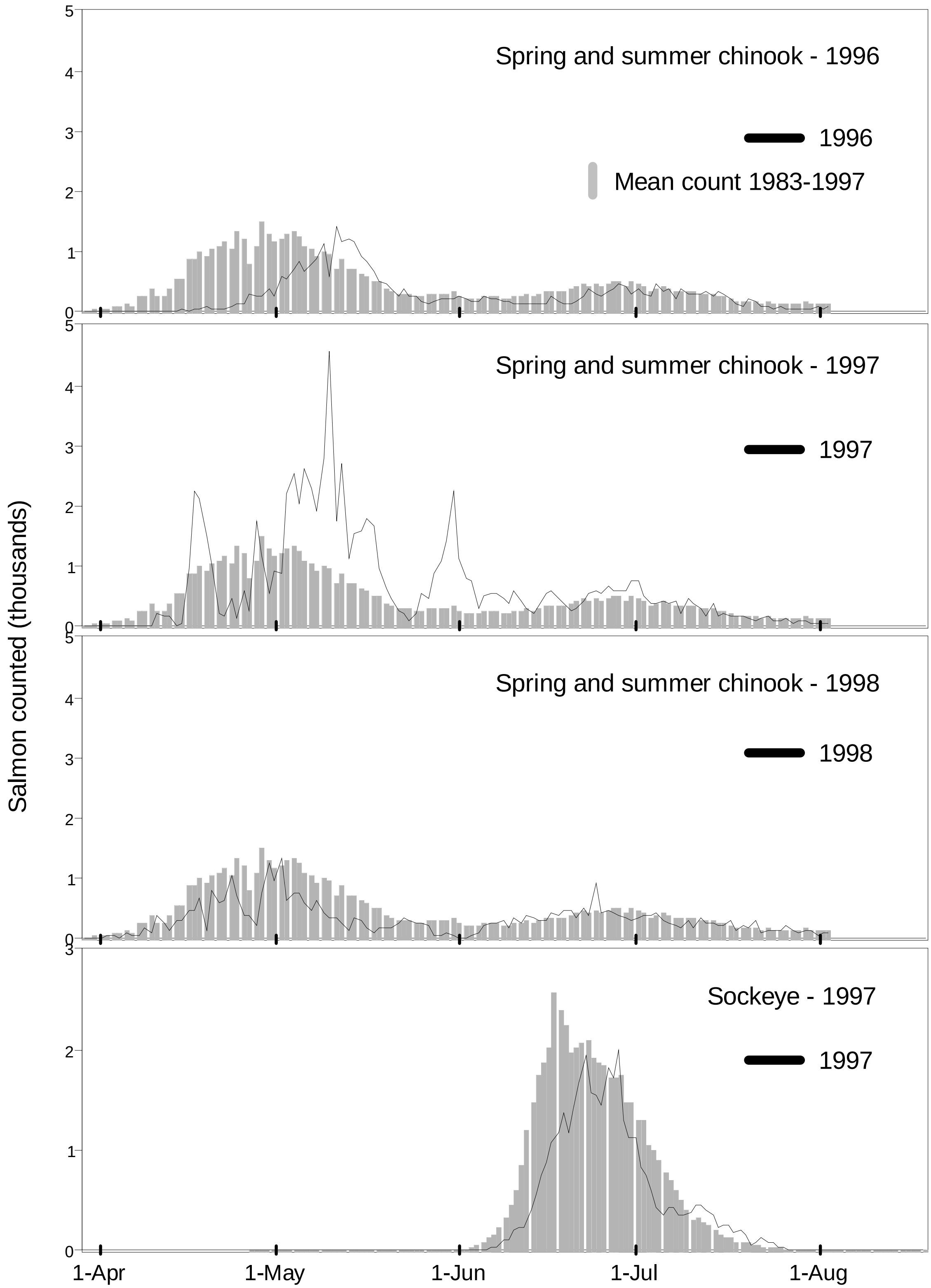

Figure 11. Daily spring and summer chinook salmon, sockeye salmon, steelhead, and fall chinook salmon counts at John Day Dam in 1996, 1997, and 1998, with average counts from 1984 to 1998.

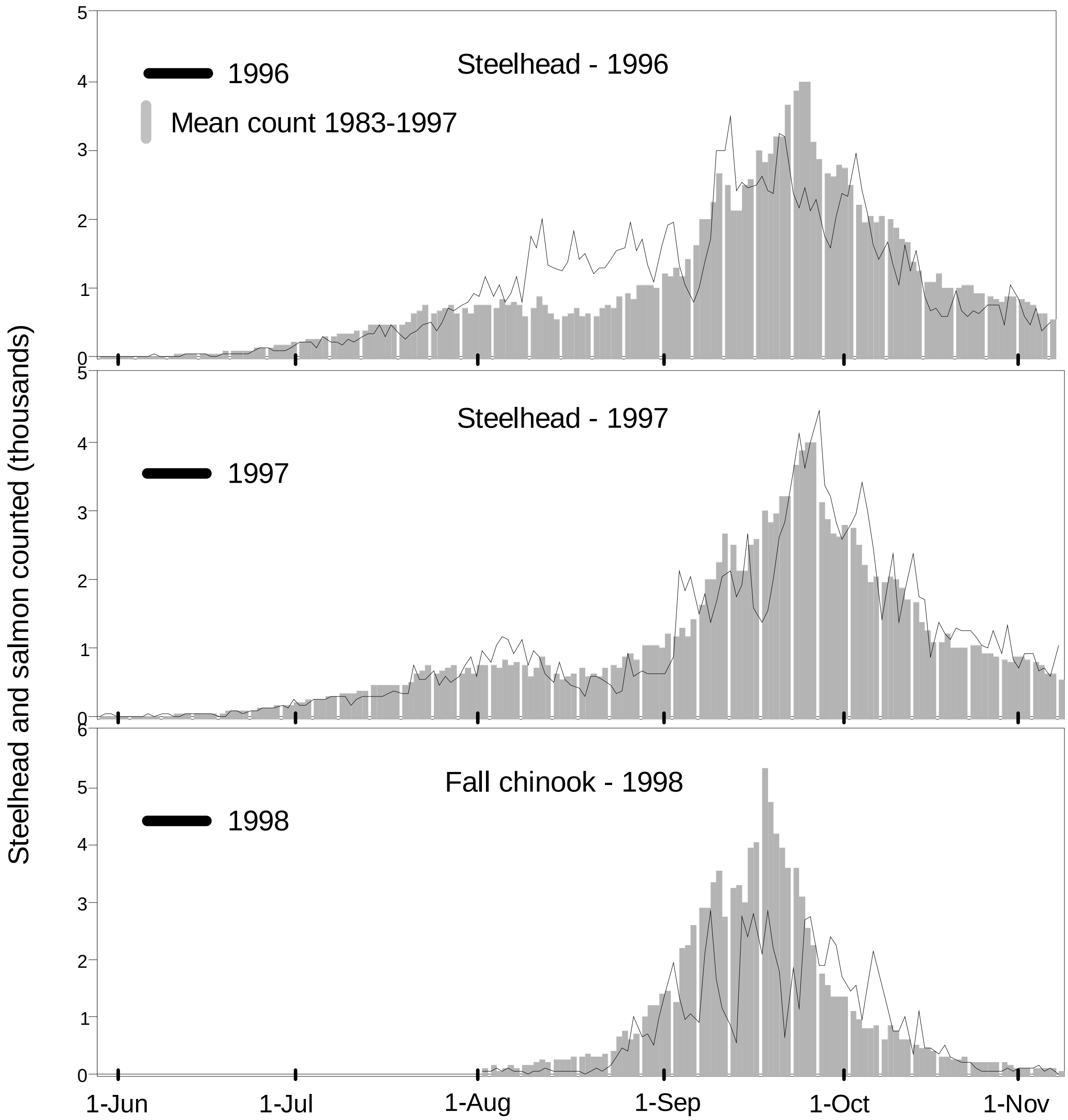

Figure 11 cont.

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.

Antenna coverage relevant to monitoring of fallback behavior of fish at John Day Dam varied slightly between years (Figure 12). Coverage in 1996 was limited to Yagi antennas on both sides of the river about 1.9 km downstream from the dam, underwater antennas at the tops of the ladders, and antennas in the Oregon-shore transition pool and ladder. Coverage was expanded for 1997 with the addition of underwater antennas at fishway entrances at each end of the powerhouse, at the entrance to the Washington- shore ladder, and in the Washington-shore transition pool and ladder. Coverage at entrances, transition pools, and in the ladders varied slightly between 1997 and 1998, but differences should not have affected fallback analyses.

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 John Day Dam (12.3% in 1996, 9.4% in 1997, and 10.5% 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 John Day Dam via any route (Table 1). When only fish recorded at top-of-ladder receivers were used as the denominator, fallback percentages were 13.1% in 1996, 9.7% in 1997, and 11.3% 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 John Day 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 John Day Dam were 14.4% in 1996, 12.1% in 1997, and 11.4% in 1998 (Table 2). When only fish

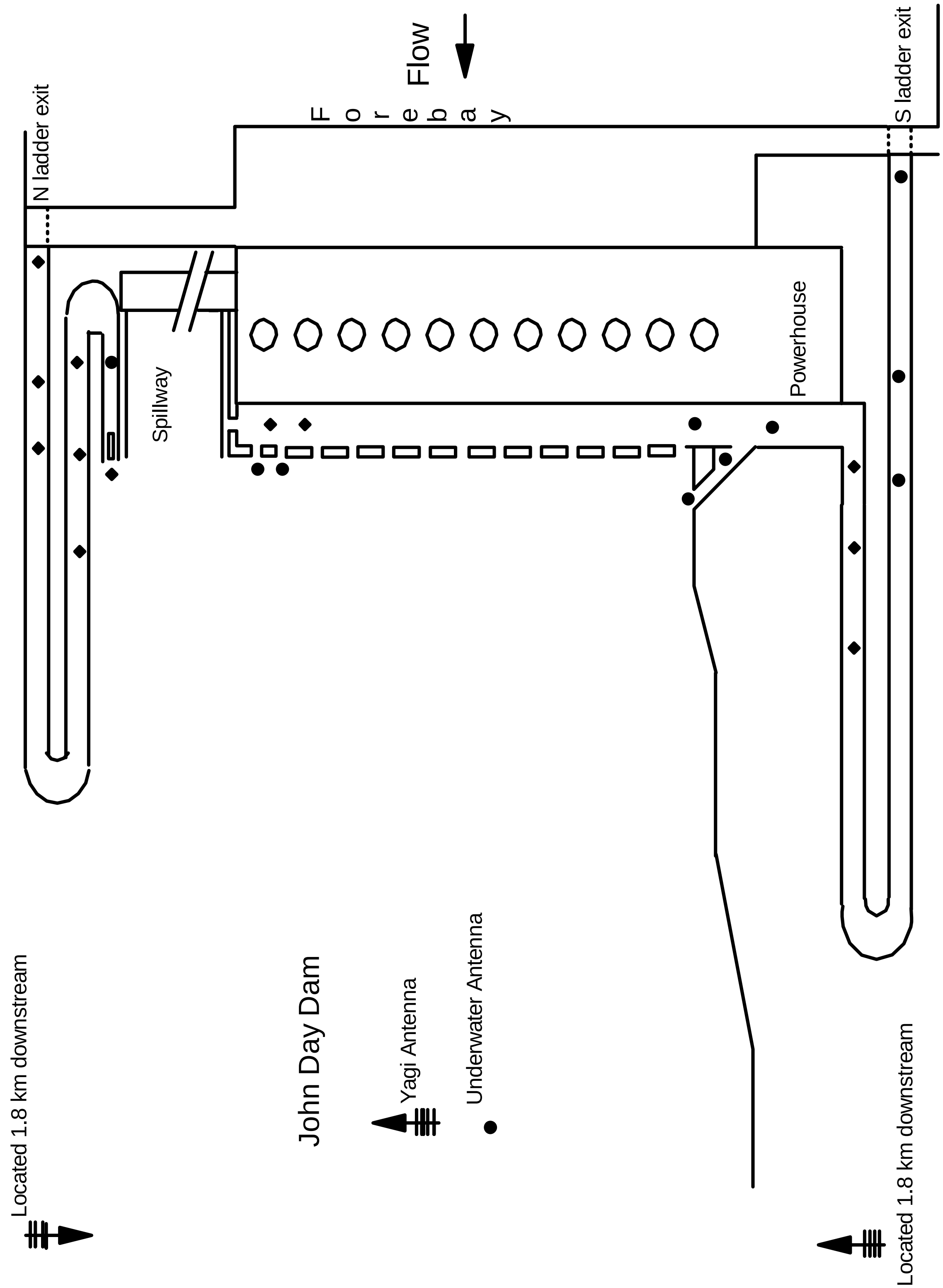

Figure 12. Location of aerial antennas at John Day Dam in 1996, 1997, and 1998, and underwater antennas in 1997 and 1998. See text for underwater antenna locations in 1996.

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 John Day 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	47	383	359	12.3 (9.0-15.6)	13.1 (9.6-16.6)
1997 CK	59	630	611	9.4 (7.1-11.6)	9.7 (7.3-12.0)
1998 CK	67	639	594	10.5 (8.1-12.9)	11.3 (8.7-13.8)
1996 SH[1]	46	460	440	10.0 (7.3-12.7)	10.5 (7.6-13.3)
1996 SH[2]	26	434	417	6.0 (3.8-8.2)	6.2 (3.9-8.6)
1997 SH[1]	44	554	531	7.9 (5.7-10.2)	8.3 (5.9-10.6)
1997 SH[2]	34	506	493	6.7 (4.5-8.9)	6.9 (4.7-9.1)
1997 SK	18	468	430	3.8 (2.1-5.6)	4.2 (2.3-6.1)
1998 FCK	19	481	410	4.0 (2.2-5.7)	4.6 (2.6-6.7)

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

recorded at top-of-ladder receivers were used as the divisor, fallback rates were 15.3% in 1996, 12.4% in 1997, and 12.3% 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 +/- 3.7%. 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 average fallback rate during the time that radio-tagged fish were passing the dam. Weighted fallback rates were within 2% of those based on pooled data in all three years, and confidence intervals were similar for weighted and pooled rates (Figure 14).

Fallback rates, as defined here, offered a more comprehensive view of fallback behavior by spring and summer chinook salmon at John Day Dam because multiple fallbacks by individual fish

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 John Day 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 at top of fishways	FB rate of fish known to pass dam	FB rate of fish that passed fishways
1996 CK	55	383	359	14.4 (10.8-17.9)	15.3 (11.6-19.0)
1997 CK	76	630	611	12.1 (9.5-14.6)	12.4 (9.8-15.1)
1998 CK	73	639	594	11.4 (9.0-13.9)	12.3 (9.6-14.9)
1996 SH[1]	51	460	440	11.1 (8.2-14.0)	11.6 (8.6-14.6)
1996 SH[2]	28	434	417	6.5 (4.1-8.8)	6.7 (4.3-9.1)
1997 SH[1]	50	554	531	9.0 (6.6-11.4)	9.4 (6.9-11.9)
1997 SH[2]	34	506	493	6.7 (4.5-8.9)	6.9 (4.7-9.1)
1997 SK	19	468	430	4.1 (2.3-5.8)	4.4 (2.5-6.4)
1998 FCK	19	481	410	4.0 (2.2-5.7)	4.6 (2.6-6.7)

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

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 escapement adjustment factors).

Of 47 spring and summer chinook salmon that fell back at John Day Dam in 1996, 40 (85%) fell back once, 6 (13%) fell back twice, and 1 (2%) fell back three times; 60% of the fish that fell back ultimately reascended and passed the dam. Of 59 chinook salmon that fell back in 1997, 47 (80%) fell back once, 7 (12%) fell back twice, and 5 (8%) fell back 3 times; 68% of the fish that fell back ultimately reascended and passed the dam. Of 67 chinook salmon that fell back in 1998, 61 (91%) fell back once, and 6 (9%) fell back twice; 64% of the fish that fell back ultimately reascended and passed the dam.

Spring and summer chinook salmon with transmitters that fell back over John Day 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.

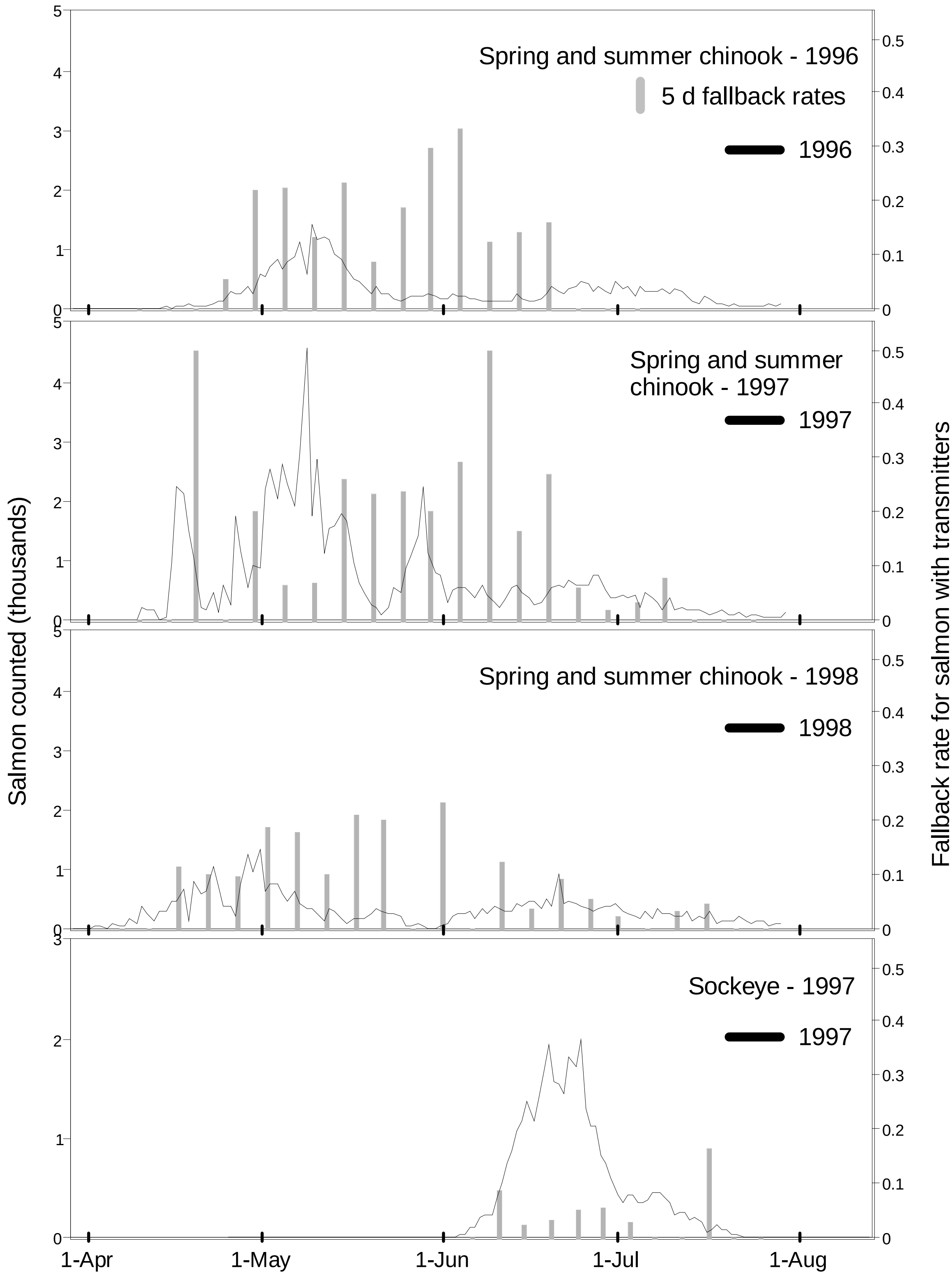

Figure 13. Fallback rates for chinook and sockeye salmon with transmitters based on 5-d blocks, with total salmon counts at John Day Dam ladders in 1996, 1997, and 1998.

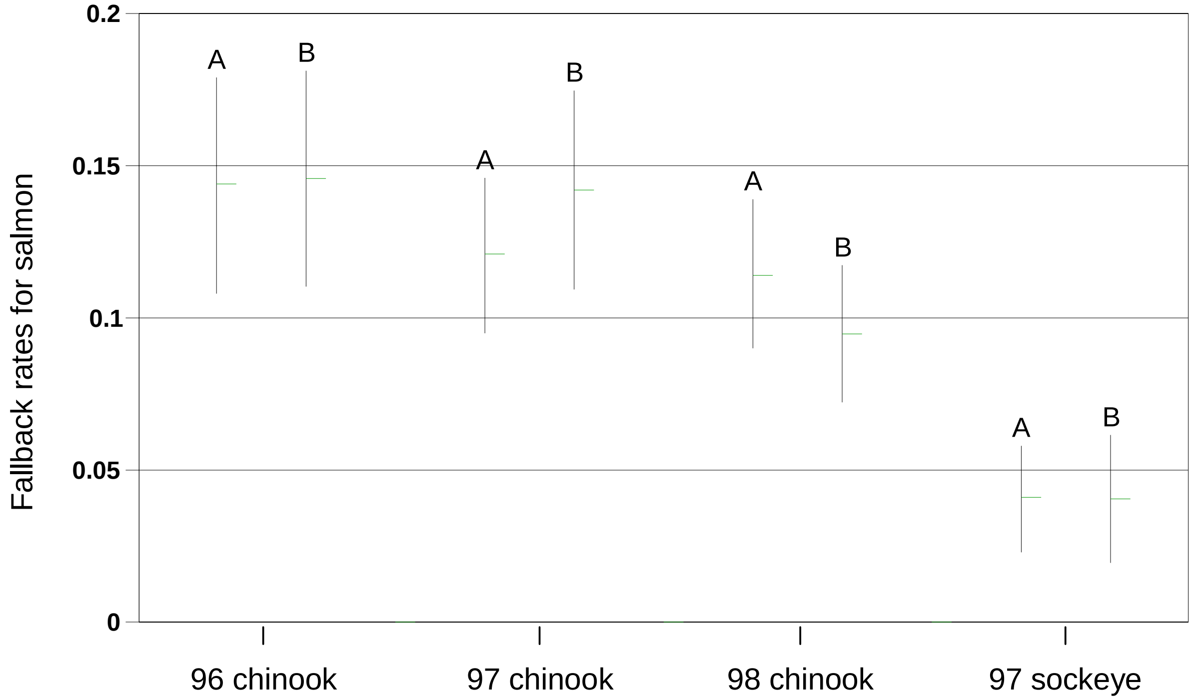

Figure 14. Fallback rates with 95% confidence intervals for radio-tagged spring and summer chinook salmon and sockeye salmon at John Day Dam in 1996, 1997, and 1998. Confidence intervals calculated by (A) pooling all telemetry data, (B) weighting 5-d blocks by total counts of salmon passing ladders and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

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 John Day Dam prior to fallback events at John Day Dam.

In 1996, 24% of all fallback events by spring and summer chinook salmon at John Day Dam occurred less than 24 h after the fish exited from the top of a fishway (Table 3), and 16% occurred less than 12 h after passage. Thirty-six percent 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 past John Day Dam. The remaining 40% of fallback events in 1996 occurred more than 24 h after passing the dam, but fish were not recorded at receivers upriver from the dam (Table 3).

In 1997, 17% of all fallback events occurred less than 24 h after passage and 12% occurred less than 12 h after passage. In 1998, 34% of all fallback events occurred less then 24 h after passage, and 21% occurred less than 12 h after passage. Forty-six percent of spring and summer chinook salmon that fell back in 1997, and 33% of those that fell back in 1998 were recorded at upriver

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 John Day 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	Not recorded upriver
1996 CK	55	13	24	40	38
1997 CK	76	13	17	46	37
1998 CK	73	25	34	33	33
1996 SH[1]	51	12	24	47	29
1996 SH[2]	28	11	39	25	36
1997 SH[1]	50	11	22	44	34
1997 SH[2]	34	11	32	21	47
1997 SK	19	18	95	5	0
1998 FCK	19	4	21	42	37

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

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, 13.5% of the unique fish recorded at the top of the south-shore fishway fell back, compared to 10.3% that fell back after passing via the north-shore fishway, a difference that was not significant (P = 0.45, Z test) (Table 4). In 1997, 10.1% of the unique fish that passed the south-shore fishway fell back, compared to 9.8% that fell back after passing via the north-shore fishway (P = 0.91). In 1998, 9.0% of the unique fish that passed the south-shore fishway fell back, compared to 15.5% that fell back after passing the north-shore fishway, a difference that was significant (P = 0.02) (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 15.9% and the rate for the north-shore fishway was 10.3%, a difference that was no significant (P = 0.21, Z test) (Table 5). In 1997, the fallback rate for the south-shore fishway was 11.8% and the rate for the north-shore fishway was 13.1% (P = 0.67). In 1998, the fallback rate for the south-shore fishway was 9.0% and the rate for the north-shore fishway

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 John Day 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 fishway	Unique fish that fell back	% past SS ladder that FB	Unique fish at top of NS fishway	Unique fish that fell back	% past NS ladder that FB
1996 CK	289	39	13.5	78	8	10.3
1997 CK	475	48	10.1	153	15	9.8
1998 CK	465	42	9.0	187	29	15.5
1996 SH[1]	377	41	10.9	73	6	8.2
1996 SH[2]	355	21	5.9	69	5	7.2
1997 SH[1]	426	36	8.5	120	11	9.2
1997 SH[2]	393	26	6.6	111	8	7.2
1997 SK	265	9	3.4	177	8	4.5
1998 FCK	342	13	3.8	129	5	3.9

[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 John Day 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	289	46	15.9	78	8	10.3
1997 CK	475	56	11.8	153	20	13.1
1998 CK	465	42	9.0	187	31	16.6
1996 SH[1]	377	44	11.7	73	7	9.6
1996 SH[2]	355	22	6.2	69	6	8.7
1997 SH[1]	426	39	9.2	120	11	9.2
1997 SH[2]	393	26	6.6	111	8	7.2
1997 SK	265	9	3.4	177	9	5.1
1998 FCK	342	13	3.8	129	5	3.9

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

was 16.6%, a difference that was significant (P = 0.006) (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 84% of all fallback events in 1996, 74% of all events in 1997, and 58% of all events in 1998 (Table 6). When we only considered fallbacks that occurred within 24 h of passing John Day Dam, chinook salmon had passed via the south-shore fishway prior to 85% of the 1996 events, 54% of the 1997 events, and 56% of the 1998 events (Table 6). More than 70% of tagged spring and summer chinook salmon passed via the south-shore fishway than the north-shore in all years. Fallback rates within 24 h of dam passage were higher for the north-shore ladder in 1997 (p = 0.06) and 1998 (P = 0.08) and higher for the south-shore ladder in 1996 (P = 0.60), but sample sizes were relatively low for the comparisons.

Fallback Percentages and Rates for Sockeye Salmon

The percentage of unique sockeye salmon with transmitters that fell back over John Day Dam in 1997 (3.8%) was calculated by dividing the number of unique fish with transmitters that fell back by the number of unique salmon known to have passed John Day 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 4.2%, and the 95% confidence interval was 2.3% to 6.1% (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 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 John Day Dam in 1997 was 4.1%; the rate was 4.4% using only the number recorded at top-of-ladder receivers with a standard 95% confidence interval from 2.5% to 6.4% (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).

Seventeen of 18 sockeye salmon that fell back at John Day Dam in 1997 fell back once, and one fish fell back twice. Eighty-nine percent of the fish that fell back ultimately reascended and passed the dam.

Ninety-five percent of all fallback events by sockeye salmon in 1997 occurred less than 24 h after fish exited

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 John Day 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	55	84	15	13	85	15
1997 CK	76	74	26	13	54	46
1998 CK	73	58	42	25	56	44
1996 SH[1]	51	86	14	12	83	17
1996 SH[2]	28	79	21	11	82	18
1997 SH[1]	50	78	22	12	82	18
1997 SH[2]	34	76	24	12	82	18
1997 SK	19	47	47	18	50	50
1998 FCK	19	68	26	4	50	50

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

from the top of a fishway (Table 3), and 63% occurred less than 12 h after passage. Just one fish (5%) was recorded at an upstream site before falling back at John Day Dam (Table 3).

Fallback percentages were not 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 3.4% of the unique fish recorded at the top of the south-shore fishway fell back, compared to 4.5% that fell back after passing via the north-shore fishway ($P = 0.55$, Z test) (Table 4). Fallback rates, the number of fallback events divided by the number of unique fish past a fishway, were similar to fallback percentages: 3.4% for the south-shore fishway and 5.1% for the north-shore fishway ($P = 0.38$) (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 47% of all fallback events in 1997, and via the north-shore fishway prior to 47% of all events. When we only considered fallbacks that occurred within 24 h of passing John Day Dam, sockeye salmon had passed via the south-shore fishway prior to 50% of the 1997 events, and via the north-shore fishway prior to 50% of all events (Table 6). Fallback rates within 24 h of dam passage were not significantly different for the two fishways ($P = 0.38$, 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 John Day 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 8% of radio-tagged fish passed the dam for the first time after 31 October in both years, but 45% of all fallbacks by steelhead tagged in 1996 and 32% 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 insight into fallback behavior by steelhead at John Day Dam.

All passages and fallbacks included: - The percentage of unique steelhead with transmitters that fell back over John Day Dam (10.0% for fish tagged in 1996, 7.9% 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 John Day 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 10.5% for fish tagged in 1996 and 8.3% for fish tagged in 1997. Standard 95% confidence intervals for steelhead fallback percentages were +/- 2.9% in 1996 and +/- 2.4% 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 John Day Dam, were 11.1% (+/- 2.9%) for fish tagged in 1996 and 9.0% (+/- 2.4%) for fish tagged in 1997 (Table 2). When only fish recorded at top-of-ladder receivers were included, fallback rates were 11.6% (+/-3.0%) for 1996 fish and 9.4% (+/- 2.5%) for 1997 fish. Confidence intervals in Table 2 were based on pooled data for all radio-tagged fish in each tagging year.

Of 46 steelhead tagged in 1996 that fell back at John Day Dam, 42 (91%) fell back once, 3 (7%) fell back twice, and 1 (2%) fell back three times; 46% of the steelhead that fell back ultimately reascended and passed the dam. Of 44 steelhead tagged in 1997 that fell back at John Day Dam, 39 (89%) fell back once, 4 (9%) fell back twice and 1 fish fell back 3 times. Thirty-three (75%) of the steelhead that fell back ultimately reascended and passed the dam.

Twenty-four percent of all fallback events by steelhead tagged in 1996 and 22% 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). Forty-seven percent steelhead tagged in 1996 and 44% of those tagged in 1997 were recorded at upriver tributaries or dams before they fell back. The remaining 29% of events by 1996 steelhead and 34% of events by 1997 fish occurred more than 24 h after passing, but fish 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 10.9% percent of the unique fish recorded at the top of the south-shore fishway fell back, compared to 8.9% that fell back after passing via the north-shore fishway (P = 0.50, 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 11.7% and the rate for the north-shore fishway was 9.6% (P = 0.61) (Table 5).

Fallback percentages for steelhead tagged in 1997 were 8.5% for fish that passed via the south-shore fishway and 9.2% for fish that passed the north-shore fishway, a non-significant difference (P = 0.80, 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 9.2% for fish that passed the south-shore fishway as well as for fish that passed the north-shore fishway (P = 0.99) (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 86% of all fallback events, and via the north-shore fishway prior to 14% of all events. When we only considered fallbacks that occurred within 24 h of passing John Day Dam, steelhead tagged in 1996 had passed via the south-shore fishway prior to 83% of all events (Table 6). Steelhead tagged in 1997 passed via the south-shore fishway prior to 78% of all fallback events, and via the north-shore fishway prior to 22% of all events. Steelhead had passed the south-shore fishway prior to 9 (82%) of 11 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 > 0.50, Z tests).

Passages and fallbacks through 31 October of tagging year: - Twenty-six of 46 (57%) steelhead tagged in 1996 that fell back at John Day Dam fell back at least once before 1 November; 20 fish fell back 23 times after 31 October 1996, with 15 of the events in 1997. Among steelhead tagged in 1997, 34 of 44 (77%) that fell back at John Day Dam fell back at least once before 1 November; 15 fish fell back 16 times after 31 October, with 10 of the events in 1998 (see Figure 36). We calculated the percentage of unique steelhead with transmitters that fell back over John Day Dam through 31 October of the tagging year (6.0% for fish tagged in 1996, 6.7% 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 John Day Dam (Table 1). When only fish recorded at top-of-ladder receivers were used as the divisor, the fallback percentage was 6.2% (+/- 2.3%) for fish tagged in 1996 and 6.9% (+/- 2.2%) 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 John Day Dam through 31 October were 6.5% in 1996 and 6.7% in 1997 (Table 2). When only fish recorded at top-of-ladder receivers were included, the fallback rate was 6.7% (+/- 2.4%) for 1996 fish and 6.9% (+/- 2.2%) 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 John Day Dam. Despite the gap between passage date and fallback date for some steelhead, the weighted fallback rate was very similar to the pooled rate for fish outfitted with transmitters in 1997. The weighted rate was lower than the pooled rate for 1996, mostly because some 5-d blocks with high numbers of steelhead counted passing the dam had relatively low fallback rates for radio-tagged fish (Figure 16.)

Of 26 steelhead that fell back at John Day Dam through 31 October 1996, 24 (92%) fell back once and 2 (8%) fell back twice; 62% ultimately reascended and passed the dam. All 34 steelhead that fell back at John Day Dam through 31 October 1997 fell back once; 74% ultimately reascended and passed the dam.

Thirty-nine percent of 28 fallback events by steelhead through 31 October 1996 occurred less than 24 h after the fish exited from the top of a ladder at John Day Dam; 25% were recorded at upstream tributaries or dams before they fell back, and 36% fell back more than 24 h after passage, but were not recorded upstream (Table 3). Thirty- two percent of 34 fallback events by steelhead through 31 October 1997 occurred less than 24 h after the fish exited from the top of a ladder; 21% were recorded at upstream tributaries or dams before they fell back, and 47% 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, 5.9% of the unique fish that were recorded at the top of the south-shore fishway fell back, compared to 7.2% that fell back after passing via the north-shore fishway (P = 0.67, 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 6.2% and the rate for the north-shore fishway was 8.7% (P = 0.45) (Table 5).

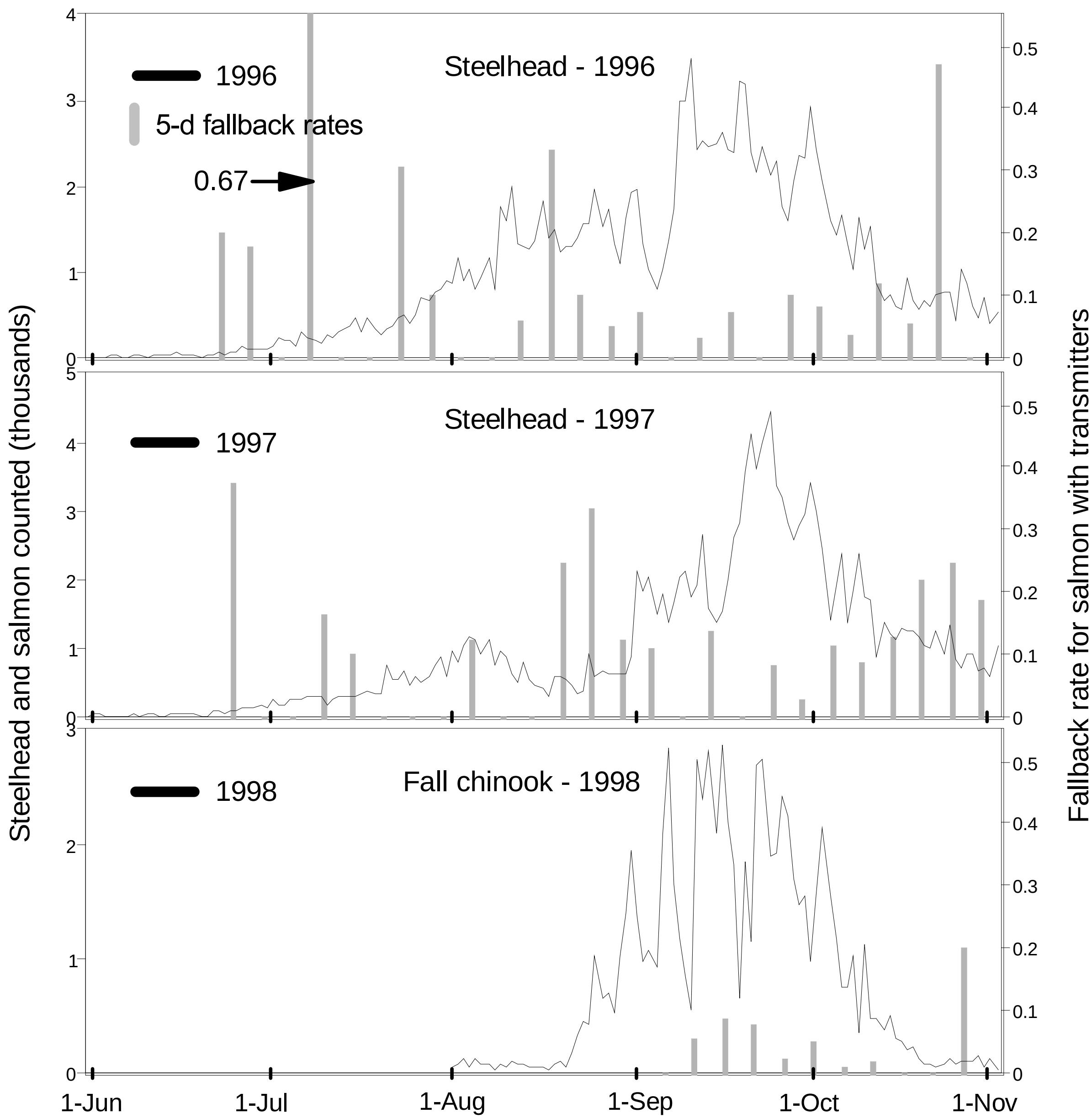

Figure 15. Fallback rates for steelhead and fall chinook salmon with transmitters based on 5-d blocks, with total counts at John Day Dam ladders in 1996, 1997, and 1998.

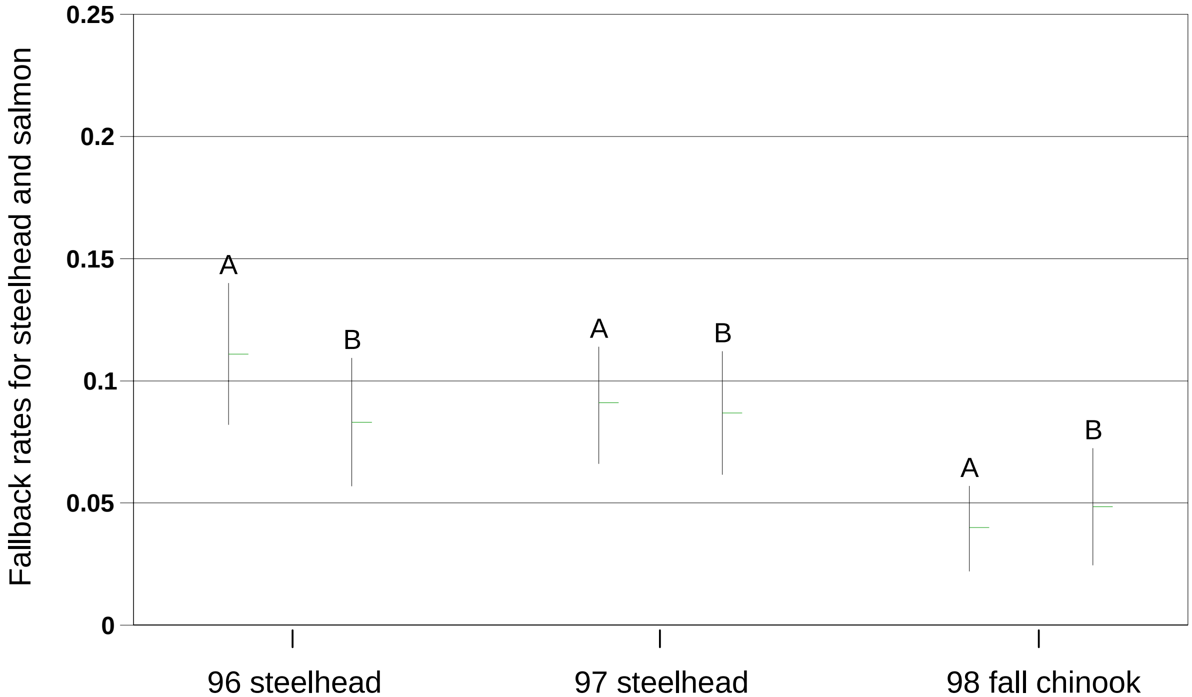

Figure 16. Fallback rates with 95% confidence intervals for radio-tagged steelhead and fall chinook salmon at John Day Dam in 1996, 1997, and 1998. Confidence intervals calculated by (A) pooling all telemetry data, (B) weighting 5-d blocks by total counts of salmon passing ladders and computing fallback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

Fallback percentages and rates for steelhead tagged in 1997 through 31 October were 6.6% for fish that passed via the south-shore fishway and 7.2% for fish that passed the north-shore fishway (Table 4). Differences in percentages and rates between ladders were not significant (P = 0.83, 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 79% of all fallback events, and via the north-shore fishway prior to 21% of all events. When we only considered fallbacks that occurred within 24 h of passing John Day Dam, steelhead tagged in 1996 had passed via the south-shore fishway prior to 82% of all events (Table 6). Through 31 October, steelhead tagged in 1997 passed via the south-shore fishway prior to 76% of all fallback events, and via the north-shore fishway prior to 24% of all events. Steelhead had passed the south-shore fishway prior to 82% of 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 > 0.50, Z tests).

Fallback Percentages and Rates for Fall Chinook Salmon

The percentage of unique fall chinook salmon with transmitters that fell back over John Day Dam in 1998 (4.0%) was calculated by dividing the number of unique fish with transmitters that fell back by the number of unique fish known to have passed John Day 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 4.6%, and the 95% confidence interval was 2.6% to 6.7% (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 John Day Dam in 1998 was 4.0%; the rate was 4.6% using only the number recorded at top-of-ladder receivers with a standard 95% confidence interval from 2.6% to 6.7% (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 was not strictly proportional to the portion sampled, weighted 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%.

All 19 fall chinook salmon that fell back at John Day Dam in 1998 fell back one time. Just one fish (5%) that fell back ultimately reascended and passed the dam.

Twenty-one 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). Forty-two percent were recorded at upstream tributaries or dams before falling back at John Day Dam, and 37% 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 3.8% of the unique fish recorded at the top of the south-shore fishway fell back, compared to 3.9% that fell back after passing via the north-shore fishway ($P = 0.97$, Z test) (Table 4). Ladder fallback rates, the number of fallback events divided by the number of unique fish past a fishway, were also 3.8% for the south-shore fishway and 3.9% for the north-shore fishway (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 68% of all fallback events in 1998, and via the north-shore fishway prior to 26% of all events. When we only considered fallbacks that occurred within 24 h of passing John Day Dam, fall chinook salmon had passed via the each fishway prior to 50% of the events (Table 6). Fallback rates within 24 h of dam passage were 0.6% for the south-shore fishway and 1.6% for the north-shore fishway, a difference that was not significant (P = 0.27, Z test).

Escapement Past John Day 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 John Day 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 John Day 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 or fishway receivers that were not recorded passing via ladders while receivers were functioning, but were recorded at sites upstream from John Day Dam. Based on those criteria, we suspected that 1.4% to 3.6% of radio-tagged spring and summer chinook salmon, 1.3% to 1.7% of steelhead, 7.9% of sockeye salmon, and 1.9% 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 John Day 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 John Day 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 John Day Dam were 0.871 in 1996, 0.889 in 1997, and 0.894 in 1998, with standard 95% confidence intervals confidence of +/- 0.014 (Table 7). Intervals for pooled values were assuming normally distributed errors and a normal binomial approximation. Weighted AF values based on all data for radio-tagged fish differed from pooled values by less than 0.004 in all years, an indication that temporal variation in spring and summer chinook salmon fallback and reascension rates was relatively minor (Figure 17). The 95% confidence intervals for weighted AF values were +/- 0.030.

We calculated escapements of spring and summer chinook salmon past John Day Dam by multiplying fish counts reported by USACE by pooled and weighted AFs (Table 8). In 1996 the

Table 7. Unique fish with transmitters known to have passed John Day 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	383	n/a	47	28	418	0.871
1997 CK	630	n/a	59	40	687	0.889
1998 CK	639	n/a	67	43	688	0.894
1996 SH	460	n/a	46	21	486	0.895
1997 SH	554	n/a	44	33	593	0.916
1997 SK	468	n/a	18	16	485	0.961
1998 FCK	481	n/a	19	1	482	0.961

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

USACE adult spring and summer chinook salmon count at John Day Dam was 30,481 fish. The adjusted count using the pooled AF at was 26,549 with a positive bias of 3,962 fish (14.9%) (Table 8). The 1997 USACE adult chinook salmon count at Bonneville Dam was 82,761 fish and the adjusted count using the pooled AF 73,575 with a positive bias of 9,186 fish (12.5%). The 1998 USACE adult chinook salmon count was 38,046 fish and the adjusted count using the pooled AF was 34,013 with a positive bias of 4,033 fish (11.9%) (Table 8). Standard 95% confidence intervals for the adjusted escapements were within +/- 1.4%, or +/- 366 fish in 1996, 1,075 fish in 1997, and 533 fish in 1998.

Pooled AF values in Table 7 did not include estimated passage through the navigation lock. Adjustment values increased by 0.03 in 1996, 0.017 and 1997 and 0.012 in 1998 with the inclusion of estimated lock passage and positive biases decreased by about 910 fish in 1996, 1,490 fish in 1997, and 460 fish in 1998.

Because weighted adjustment factors for spring and summer chinook salmon were not substantially different from pooled factors, weighted escapement biases were similar to pooled biases at 3,749 fish (14.0%) in 1996, 8,276 fish (11.1%) in 1997, and 3,843 fish (11.2%) in 1998 (Table 8). Biases based on pooled data were slightly higher than weighted biases in all years.

Sockeye salmon: - We calculated pooled and weighted adjustment factors (AF) for sockeye salmon at John Day Dam using the same methods described above for spring and summer chinook salmon. The pooled AF was 0.961, and included all passages and fallbacks by sockeye

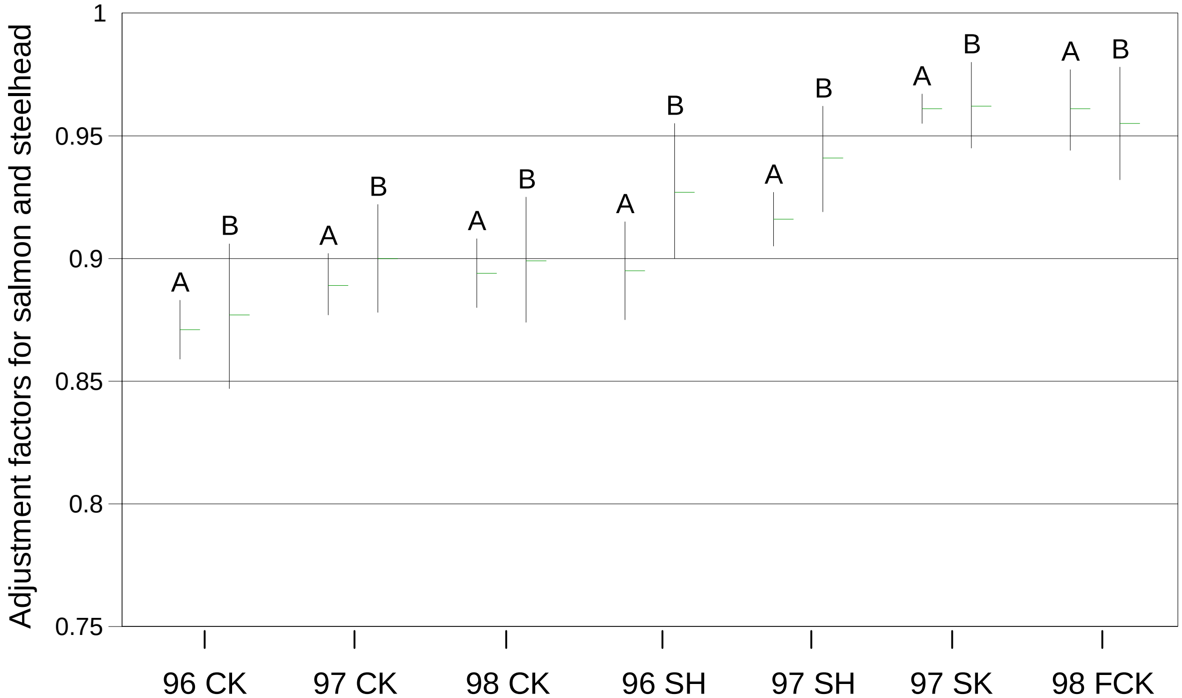

Figure 17. Values for escapement adjustment factor for chinook salmon, steelhead, sockeye salmon, and fall chinook salmon at John Day Dam from 1996 to 1998. 95% confidence intervals calculated by (A) pooling all radio-telemetry data and taking standard binomial distribution, (B) weighting 5-d blocks 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 John Day 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	30,481	26,549 (+/- 366)	3,932	3,749
1997 CK	82,761	73,575 (+/- 1,075)	9,186	8,276
1998 CK	38,046	34,013 (+/- 533)	4,033	3,843
1996 SH	156,924	140,447 (+/- 3,138)	16,477	11,455
1997 SH	159,442	146,049 (+/- 1,754)	13,393	9,407
1997 SK	35,830	34,433 (+/- 215)	1,397	1,362
1998 FCK	78,237	75,186 (+/- 1,251)	3,051	3,521

salmon (Table 7). We calculated escapements of sockeye salmon past John Day Dam by multiplying fish counts reported by USACE by the pooled adjustment factor. The adult count in 1997 was 35,830 fish, and the adjusted escapement count was 34,433 fish (+/- 215) with a positive bias of 1,397 (4.1%) (Table 8).

The pooled AF value in Table 7 did not include an estimated passage rate of 7.9% through the navigation lock. The pooled AF increased by ~ 0.079 to 1.040 with the inclusion of estimated lock passage, indicating that passage through the lock more than compensated for positive bias created by fallback and reascension. With the estimated lock passage, we found a negative bias of 1,433 sockeye salmon (3.8%).

The weighted AF for sockeye salmon was 0.962 with all radio-tagged fish included, with a positive bias of 1,362 fish (4.0%) (Table 8). The AF values were similar for both weighted and pooled AFs, an indication that our sampling was reasonably representative and that temporal variation in sockeye salmon fallback and reascension rates was relatively minor (Figure 17).

Steelhead: - We calculated pooled and weighted adjustment factors (AF) for steelhead at John Day Dam using the same methods described above for spring and summer chinook salmon. Pooled AFs were 0.895 for steelhead tagged in 1996 and 0.916 for those tagged in 1997, and included all passages and fallbacks by steelhead (Table 7).

We calculated escapements of steelhead past John Day Dam by multiplying fish counts reported by USACE by the pooled AFs. The adult count for the 1996-1997 run- year was 156,924 fish, and the adjusted escapement count was 140,447 fish with a positive bias of 16,477 (11.7%). The 1997-1998 run-year count was 159,442, and the adjusted count was 146,049 fish with a positive bias of 13,393 fish (9.2%) (Table 8). The standard 95% confidence intervals for pooled adjustments were +/- 3,140 steelhead in the 1996-1997 run-year and +/- 1,750 fish in the 1997-1998 run-year (Table 8).

Pooled AF values in Table 7 did not include estimated passage rates of 1.7% and 1.3% through the navigation lock in the two years. Pooled AFs increased by about 0.015 and 0.011 with the inclusion of estimated lock passage and positive biases decreased by about 2,350 fish in the 1996-1997 run-year, and 1,750 fish in the 1997-1998 run-year.

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 John Day 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 John Day Dam, we could not include in calculations those fallbacks and reascensions by radio-tagged steelhead that occurred after 31 October. Weighted AFs were 0.927 for fish tagged in 1996 and 0.941 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 11,455 fish

(7.9%) in the 1996-1997 run-year and 9,407 fish (6.3%) in the 1997-1998 run-year (Table 8).

Fall chinook salmon: - We calculated pooled and weighted adjustment factors (AF) for fall chinook salmon at John Day 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 John Day Dam were higher in August when spill was occurring than during the no-spill period that began 1 September.

The pooled AF was 0.961, and included all passages and fallbacks by fall chinook salmon (Table 7). We calculated escapements of fall chinook salmon past John Day Dam by multiplying fish counts reported by USACE by the pooled adjustment factor. The full-season adult count in 1998 was 78,237 fish, and the adjusted escapement count was 75,186 fish (+/- 1,250) with a positive bias of 3,051 (4.1%) (Table 8). The 1998 fall chinook salmon count from 1 September to 31 October was 68,478. When we applied the pooled AF to this portion of the run only, the positive bias was 2,671 (4.1%).

The pooled AF value in Table 7 did not include an estimated passage rate of 1.9% through the navigation lock. The pooled AF increased by 0.018 to 0.979 with the inclusion of estimated lock passage, and positive bias decreased by about 1,410 fall chinook salmon.

The weighted AF was slightly lower than the pooled AF for fall chinook salmon because the highest fallback rates were recorded when relatively few fall chinook salmon were passing the dam at the end of the migration (Figure 17; also see Figure 15). The weighted AF was 0.955 with all radio-tagged fish included, with a positive bias of 3,521 fish (4.7%) (Table 8).

Fallback Routes by Radio-Tagged Salmon and Steelhead

Spring and summer chinook salmon: - Antenna and receiver configurations at John Day 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 (> 68%) 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 the juvenile bypass in 1996 or 1997). In all three years, 100% of the recorded fallback events by radio-tagged fish were on days when spill was occurring. A small number of fish in each year fell back and were not recorded at any receivers, but were recorded downstream in the Deschutes River or at The Dalles Dam. Because we know those fish passed tailrace receivers, we designated the tailrace as the location of first record after fallback.

With limited fishway receiver coverage in 1996, 91% of all fallback events by chinook salmon were first recorded downstream from the dam at tailrace sites and 7% were first recorded at fishway sites. In 1997, 80% of all events were first recorded at tailrace sites, 8% were first recorded at north-shore fishway entrances adjacent to the spillway, and 11% were first recorded at powerhouse fishway entrances. In 1998, 69% of all events were first recorded at tailrace sites, 7% were first recorded at north-shore fishway entrances adjacent to the spillway, 16% were first recorded at powerhouse fishway entrances, and 8% were recorded falling back through the juvenile collection channel. The juvenile bypass was only monitored in 1998.

In 1996, 77% of all salmon that fell back within 24 h were first recorded at tailrace receivers. In 1997 and 1998, 40% to 46% of fallback events within 24 h were first recorded at tailrace sites. Another 16% to 23% were first recorded at antennas in the north-shore fishway entrance adjacent to the spillway, and 31% to 36% were recorded at powerhouse fishway entrances. Two fish (8%) that fell back within 24 h in 1998 fell back through the juvenile channel.

We believe 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.

Sockeye salmon: - As with chinook salmon, we believe most sockeye salmon with transmitters that fell back over John Day 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, 53% of the sockeye salmon were first recorded at the tailrace sites, 26% were first recorded at powerhouse fishway entrances, and 21% were first recorded at antennas in the north-shore fishway entrance adjacent to the spillway. Only one sockeye salmon fell back more than 24 h after passage, and it was first recorded in the tailrace.

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

Steelhead: - We estimated that approximately 76% of fallback events by steelhead tagged in 1996 and 46% of events by steelhead tagged in 1997 fell back on days when spill was occurring at John Day Dam. (Note: about 33% of all fallback events in 1996 occurred during September and October when spill was approximately 1 kcfs; about 50% of all events in 1997 occurred in September and October when spill alternated between approximately 0 and 1 kcfs). With limited fishway receiver coverage in 1996, 82% of all fallback events were first recorded at tailrace sites and 18% were first recorded at fishway receivers. Seven of 12 (58%) fallbacks that occurred within 24 h of passage in 1996 were first recorded at fishway receivers. All of the fallback events within 24 h of passage occurred on days with spill, including 7 on days when spill was approximately 1 kcfs.

In 1997, 64% of all fallback events were first recorded at tailrace sites, 28% were first recorded at powerhouse fishway sites, and 4% were first recorded at north-shore fishway entrances adjacent to the spillway. For the events that occurred within 24 h of passage in 1997, 55% were first recorded at tailrace sites, 36% were first recorded at the powerhouse fishway receivers, and 9% were first recorded at north-shore fishway entrances adjacent to the spillway.

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

Fall chinook salmon: - Because radio-tagged fall chinook salmon did not begin passing John Day 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 John Day Dam were also via the lock.

After all fallback events at John Day Dam, 79% of the fall chinook salmon were first recorded at the tailrace sites, 16% were first recorded at powerhouse sites, and 5% were first recorded at north-shore fishway entrances adjacent to the spillway. Three off the 4 fallbacks within 24 h were first recorded at tailrace sites. As with other species, inferences regarding fallback routes based on first downstream telemetry records at John Day Dam should be made with caution.

Effects of Environmental Factors on Spring/Summer Chinook Salmon Fallbacks

Flow, spill, turbidity, and dissolved gas levels at John Day 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 John Day 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. To address these concerns we analyzed fallback rates using moving average techniques, multi-day blocks, blocks based on flow and spill, 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 would 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 had positive slopes in all three years (Figures 18 and 19), but flow and spill accounted for a small proportion of the variability of that measure of fallback rate (r^2 = 0.06 to 0.15). 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 John Day 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.

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 John Day Dam. Correlations between moving average ratios and environmental variables at the dam (flow, spill, turbidity, dissolved gas, temperature) were relatively weak in 1996 and 1998 and moderate in 1997 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, 13 chinook salmon with transmitters fell back within 24 h of passage at John Day Dam. Using only these fallback events, the highest moving average ratios of 5-d mean fallback events to 5-d mean passage occurred during late May (Figure 20). A fallback ratio nadir occurred during mid-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 12 April and 10 July, the period when all radio-tagged spring and summer chinook salmon passed John Day Dam in 1996. Very low proportions of the variability in the 5-d fallback ratio were accounted for by flow, spill, dissolved gas, or Secchi disk visibility (r^2 ~ 0.02, 0.01, 0.03, and 0.00, Figure 21).

In 1997, 13 chinook salmon with transmitters fell back within 24 h of passage at John Day Dam. Fish with transmitters began to pass the dam in early April, but the first fallback within 24 h did not occur until the first week of May

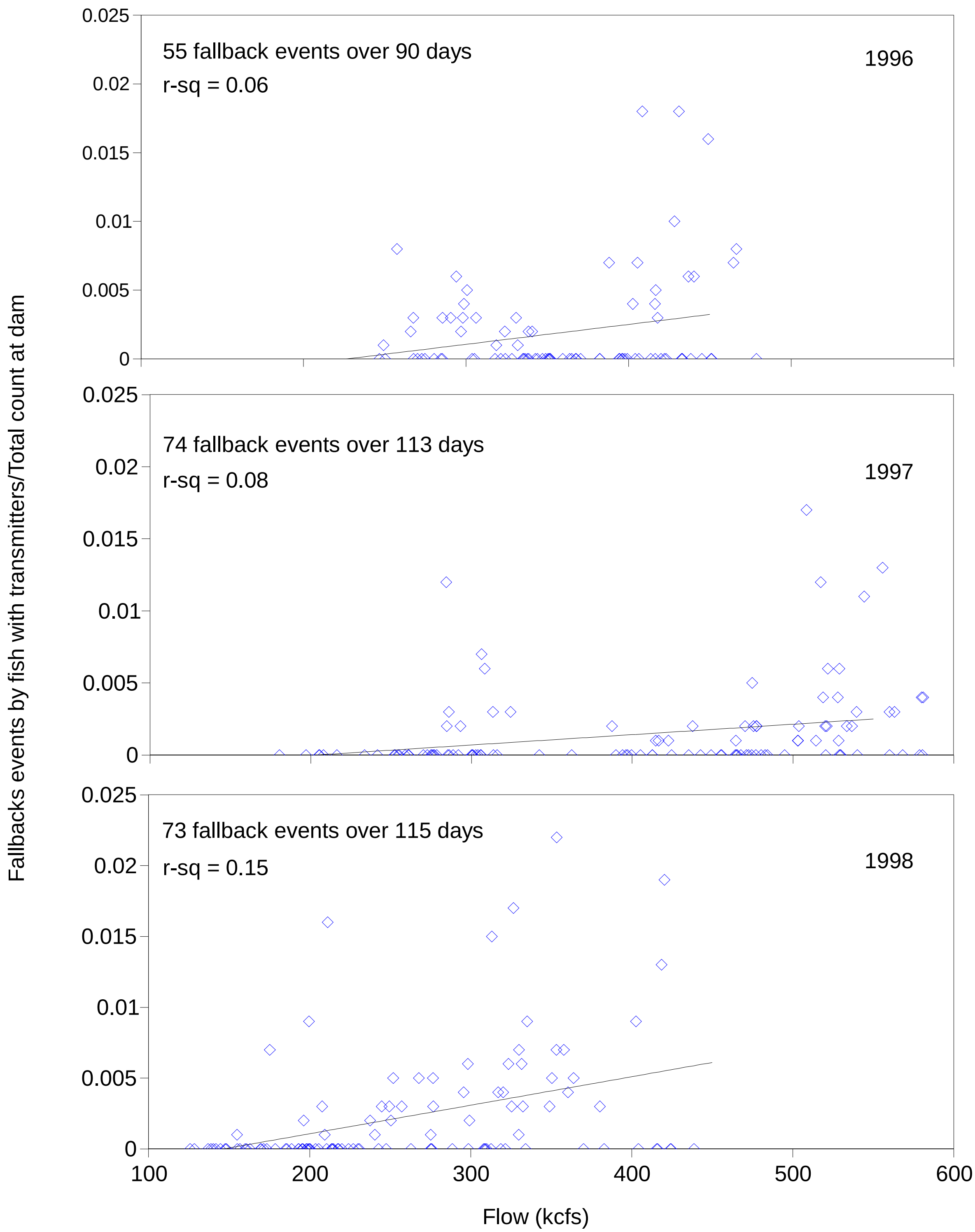

Figure 18. Relation of the ratio (fb_n/c_n) of spring and summer chinook salmon with transmitters that fell back (fb_n) divided by the number counted (c_n) each day at John Day Dam to daily flow in 1996, 1997, and 1998.

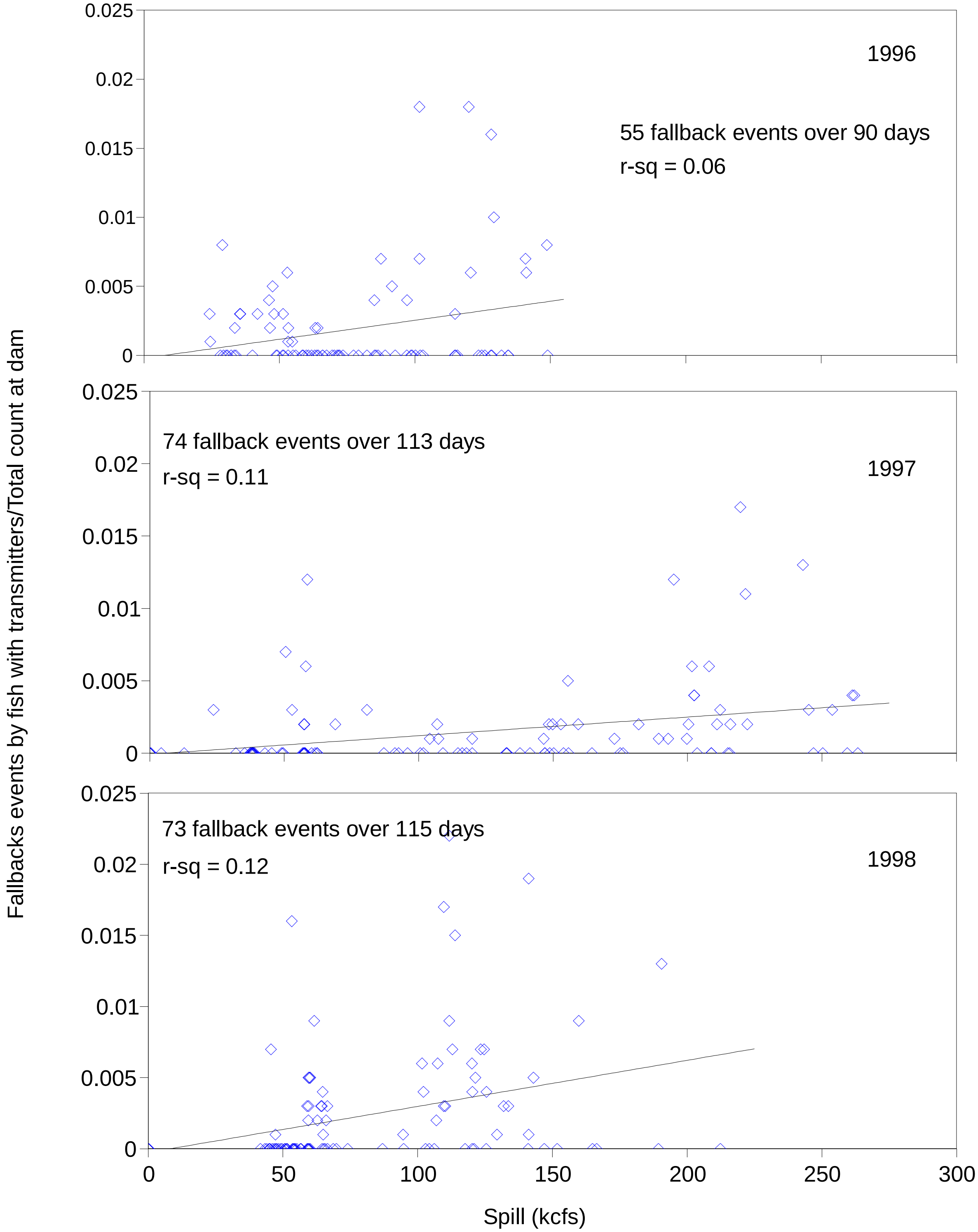

Figure 19. Relation of the ratio (fb_n/c_n) of spring and summer chinook salmon with transmitters that fell back (fb_n) divided by the number counted (c_n) each day at John Day Dam to daily spill in 1996, 1997, and 1998.

(Figure 22). Fallback ratios were zero during parts of April, May, June, and July; the highest ratio values were in mid-June and early August. One fallback event in early August inflated ratios to > 0.50 when few chinook salmon with transmitters were passing the dam, and one fallback in mid-June when few fish were passing the dam may also have produced inflated ratios. Fallback ratios were positively correlated with daily flow, spill, and dissolved gas, and negatively correlated with Secchi disk visibility between 12 April and 2 August, the period when 99% of all radio-tagged spring and summer chinook salmon passed John Day Dam in 1997 (one fallback event and three passages not included) (Figure 23). The r^2 values for regressions of all environmental variables with the moving average fallback ratio were ~ 0.21 and 0.25 for flow and spill, ~ 0.05 for Secchi depth, and ~ 0.13 for dissolved gas. When we only included fish that passed before 17-June in the ratio analysis (65% of all passages), r^2 values decreased to ~ 0.11 for flow, spill, and dissolved gas, and to ~ 0.00 for Secchi disk visibility (Figure 23).

In 1998, 25 spring and summer chinook salmon with transmitters fell back within 24 h of passage at John Day Dam. Fish with transmitters began to pass the dam in the second week of April, and the first fallbacks within 24 h of passage occurred in mid-April (Figure 24). The moving average fallback ratio did not have clear peaks and nadirs in 1998, although 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 positively correlated with flow and spill, and negatively correlated with Secchi disk visibility and dissolved gas between 9 April and 1 August, the period when all radio-tagged spring and summer chinook salmon passed John Day Dam in 1998 (Figure 25). The r^2 values were all less than ~ 0.02.

Water temperature and moving-average fallback ratios: - Water temperatures were negatively correlated with moving average fallback ratios in all three years, but correlations were weak (r^2 values < ~ 0.04) (Figure 26). When we only included the 1997 data through 16 June (65% of all passages), fallback ratios increased with increasing water temperature (r^2 ~ 0.22).

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 John Day 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 John Day Dam for each year. For ease

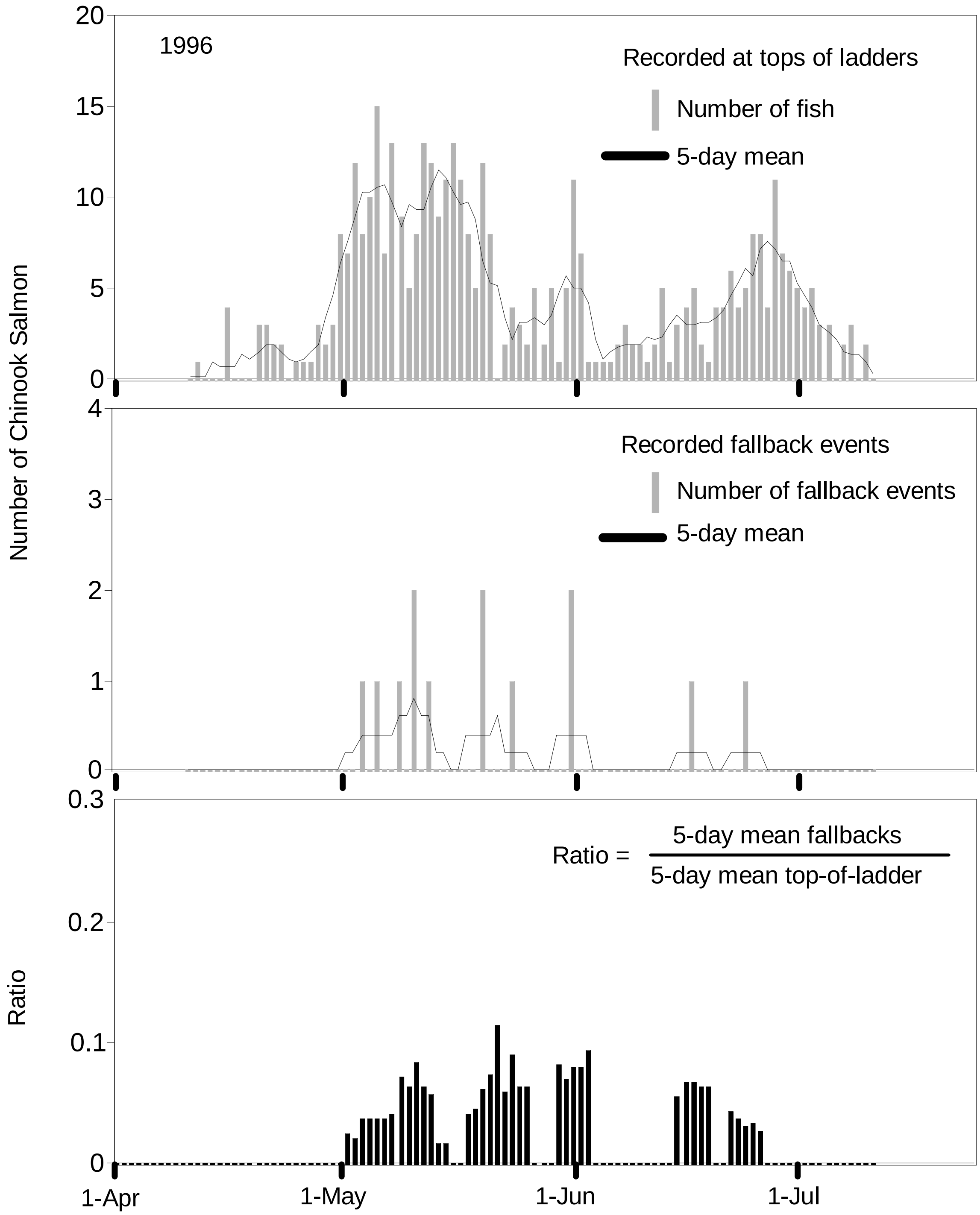

Figure 20. Daily number and 5-d moving average of recorded passages at John Day Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for spring and summer chinook salmon with transmitters in 1996.

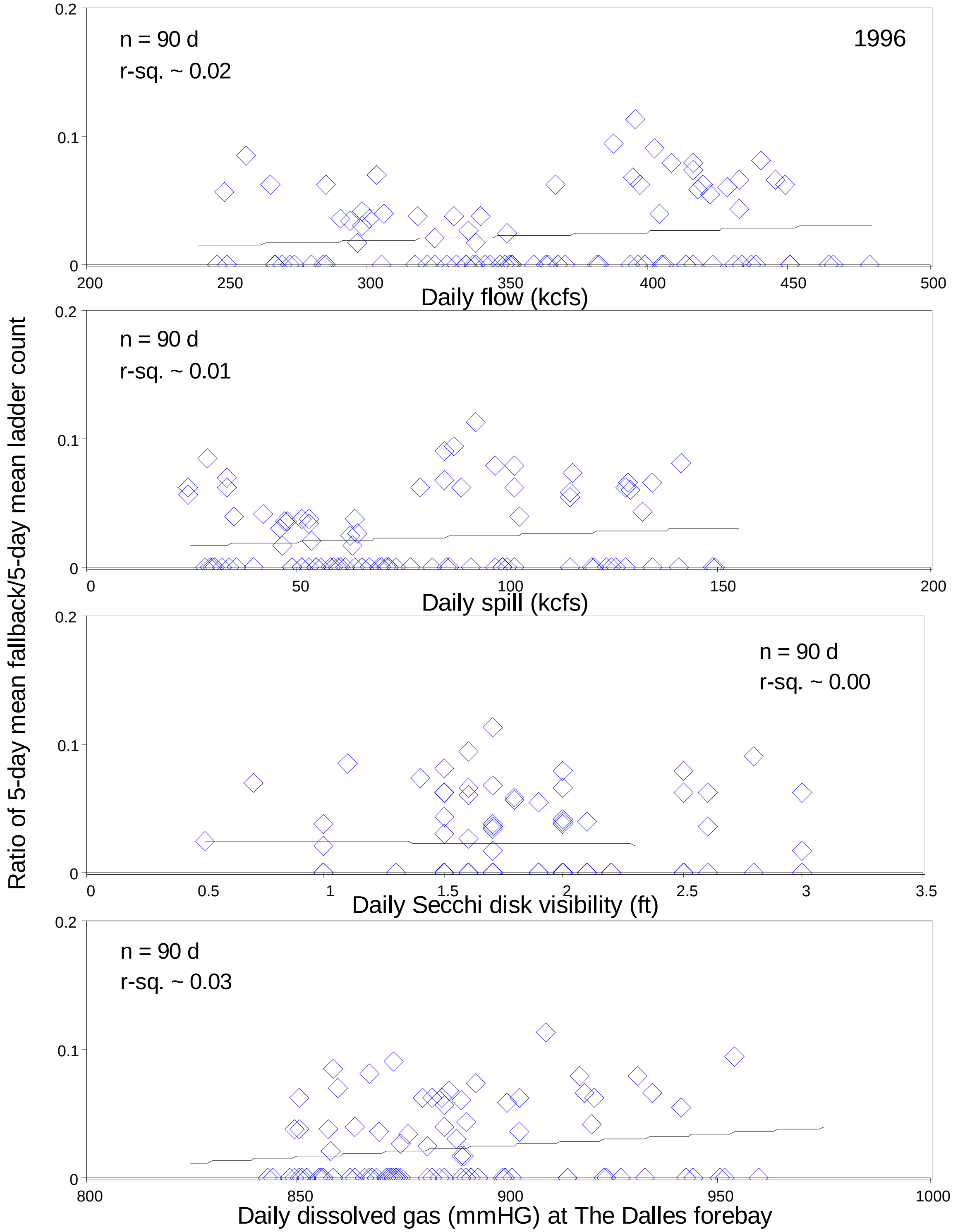

Figure 21. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at John Day Dam in 1996. r-sq values approximate

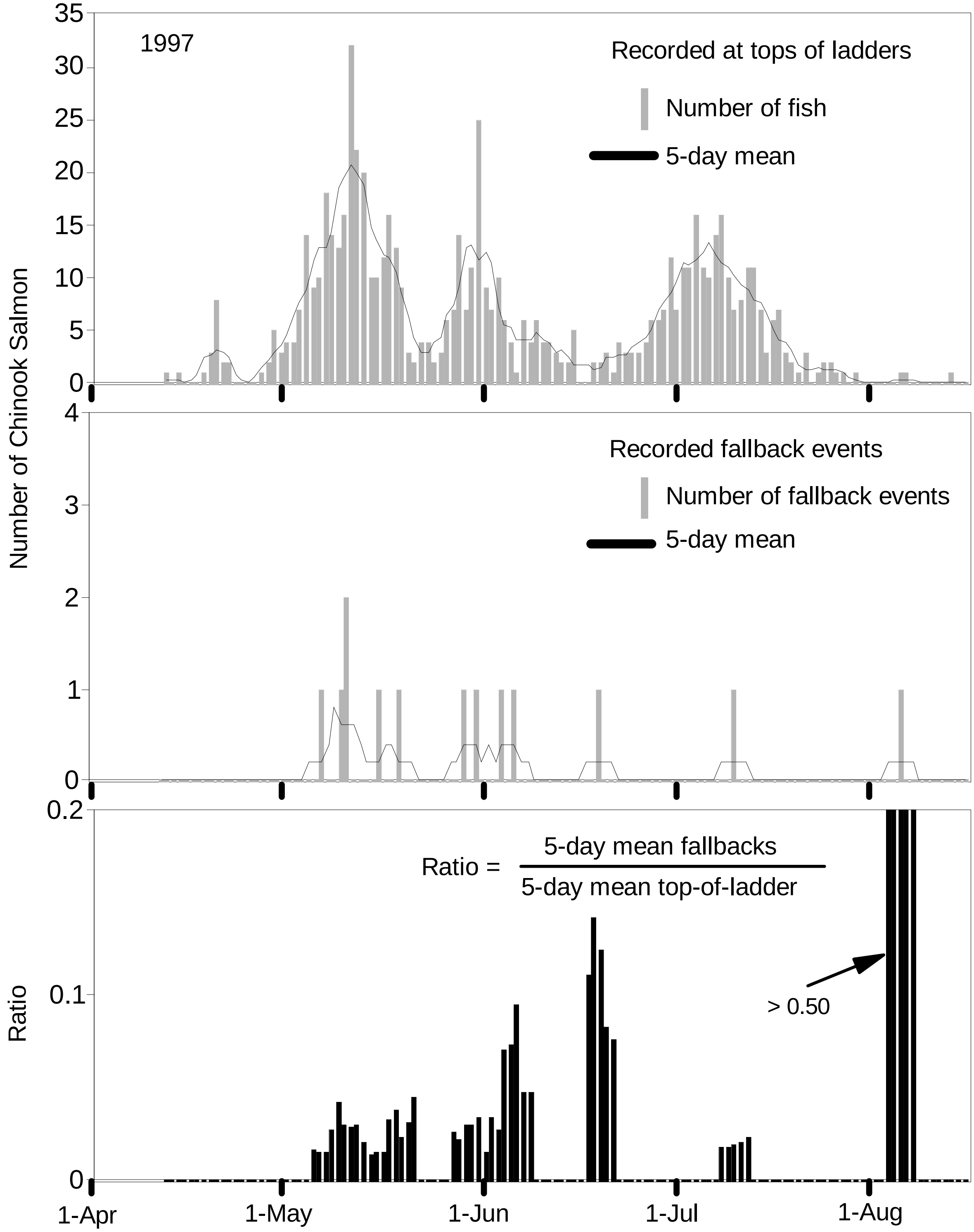

Figure 22. Daily number and 5-d moving average of recorded passages at John Day Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for spring and summer chinook salmon with transmitters in 1997.

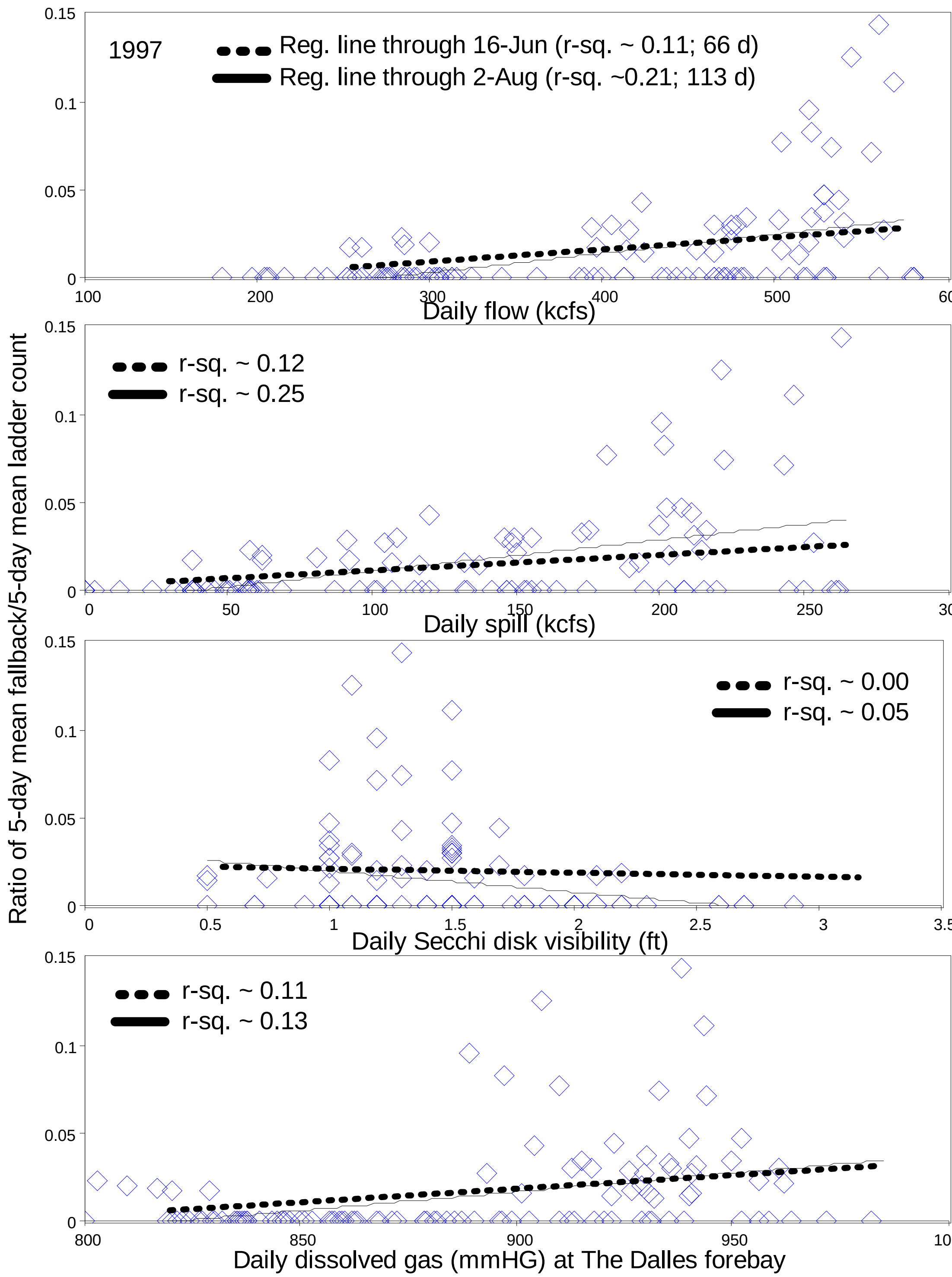

Figure 23. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at John Day Dam in 1997. r-sq values approximate

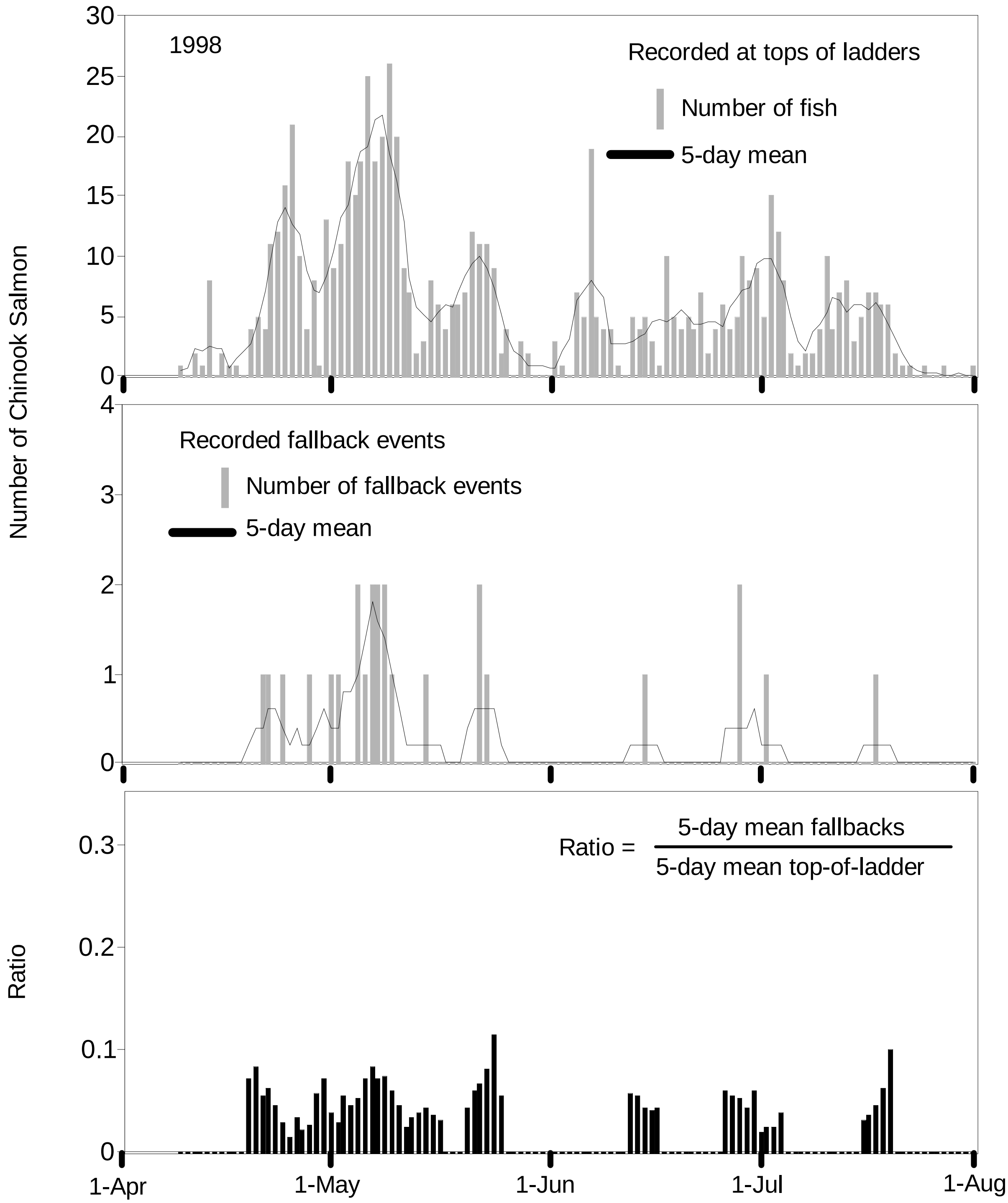

Figure 24. Daily number and 5-d moving average of recorded passages at John Day Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for spring and summer chinook salmon with transmitters in 1998.

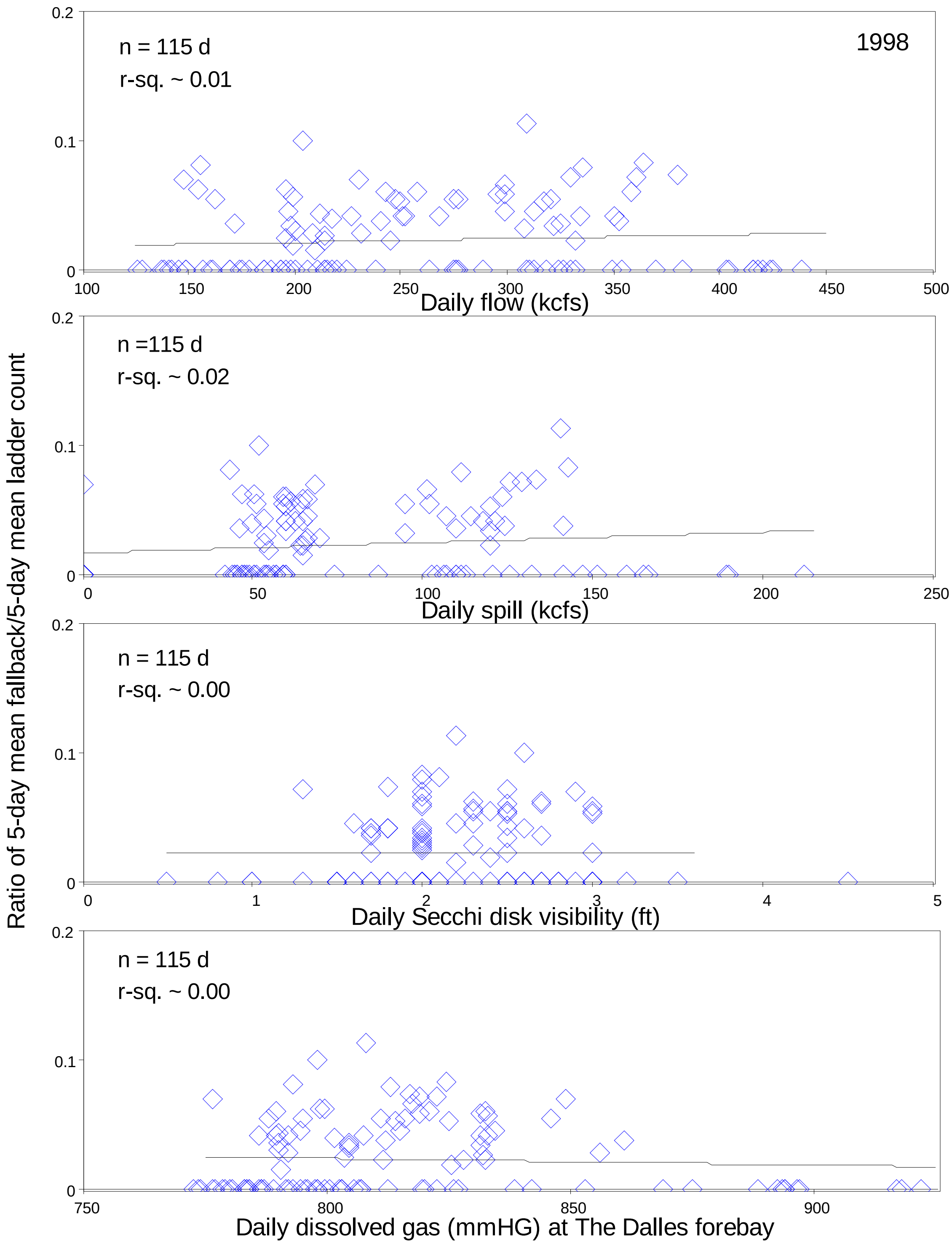

Figure 25. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at John Day Dam in 1998. r-sq values approximate

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, a series we believe was representative in each year. The average number of fish/block was between 23 and 31, and standard deviations were from 16 to 25 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 lower for the variable-day-bin method in 1996, and slightly higher 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, which we believe best handled data variability concerns.

In 1996, fallback ratios based on 5-d blocks were positively correlated with flow, spill, and dissolved gas levels, and negatively correlated with Secchi visibility and water temperature, but no linear or logistic models were significant at $P < 0.05$. The r^2 values for weighted and unweighted linear regressions were < 0.03 for flow ($P > 0.50$), < 0.02 for spill ($P > 0.65$), and about 0.10 for dissolved gas ($P \sim 0.21$). With Secchi visibility, r^2 values were 0.00 for the unweighted model ($P = 0.81$) and 0.08 for the weighted model ($P = 0.24$); P was 0.32 for the logistic model. Fallback ratios were negatively correlated with water temperature, but models were not significant ($P = 0.44$ for logistic model; $P = 0.84$ for unweighted linear model; $P = 0.38$ for weighted linear model).

Using all 1997 data through 30 July (> 99% of all passages) , fallback ratios based on 5-d blocks were negatively correlated with Secchi depth visibility and water temperature, and positively correlated with flow, spill, and dissolved gas. For flow, r^2 values were 0.20 for the unweighted linear model ($P = 0.04$) and 0.15 for the weighted linear model ($P = 0.08$); P was 0.11 for the logistic model. For spill, r^2 values were 0.25 for the unweighted linear model ($P = 0.02$) and 0.16 for the weighted linear model ($P = 0.06$); P was 0.10 for the logistic model.

For dissolved gas, r^2 values were 0.17 for both weighted and unweighted linear models ($P \sim 0.053$); P was 0.08 for the logistic model. P values for water temperature were 0.99 for the unweighted and 0.27 for the weighted linear models (r^2 values < 0.06), and 0.31 for the logistic model. For Secchi visibility, r^2 values were 0.06 for the unweighted linear model ($P = 0.28$) and 0.10 for the weighted linear model ($P = 0.15$); P was 0.19 for the logistic model.

In 1998, fallback ratios based on 5-d blocks were positively correlated with flow, spill, and Secchi visibility. Ratios were negatively correlated with water temperature, and had a weak negative correlation with dissolved gas levels. For flow, r^2 values were < 0.06 for the unweighted and weighted linear models ($P > 0.24$); P was 0.39 for the logistic model. For spill, r^2 values were 0.07 for the unweighted linear model ($P = 0.23$)

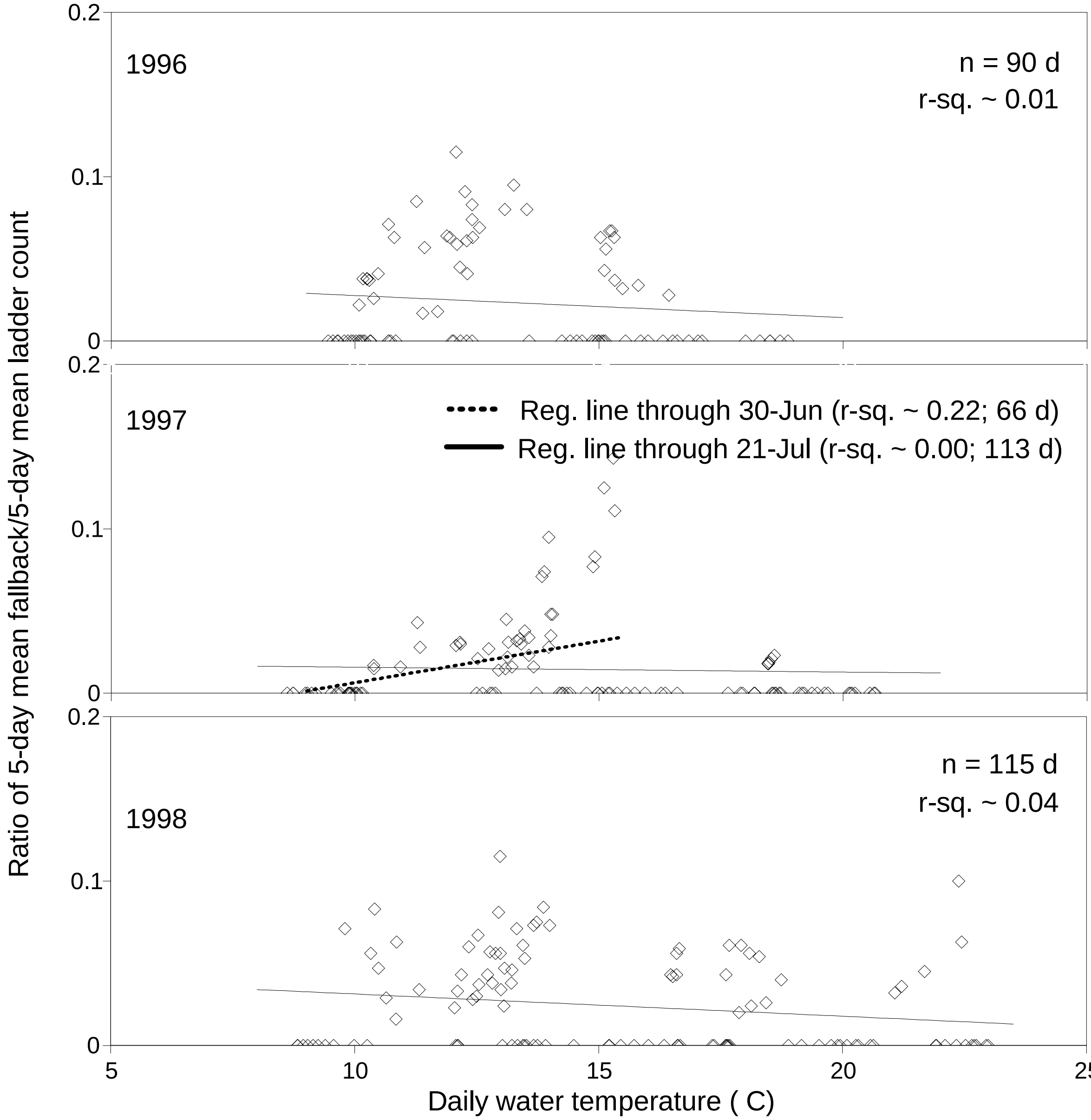

Figure 26. Regressions of daily mean water temperature in the tailrace with 5-d moving average fallback ratios for spring and summer chinook salmon with transmitters at John Day Dam for 1996, 1997, and 1998. r-sq values approximate

and 0.13 for the weighted linear model ($P = 0.09$); P was 0.22 for the logistic model. For dissolved gas, r^2 values were near zero for both weighted and unweighted linear models ($P > 0.88$); P was 0.92 for the logistic model. For temperature, r^2 values were 0.07 for the unweighted linear model ($P = 0.23$) and 0.13 for the weighted linear models ($P = 0.09$); P was 0.22 for the logistic model. For Secchi visibility, r^2 values were < 0.03 for the linear models ($P > 0.42$); P was 0.55 for the logistic model.

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 14 to 23 bins, with an average of approximately 30 fish/bin (standard deviation ~ 4 to 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 14 bins for the 1996 data set, with a mean of 6.4 d/bin (median 4 d/bin). Bin fallback ratios were positively correlated with mean flow, spill, and dissolved gas, negatively correlated with water temperature, and had almost no correlation with Secchi visibility; logistic regressions using maximum likelihood methods produced similar trends (Figure 27). Unweighted and weighted linear models had r^2 values between 0.06 and 0.09 for flow, spill, and dissolved gas (P values 0.29 to 0.38); logistic models had P values from 0.32 to 0.35. P values were > 0.48 for all water temperature models and > 0.84 for all models using Secchi visibility (Figure 27).

For the 1997 data through 30 July (>99% of all data), we created 21 bins with a mean of 4.6 d/bin (median 3 d/bin). Bin fallback ratios were positively correlated with mean flow, spill, and dissolved gas, and negatively correlated with water temperature and Secchi visibility; logistic regressions using maximum likelihood methods produced similar trends (Figure 28). For flow, unweighted and weighted linear models had r^2 values of 0.12 and 0.10 ($P = 0.11$ and 0.15); P was 0.13 for the logistic model. The r^2 values for spill were 0.15 for the unweighted model ($P = 0.07$) and 0.12 for the weighted model ($P = 0.12$); P was 0.11 for the logistic model. The r^2 values for dissolved gas were 0.16 for the unweighted model ($P = 0.07$) and 0.18 for the weighted model ($P = 0.053$); P was 0.047 for the logistic model. P values were > 0.30 for all Secchi visibility models, with r^2 values ~ 0.05 for the linear models. The r^2 values were < 0.05 for the linear water temperature models ($P > 0.36$) and P was 0.34 for the logistic water temperature model (Figure 28).

For 1998, we created 23 bins with a mean of 5.0 d/bin (median 5 d/bin). Bin fallback ratios were positively correlated with mean flow and spill and negatively correlated with water temperature. Correlations with Secchi visibility and dissolved gas were very weak. For flow, r^2 values were < 0.06 for the linear

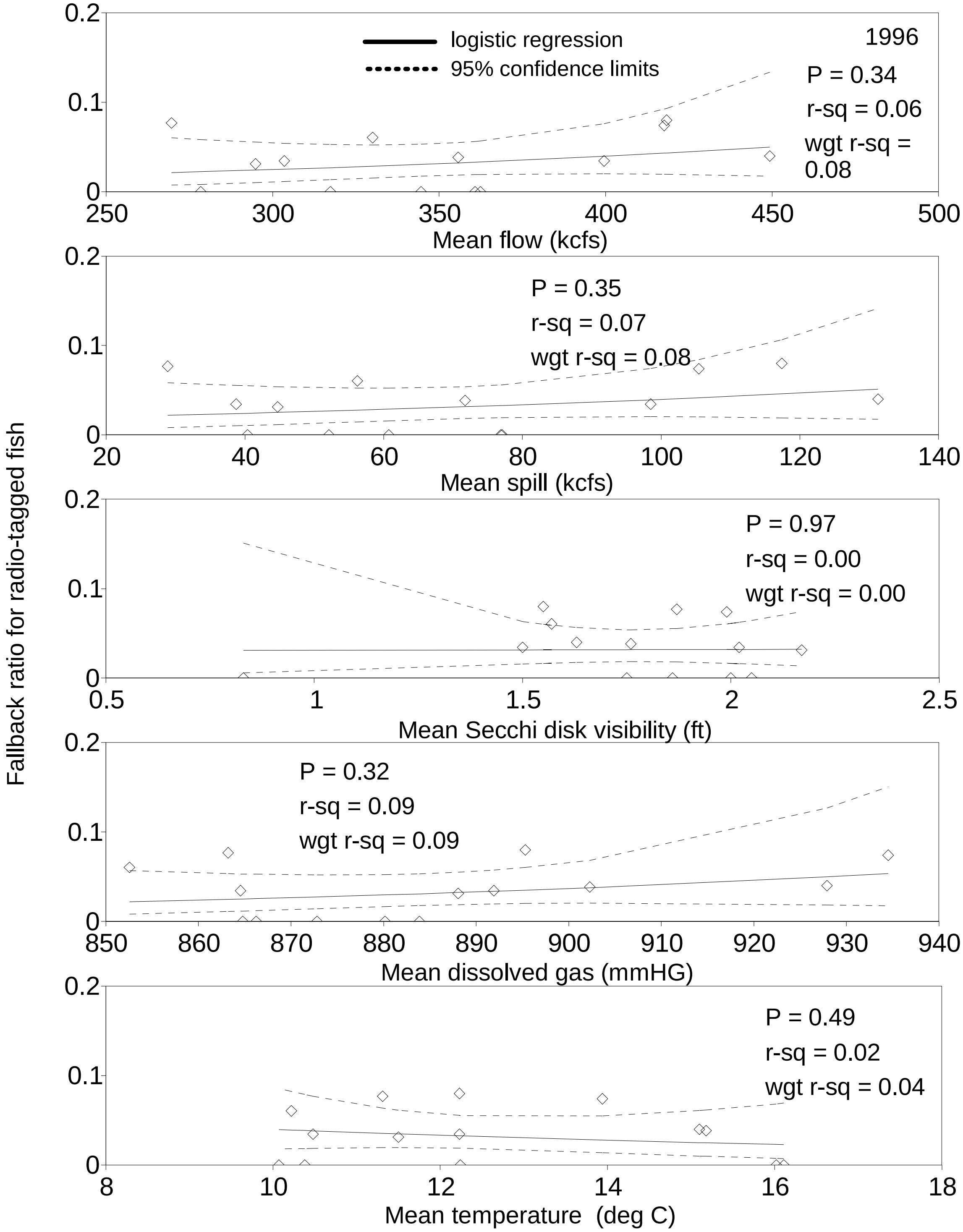

Figure 27. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of chinook salmon fallbacks within 24 h at John Day Dam in 1996; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width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

models (P > 0.28) and P was 0.29 for the logistic model. For spill, r^2 values were 0.08 for the unweighted linear model (P = 0.20) and 0.09 for the weighted linear model (P = 0.16); P was 0.16 for the logistic model. For dissolved gas, r^2 values were near zero for linear models (P > 0.81); P was 0.82 for the logistic model. P values for water temperature were > 0.30 for linear models (r^2 values ~ 0.05), and 0.30 for the logistic model. For Secchi visibility, r^2 values were near zero for the linear models (P > 0.90) and P was 0.90 for the logistic model (Figure 29).

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 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 John Day Dam during the passage of radio-tagged spring and summer chinook salmon ranged from about 180 kcfs to 480 kcfs (Table 9). We grouped chinook salmon based on mean daily flow increments of 10 kcfs. The 25 groups had a mean of 16 chinook salmon per group (median of 13).

Forty-four percent of 409 recorded passages of John Day Dam occurred at flows less than 330 kcfs, for which the aggregated fallback ratio was 0.033. Of all passages by radio-tagged chinook salmon at John Day Dam, 228 (56%) occurred at flows greater than 330 kcfs. The aggregated fallback ratio for all passage when flows were 330 kcfs or more was 0.031, 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 (P > 0.60 for all models). Fifteen flow increments (48% of all passages) with fallback ratio of zero were scattered throughout the range (Table 9), but removing those increments had little impact on model fit.

In 1997, flow at John Day 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 33 groups with fish had a mean of 21 chinook salmon per group (median of 15) (Table 9). Fifty percent of 691 passages of salmon at John Day Dam occurred at flows less than 420 kcfs, for which the aggregated fallback ratio was 0.017. Of all passages by radio-tagged chinook at John Day Dam, 344 (50%) occurred at flows greater than 420 kcfs. The aggregated fallback ratio for all passages when flows exceeded 420 kcfs or more was 0.020, slightly higher than the ratio when flows were less than 420 kcfs.

Fallback ratios were positively correlated with flow (P = 0.055 for an unweighted linear model, P = 0.17 for a weighted linear model, and P = 0.13 for

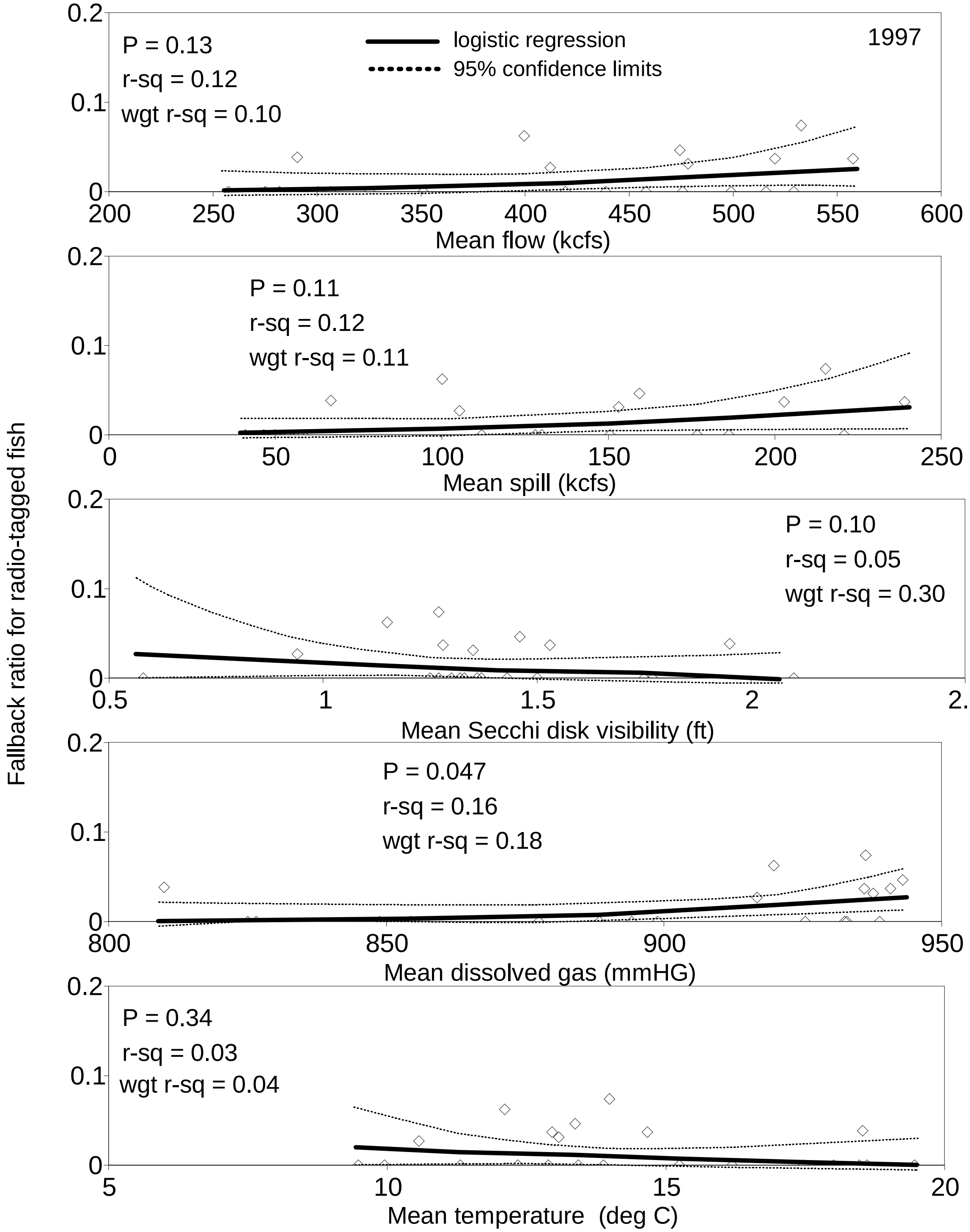

Figure 28. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of chinook salmon fallbacks within 24 h at John Day Dam in 1997; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width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

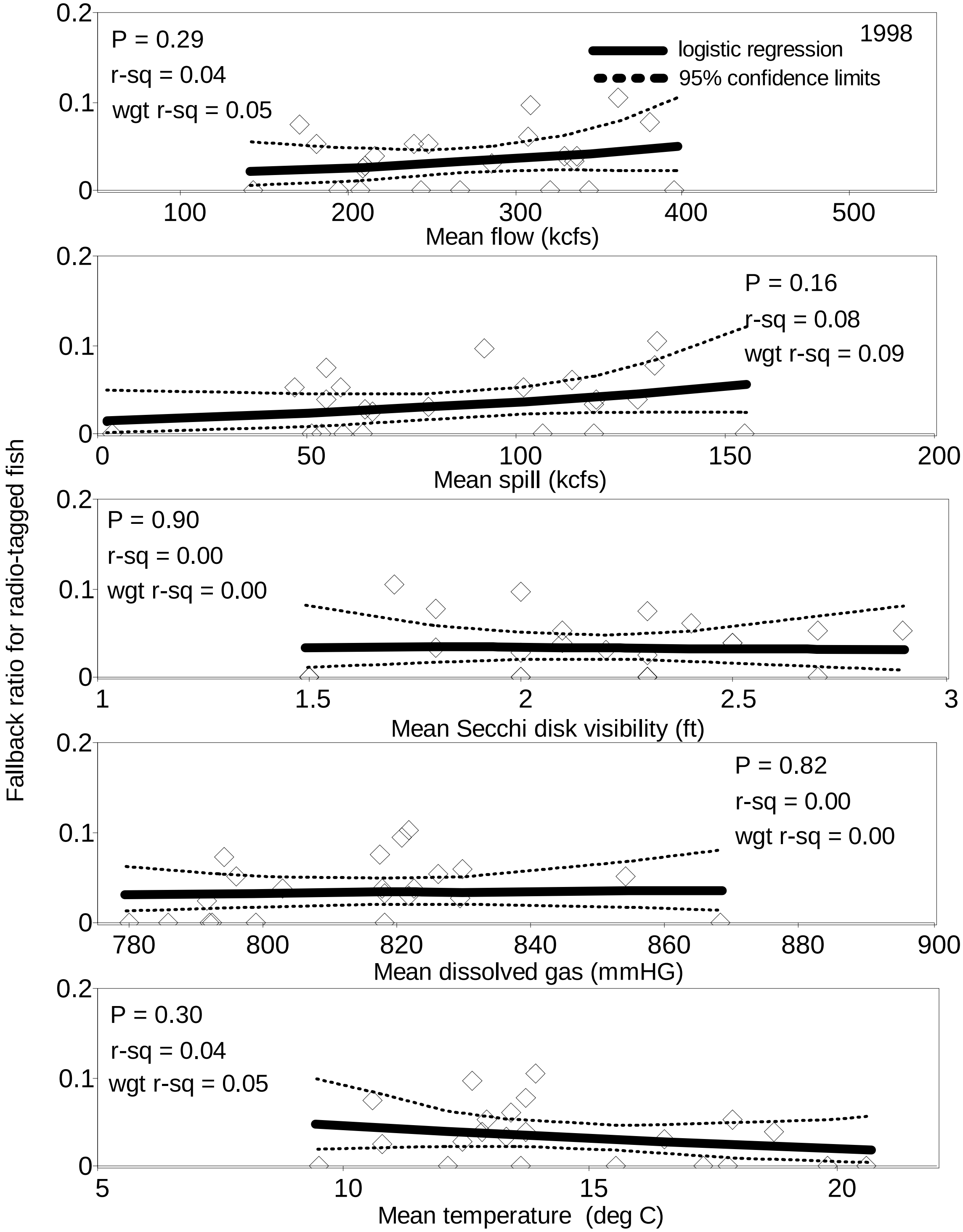

Figure 29. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of chinook salmon fallbacks within 24 h at John Day Dam in 1998; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width time bins that included at least 25 fish.

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 John Day 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							1	0	0.00
130-139							--	--	--
140-149							17	0	0.00
150-159							18	1	0.06
160-169							5	1	0.20
170-179							17	0	0.00
180-189	1	0	0.00				4	0	0.00
190-199	--	--	--				71	1	0.01
200-209	--	--	--	2	1	0.50	43	1	0.02
210-219	--	--	--	1	0	0.00	45	2	0.04
220-229	--	--	--	--	--	--	9	1	0.11
230-239	--	--	--	1	0	0.00	29	1	0.03
240-249	16	1	0.06	--	--	--	44	4	0.09
250-259	13	2	0.15	21	0	0.00	16	0	0.00
260-269	16	0	0.00	21	0	0.00	14	0	0.00
270-279	8	0	0.00	13	0	0.00	39	0	0.00
280-289	12	0	0.00	24	1	0.04	4	0	0.00
290-299	32	1	0.03	30	0	0.00	41	2	0.05
300-309	35	1	0.03	71	0	0.00	11	0	0.00
310-319	19	1	0.05	17	0	0.00	34	2	0.06
320-329	29	0	0.00	11	0	0.00	50	1	0.02
330-339	55	0	0.00	--	--	--	37	1	0.03
340-349	12	1	0.08	2	--	0.00	19	0	0.00
350-359	32	0	0.00	--	--	--	35	2	0.06
360-369	4	0	0.00	7	0	0.00	38	4	0.11
370-379	5	0	0.00	--	--	--	7	0	0.00
380-389	7	0	0.00	11	0	0.00	31	2	0.07
390-399	10	0	0.00	50	2	0.04	--	--	--
400-409	21	1	0.05	16	1	0.06	3	0	0.00
410-419	26	2	0.08	49	1	0.02	3	0	0.00
420-429	21	2	0.10	23	0	0.00	3	0	0.00
430-439	16	1	0.06	1	0	0.00			
440-449	7	0	0.00	9	0	0.00			
450-459	7	0	0.00	12	1	0.11			
460-469	4	0	0.00	27	0	0.00			
470-479	1	0	0.00	70	1	0.01			
480-489				32	1	0.03			
490-499				4	0	0.00			
500-509				29	0	0.00			
510-519				18	0	0.00			
520-529				68	1	0.01			
530-539				9	0	0.00			
540-549				12	2	0.17			
>550				30	1	0.03			

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

a logistic model). We excluded two fish, one of which fell back (fallback ratio = 0.50), that passed when flow was about 200 kcfs from all models. Lack of correlation was caused in part by 22 flow increments (51% of all passages) with fallback ratios of zero scattered throughout the range (Table 9). Removing groups with fallback ratios of zero, leaving 49% of all passages in the model, improved the unweighted model fit slightly from $r^2 = 0.12$ to $r^2 = 0.25$ ($P = 0.15$).

In 1998, flow at John Day Dam during the passage of radio-tagged spring and summer chinook salmon ranged from approximately 120 kcfs to 430 kcfs. We grouped chinook salmon based on mean daily flow increments of 10 kcfs. The 29 groups had a mean of 24 chinook salmon per group (median of 18). Forty-eight percent of 688 passages of John Day Dam occurred at flows less than 270 kcfs, for which the aggregated fallback ratio was 0.033. Of all passages by radio-tagged chinook salmon at John Day Dam, 355 (52%) occurred at flows greater than 270 kcfs. The aggregated fallback ratio for all passage when flows were 270 kcfs or more was 0.039, slightly higher than the ratio for passage when flows were less than 270 kcfs.

Flow and fallback ratios were positively correlated when all data was included in a weighted linear model and a logistic model. P values were 0.24 for the logistic model, and 0.23 for the weighted linear model ($r^2 = 0.05$). Fifteen flow increments (33% of all passages) had fallback ratio of zero scattered throughout the range (Table 9). In addition, 1 of 5 chinook salmon fell back within 24 h during flows of 160 to 170 kcfs, creating an outlying fallback ratio of 0.20. Removing that flow level and all groups with fallback ratios of zero resulted in lower correlations.

In 1996, spill at John Day Dam during the passage of radio-tagged spring and summer chinook salmon ranged from about 20 kcfs to 150 kcfs (Table 10). Using 10-kcfs increments, we formed 13 groups that had a mean of 31 fish per group (median of 26). Of 409 passages of John Day Dam, 216 (53%) occurred at spills of less than 60 kcfs the aggregated fallback ratio was 0.028. The remaining 193 passages (47%) occurred at spills greater than 60 kcfs and the aggregated fallback ratio was 0.036.

There was almost no correlation ($P > 0.69$) between spill and fallback ratios when all data was included in weighted and unweighted linear models, and logistic models. Although 3 spill groups had fallback ratio of zero, those levels only accounted for about 9% of all passages; their removal from the models improved model fit to $P \sim 0.35$ and $r^2 \sim 0.13$.

In 1997, spill at John Day Dam during the passage of radio-tagged spring and summer chinook salmon ranged from 0 to 270 kcfs (Table 10). Using 10-kcfs increments, we formed 24 groups with a mean of 29 fish per group (median of 26). Of 691 passages by chinook salmon, 348 (50%) occurred at spills of less than 110 kcfs, and the aggregated fallback ratio for those fish was 0.017. The remaining 343 fish (50%) fell back when spill levels were greater than 110 kcfs and had an aggregated fallback ratio of 0.020. For 222 passages by chinook salmon when spill was less than

70 kcfs, one fallback event was recorded for an aggregated ratio of 0.005.

Spill was positively correlated with fallback ratios when all data was included. The unweighted linear model had an r^2 of 0.10 (P = 0.13), the weighted model r^2 was 0.07 (P = 0.20), and the logistic model P was 0.19. Two spill levels at the upper end of the spill spectrum for 1997 (220-230 kcfs and 240-250 kcfs) had the highest ratio values at 0.166 and 0.111, but included relatively few fish. Removing those two spill increments reduced model r^2 values to < 0.02. Including the highest ratio values, but removing 12 spill groups with fallback ratios of zero (48% of all passages), improved model fit slightly.

In 1998, spill at John Day Dam during the passage of radio-tagged spring and summer chinook salmon ranged from 0 to 220 kcfs (Table 10). Using 10-kcfs increments, we formed 15 groups that had a mean of 46 fish per group (median of 29). No fallback events were recorded for 20 passages by chinook salmon when spill was zero (Table 10). Of 688 recorded passages by chinook salmon, 360 (52%) occurred when spill was less than 70 kcfs, and the aggregated fallback ratio for those fish was 0.028. The 328 (48%) fish that passed when spill was greater than 70 kcfs had an aggregated fallback ratio of 0.046, about 60% higher than that for fish that passed at lower spill levels.

Spill was positively correlated with fallback ratios when all data was included in weighted linear (r^2 = 0.34, P = 0.02) and logistic models (P = 0.08); the unweighted linear model was not significant (r^2 = 0.01, P = 0.80). Seven flow increments had fallback ratio of zero, including about 9% of all passages. Removing blocks with ratios of zero from models improved fit for both unweighted (r^2 = 0.47, P = 0.06) and weighted (r^2 = 0.54, P = 0.04) linear models.

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 John Day 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 John Day 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 409 known-date passages by spring and summer chinook salmon with transmitters at John Day Dam. Following passage, 13 fish (3.2%) fell back within 24 h of passing and 396 did not. Mean flow and spill were higher for chinook salmon that fell back within 24 h, but differences were not significant (P > 0.57) (Table 11). Mean Secchi disk

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 John Day 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				6	0	0.00	20	0	0.00
10-19				8	0	0.00	--	--	--
20-29	32	3	0.09	12	0	0.00	--	--	--
30-39	51	1	0.02	23	0	0.00	--	--	--
40-49	37	1	0.03	34	1	0.03	45	1	0.02
50-59	96	1	0.01	93	0	0.00	148	4	0.03
60-69	49	1	0.02	46	0	0.00	147	5	0.03
70-79	26	0	0.00	--	--	--	5	0	0.00
80-89	17	1	0.06	13	1	0.08	4	0	0.00
90-99	18	2	0.11	47	2	0.04	22	0	0.00
100-109	17	0	0.00	66	2	0.03	54	2	0.04
110-119	15	0	0.00	32	0	0.00	45	1	0.02
120-129	30	2	0.07	--	--	--	115	7	0.06
130-139	15	1	0.07	26	1	0.04	45	2	0.04
140-149	6	0	0.00	50	0	0.00	29	3	0.10
150-159				37	1	0.03	--	--	--
160-169				3	0	0.00	4	0	0.00
170-179				45	1	0.02	--	--	--
180-189				11	0	0.00	--	--	--
190-199				26	0	0.00	2	0	0.00
200-209				46	1	0.02	--	--	--
210-219				31	1	0.03	3	0	0.00
220-229				6	1	0.17			
230-239				--	--	--			
240-249				9	1	0.13			
250-259				12	0	0.00			
260-269				9	0	0.00			
>270									

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

visibility was slightly lower for fish that fell back (P = 0.52); mean water temperature was also lower for fish that fell back, but the difference was not significant (P = 0.34). We found almost no difference in dissolved gas levels (Table 11).

In 1997, there were 691 known-date passages by spring and summer chinook salmon with transmitters at John Day Dam. Following passage, 13 fish (1.9%) fell back within 24 h of passing and 678 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 > 0.22). There was no significant difference in mean Secchi disk visibility (P = 0.89) or temperature (P = 0.86) during passage of fish that fell back.

In 1998, there were 688 known passages by spring and summer chinook salmon with transmitters at John Day Dam. Following passage, 25 fish (3.6%)

Table 11. Number of spring and summer chinook salmon (CK), sockeye salmon (SK), and steelhead (SH that either did or did not fall back within 24 h of passing John Day 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 (409 passages)							
FB in 24 h	13	3.2	350	73	1.7	882	12.2
did not FB	396	96.8	343	68	1.8	883	12.8
1997 CK (691 passages)							
FB in 24 h	13	1.9	437	143	1.4	911	14.1
did not FB	678	98.1	414	122	1.4	899	14.2
1998 CK (688 passages)							
FB in 24 h	25	3.6	306	67	1.7	845	17.6
did not FB	663	96.4	316	62	1.7	855	17.5
1997 SK (485 passages)							
FB in 24 h	18	3.7	326	205	2.1	858	16.8
did not FB	467	96.3	316	198	2.0	855	17.0
1996 SH (462 passages in 1996; all flow/spill, > 95% Secchi/temperature data available)							
FB in 24 h	11	2.4	156	13	3.0	n/a	18.7
did not FB	451	97.6	152	11	3.0	n/a	18.4
1997 SH (571 passages in 1997; all flow/spill, > 92% Secchi/temperature data available)							
FB in 24 h	11	1.9	212*	29**	2.6	n/a	18.7
did not FB	560	98.1	178*	8**	2.5	n/a	18.1

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

fell back within 24 h of passing and 663 did not (Table 11). Although flow or spill were higher for fish that fell back within 24 h, we found no significant differences in mean flow (P = 0.25), spill (P = 0.09), or dissolved gas levels (P = 0.76). There were no significant differences in mean Secchi disk visibility (P = 0.76) or water temperature (P =0.30) 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 two to three times as many fish as fallbacks for each year. In 1996, fish that fell back within 5 d of passage did not pass on days with significantly different flow (P = 0.88), spill (P = 0.71), or dissolved gas levels (P = 0.62) (Table 12). Mean Secchi depth was lower at the time of passage for fish that fell back (P = 0.08) and temperatures were significantly lower for fish that fell back within 5 d (P = 0.003).

In 1997, fish that fell back within 5 d passed during significantly higher flow (P < 0.001), spill (P < 0.001), and dissolved gas levels (P = 0.002) (Table 12). Secchi visibility was also lower for fish that fell back, but differences were not significant (P = 0.19). Water temperatures were significantly lower for fish that fell back within 5 d (P = 0.03).

In 1998, fish that fell back within 5 d fell back within 5 d also passed during significantly higher flow (P = 0.004) and spill (P < 0.001) (Table 12). Dissolved gas levels were also higher for fish that fell back (P = 0.052). Secchi visibility was lower for fish that fell back (P = 0.14), and water temperatures were lower for fallback fish (P = 0.11).

Logistic regression models that used the full binary data sets for spring and summer chinook salmon produced no significant results at P < 0.05. The probability of falling back within 24 h of passage increased with flow (P = 0.68 in 1996, P = 0.39 in 1997, P = 0.25 in 1998) and with spill (P = 0.58 in 1996, P = 0.23 in 1997, P = 0.09 in 1998) in all three years (Figure 30). The probability of falling back within 24 h decreased with increased Secchi visibility in all three years, but relationships were weak (P = 0.52 in 1996, P = 0.89 in 1997, P = 0.76 in 1998). The probability of falling back in 24 h increased with increased dissolved gas in 1997 (P = 0.34), and decreased slightly with increased gas in both 1996 (P = 0.84) and 1998 (P = 0.76). The probability of falling back in 24 h decreased with increased water temperature in all three years, but relationships were weak (P = 0.34 in 1996, P = 0.86 in 1997, P = 0.29 in 1998

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 salmon data included, the fallback proportion decreased with increased flow and spill (Figure 31). The r^2 values were 0.02 for flow and 0.01 for spill; correlations were < 0.01 when we removed one fallback event on 1 August. We included all fallback events in the analysis, including 18 sockeye salmon (95%) that fell back within 24 h of passage and 1 that fell back more than 3 weeks 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 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 the fallback event that occurred more than 24 h after a fish exited from the top of a fishway in the analysis because that fish had migrated upriver, and we believe environmental conditions at the dam at

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 John Day 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 (409 passages)							
FB in 5 d	39	12.0	342	66	1.7	881	11.8**
did not FB	370	88.0	344	68	1.8	883	12.9**
1997 CK (691 passages)							
FB in 5 d	46	6.7	463**	156**	1.3	920**	13.4*
did not FB	645	93.3	411**	120**	1.4	898**	14.3*
1998 CK (688 passages)							
FB in 5 d	52	7.6	299**	103**	2.1	827	14.0
did not FB	636	92.4	271**	85**	2.2	818	14.7
1996 SH (462 passages in 1996; all flow/spill, > 95% Secchi/temperature data available)							
FB in 5 d	16	3.5	166	15	2.9	n/a	18.9
did not FB	446	96.5	152	11	3.0	n/a	18.4
1997 SH (571 passages in 1997; all flow/spill, > 92% Secchi/temperature data available)							
FB in 5 d	22	3.9	203*	21**	2.5	n/a	17.8
did not FB	549	96.1	178*	8**	2.5	n/a	18.1
1998 FCK (482 passages; data available for > 99% of passages)							
FB in 5 d	9	1.9	105	1	2.7**	n/a	20.7
did not FB	473	98.1	105	1	3.2**	n/a	20.0

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

the time of passage were not the primary reason it fell back at John Day Dam.

Eighteen sockeye salmon with transmitters fell back within 24 h of passage at John Day Dam in 1997. Using only these fallback events, the highest moving average fallback ratios occurred during early August (Figure 32). However, during that period at the end of the sockeye salmon migration, just one 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 32).

With all data included, 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

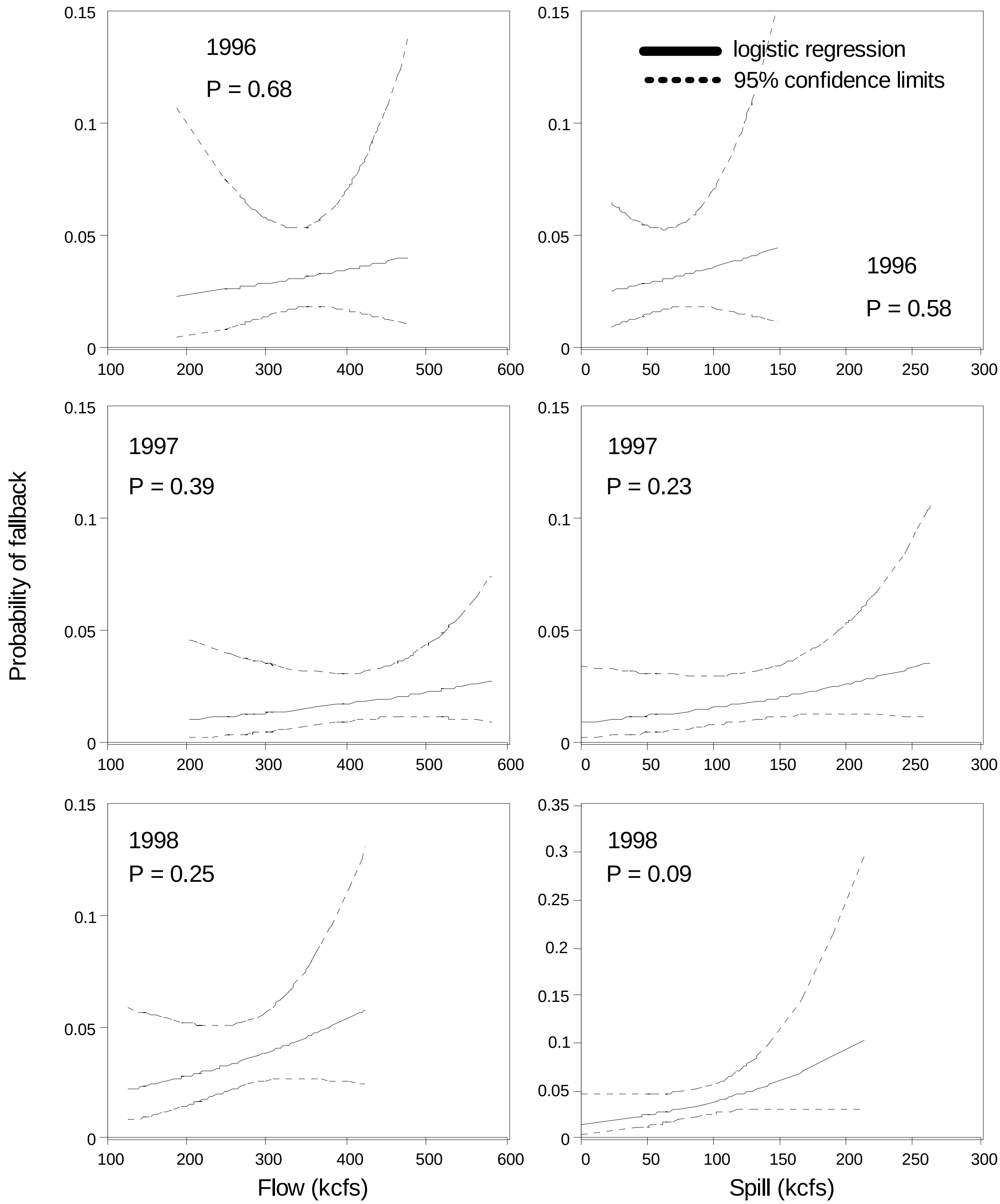

Figure 30. Probability of fallback by chinook salmon within 24 h of passing John Day Dam based on mean daily flow and spill in 1996, 1997, and 1998.

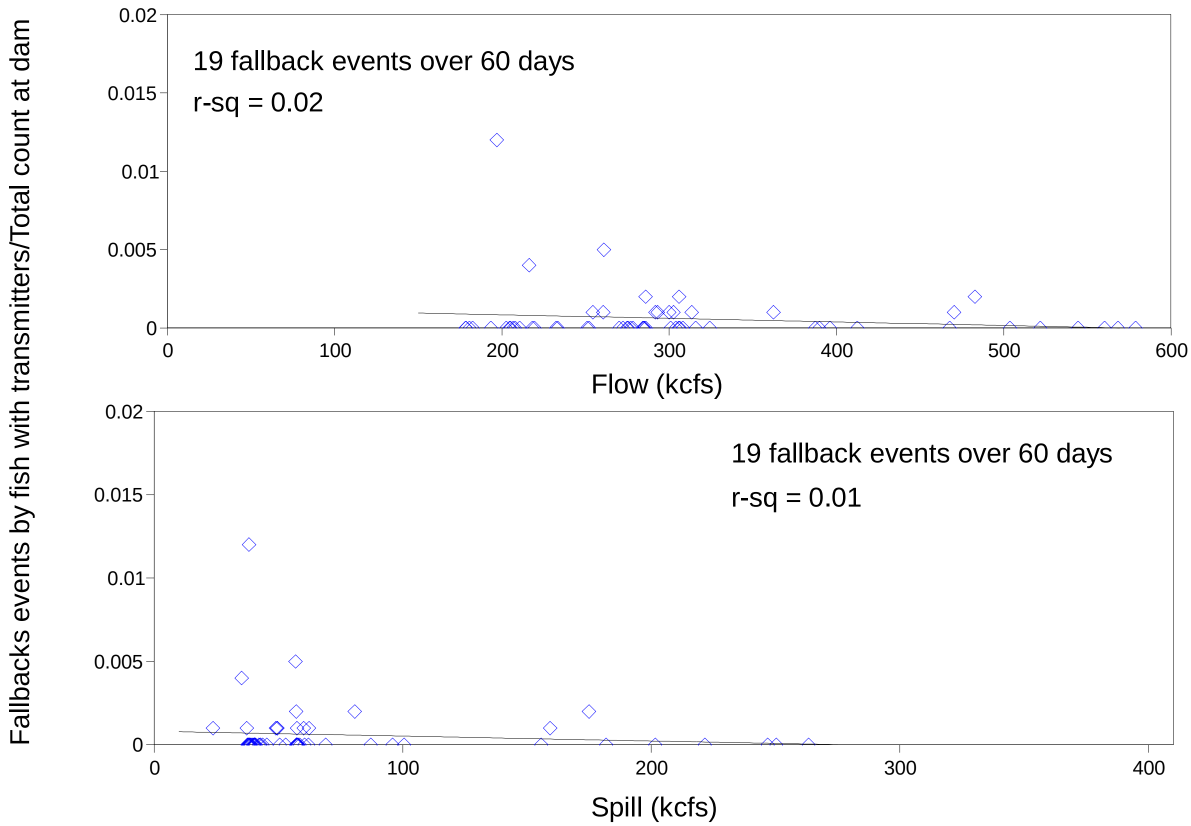

Figure 31. Relation of the ratio (fb_n/c_n) of sockeye salmon with transmitters that fell back (fb_n) divided by the number counted (c_n) each day at John Day Dam to daily flow and spill in 1997.

depth visibility and water temperatures were high. When we removed the days with outlying fallback ratios late in the migration (1 fallback event, 2.5% of all passages), fallback ratios were positively correlated with flow and spill and negatively correlated with dissolved gas and Secchi visibility (Figure 33). The r^2 values for all models were low at ~ 0.04 for flow, ~ 0.03 for spill, ~ 0.02 for dissolved gas, and ~ 0.02 for Secchi disk visibility.

The relationship between water temperature and the moving-average fallback ratio for sockeye salmon in 1997 was parabolic. For all data from 16 June through 14 August, fallback ratios were relatively high early in the migration when temperatures were about 15° C, and were more or less constant as water temperatures increased from approximately 15° to 18° C; fallback ratios increased for about 10 days at temperatures between 18° and 19° C (Figure 34). Less than 5% of the radio-tagged sockeye salmon passed John Day Dam at temperatures greater than 19° C, and moving-average ratios during that time were zero except for the 5 d affected by the fallback on 1 August

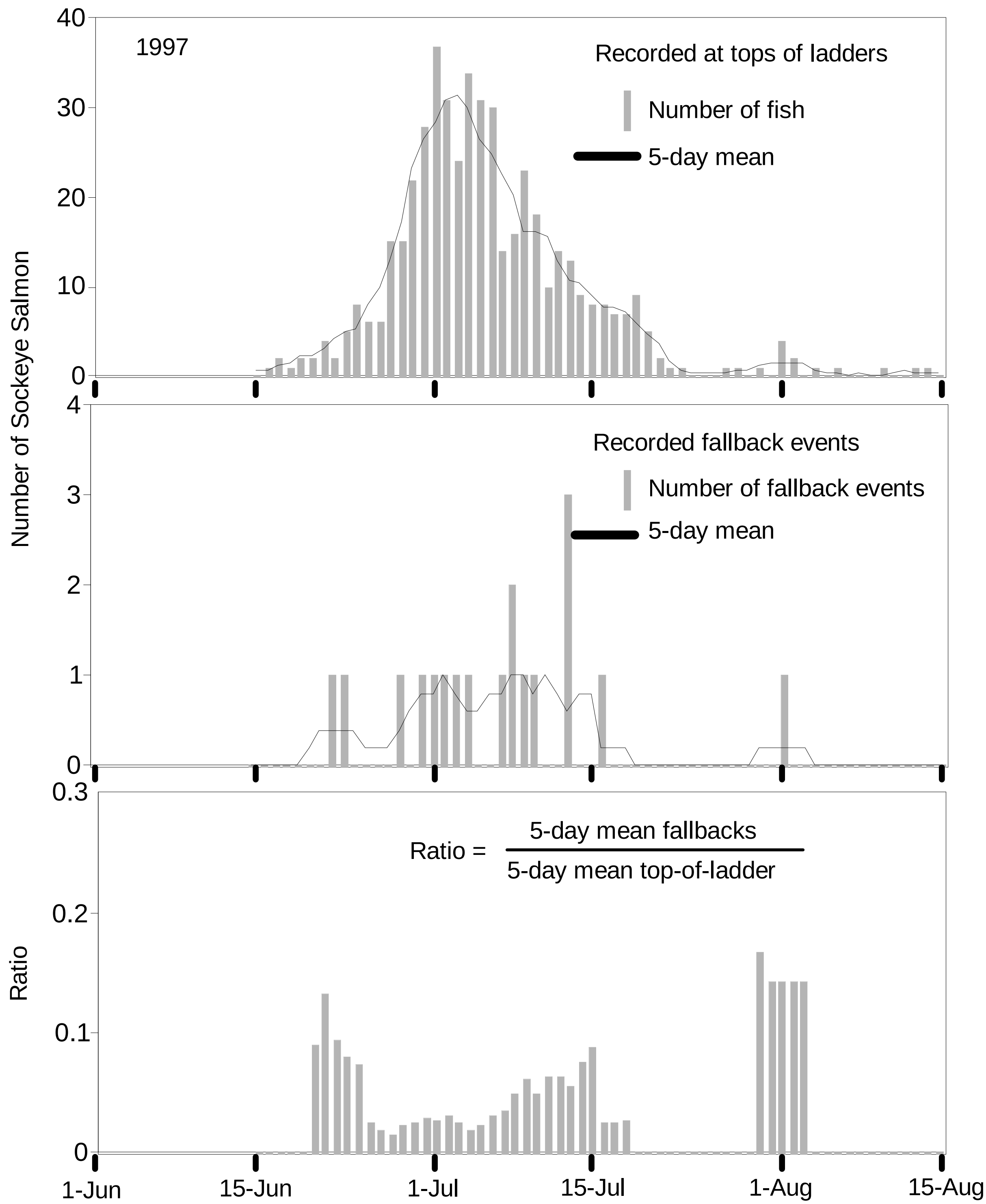

Figure 32. Daily number and 5-d moving average of recorded passages at tops of the fishways at John Day Dam, daily number and 5-d moving average fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for sockeye salmon with transmitters in 1997.

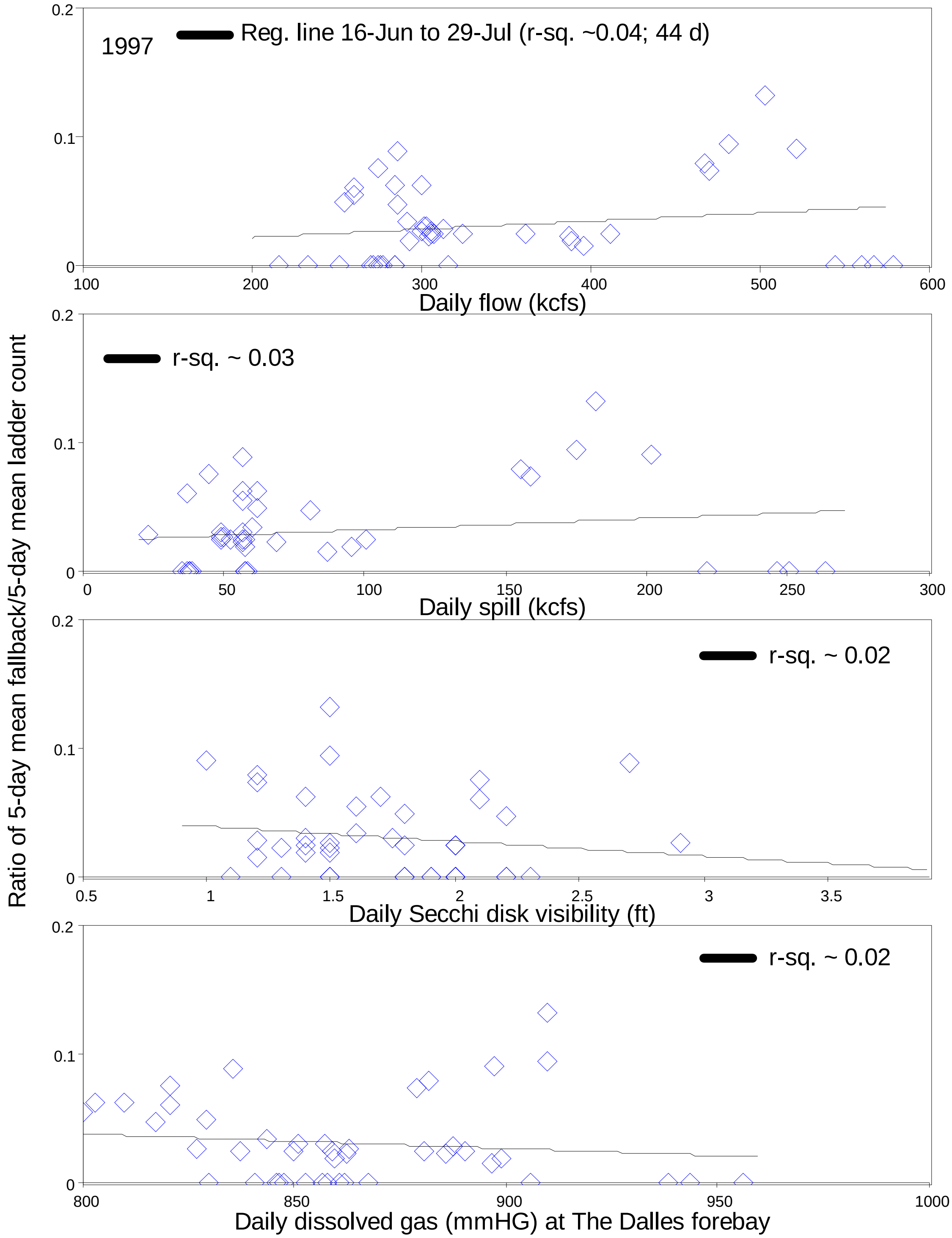

Figure 33. Regressions of daily mean flow, spill, Secchi disk visibility, and dissolved gas levels in the forebay with 5-d moving average fallback ratios for sockeye salmon with transmitters at John Day Dam from 16 June to 29 July, 1997. r-sq values approximate

discussed previously. When the fish that passed the dam between 16 June and 14 August were included, the correlation between water temperature and fallback ratios was positive and the r^2 value was ~ 0.01 (Figure 34). When we included only data through 29 July, the correlation was negative with an r^2 value of ~ 0.12. We believe there was insufficient data to fully evaluate the effects of water temperatures > 19° C at John Day Dam, but believe there is some evidence that water temperatures above approximately 18° C contributed to increased fallback by sockeye salmon at John Day Dam in 1997.

As with spring and summer chinook salmon we also used passage of sockeye salmon with transmitters and fallbacks within 24 h of passing John Day 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 John Day Dam. Sequences started on consecutive days, and each had 8 or 9 blocks. We only used data between 16 June and 29 August (97.5% o fall passages) for the reasons described above.

Using the third sequence start date, which we believed was most representative, fallback ratios were positively correlated with flow, spill, and dissolved gas and negatively correlated with Secchi visibility and water temperature. No weighted or unweighted linear regression models were significant at $P < 0.05$. The models with the highest P values were the unweighted models for spill ($P = 0.16$, $r^2 = 0.31$) and flow ($P = 0.24$, $r^2 = 0.22$); all other weighted and unweighted linear models had $P > 0.33$. 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 < 5 fish to 133 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 16 June to 20 July, we created 14 bins, with an average of 33 fish/bin (median of 31 fish; std = 8). 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 spill and negatively correlated with dissolved gas; we found almost no correlation with flow, Secchi disk visibility, or water temperature (Figure 35). Weighted and unweighted r^2 values were < 0.02 for

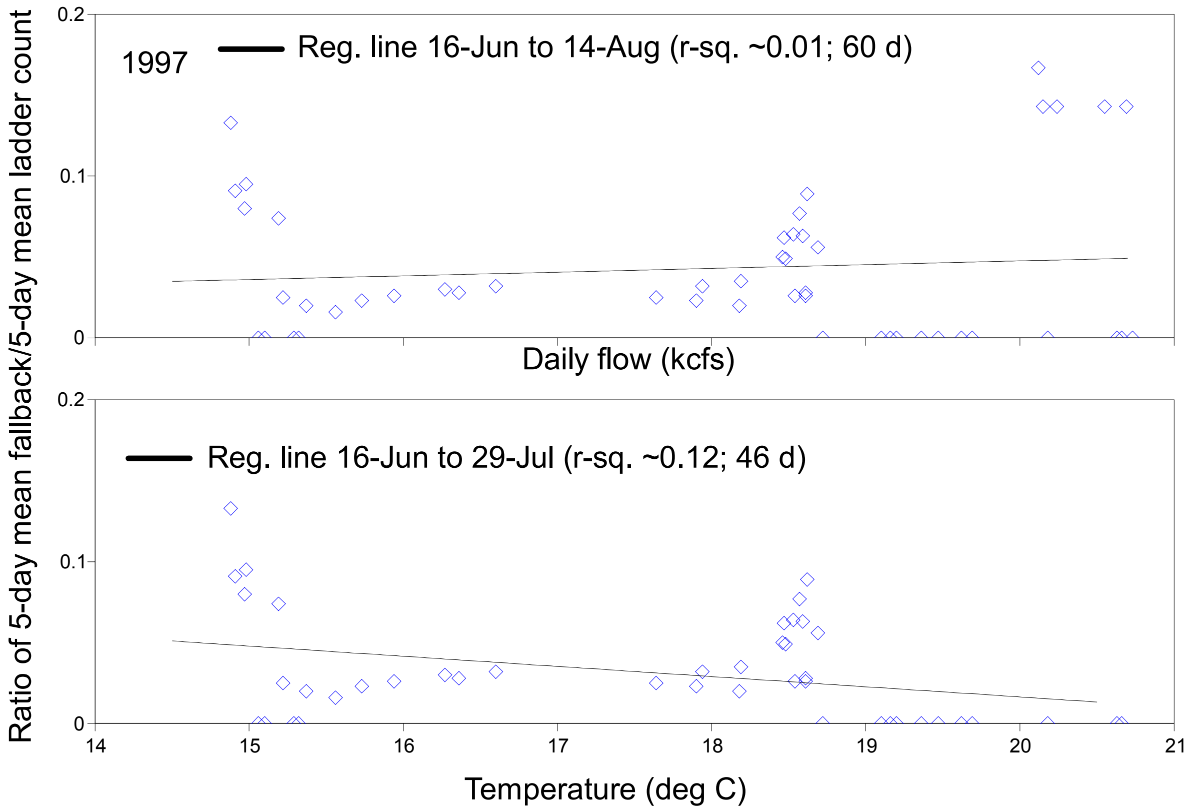

Figure 34. Regressions of daily mean water temperature with 5-d moving average fallback ratios for sockeye salmon with transmitters at John Day Dam in 1997. r-sq values approximate

flow, Secchi visibility, and water temperature and ~ 0.06 (P ~ 0.43) for spill. P values for dissolved gas models were 0.31 for the unweighted model (r^2 = 0.08) and 0.23 for the weighted model (r^2 = 0.12). Logistic regressions using maximum likelihood methods produced similar trends with P = 0.24 for dissolved gas and P = 0.49 for spill (Figure 35). Due to the 25 fish/block minimum, only one day with water temperature > 19° C was included in the variable-day bin analysis. Effects of high water temperatures could not be effectively addressed with the method.

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 John Day Dam during the passage of radio-tagged sockeye salmon ranged from about 170 kcfs to more than 570 kcfs. We grouped

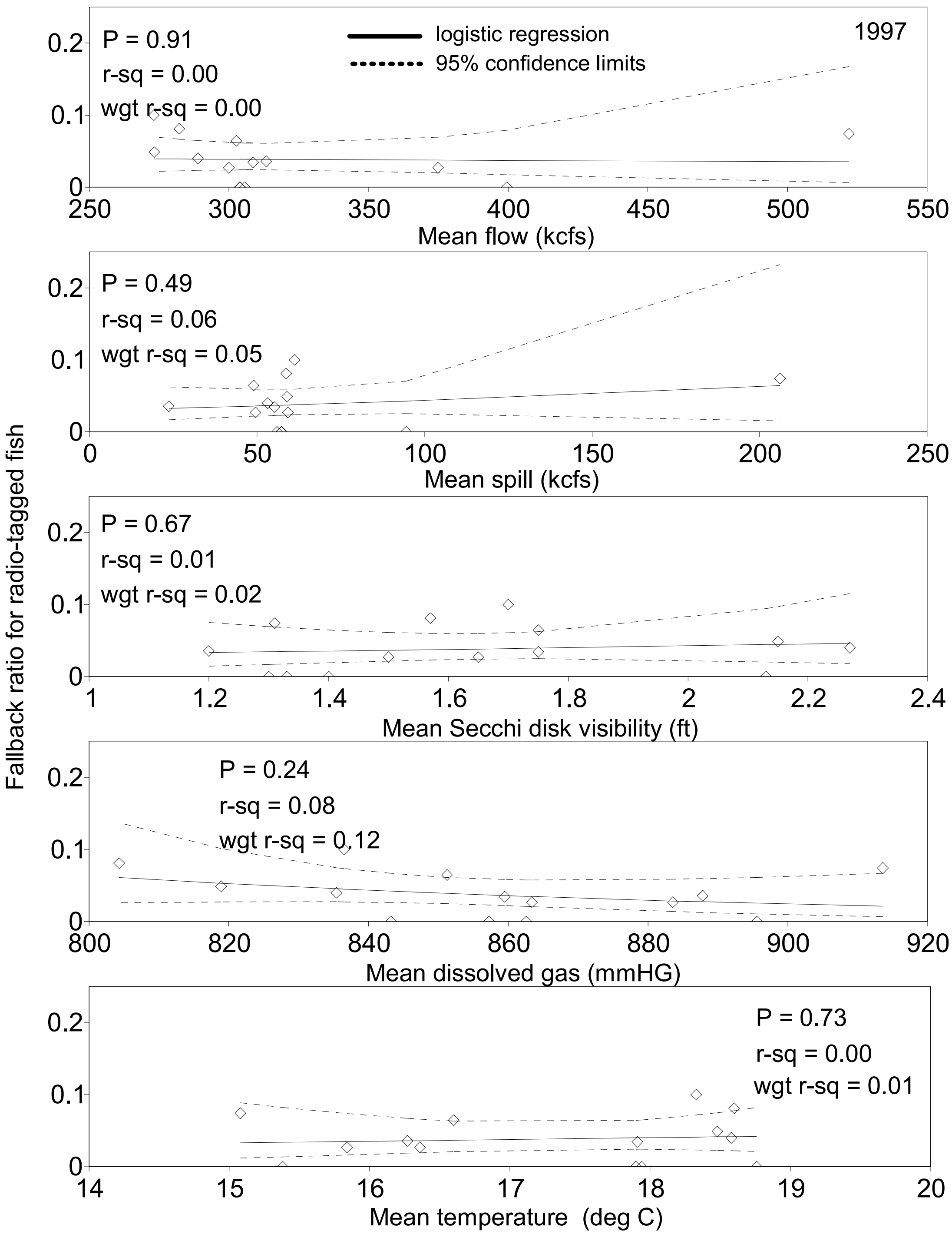

Figure 35. Logistic regression models for flow, spill, Secchi disk visibility, dissolved gas levels, temperature, and the probability of sockeye salmon fallbacks within 24 h at John Day Dam in 1997; includes r-sq values for weighted and unweighted linear regression models. All models based on variable-width time bins that included at least 25 fish.

sockeye salmon based on mean daily flow increments of 10 kcfs. The 25 groups with fish (Table 13) had a mean of 19 sockeye salmon per group (median of 6); 91% of all passages occurred with mean daily flow between 250 and 400 kcfs. Thirty-five percent of 485 known-date passages of sockeye salmon at John Day Dam occurred at flows less than 300 kcfs, for which the aggregated fallback ratio was 0.058. Of all passages by radio-tagged sockeye salmon at John Day Dam, 313 (65%) occurred at flows greater than 300 kcfs. The aggregated fallback ratio for all passages when flows were 300 kcfs or more was 0.026, less than half the rate for fish that passed at lower flow.

Spill at John Day Dam during the passage of radio-tagged sockeye salmon in 1997 ranged from about 20 to 270 kcfs; 92% of the fish passed when mean daily spill was between < 90 kcfs. Using 10-kcfs increments, we formed 16 groups with fish that had a mean of 30 fish per group (median of 6) (Table 13). For 166 (34%) passages by sockeye salmon when spill was less than 50 kcfs, 5 fallback events were recorded and the aggregated fallback ratio was 0.030. For 319 (66%) passages that occurred at spill of more than 50 kcfs the aggregated fallback ratio was 0.041 (Table 13).

Unweighted and weighted regression and logistic regression models using all groups based on flow and spill were not significant (P > 0.48) with fallback ratio as the dependent value. When we removed groups with fallback ratios equal to zero and one 2-fish block with fallback ratio of 0.50 (17% of all passages for flow groups; 5% of all passages for spill groups), P values dropped, but no weighted or unweighted models were significant for flow (P > 0.60) or spill (P > 0.22).

We also created a binary data set that included every known-date passage of John Day 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 485 known passages by sockeye salmon at John Day Dam between 16 June and 14 August, 1997. Following passage, 18 fell back within 24 h and 467 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 (P > 0.47 for flow and spill, P = 0.15 for dissolved gas). Differences in water temperature and Secchi visibility were also not significant (P > 0.56). Logistic regression models of the binary data set produced similar non-significant results.

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 only 12 steelhead in 1996 and 14 in 1997 fell back within 24 h of passage. In addition, about 70% of the steelhead tagged in 1996 that passed John Day Dam passed during the period of near-zero spill that began on 1 September. For steelhead tagged in 1997, about 80% of the tagged fish that passed the dam did so after

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 John Day 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	--	--	--	20-29	28	1	0.04
170-179	1	0	0.00	30-39	34	2	0.06
180-189	3	0	0.00	40-49	104	2	0.02
190-199	4	1	0.25	50-59	192	6	0.03
200-209	2	0	0.00	60-69	55	4	0.07
210-219	2	0	0.00	70-79	--	--	--
220-229	--	--	--	80-89	33	1	0.03
230-239	--	--	--	90-99	6	0	0.00
240-249	--	--	--	100-109	6	0	0.00
250-259	17	2	0.12	110-119	--	--	--
260-269	36	4	0.11	120-129	--	--	--
270-279	13	0	0.00	130-139	--	--	--
280-289	46	1	0.02	140-149	--	--	--
290-299	48	2	0.04	150-159	13	1	0.08
300-309	161	3	0.02	160-169	--	--	--
310-319	37	1	0.03	170-179	2	1	0.50
320-329	24	1	0.04	180-189	4	0	0.00
330-339	--	--	--	190-199	--	--	--
340-349	--	--	--	200-209	2	0	0.00
350-359	--	--	--	210-219	--	--	--
360-369	22	0	0.00	220-229	2	0	0.00
370-379	--	--	--	230-239	--	--	--
380-389	21	1	0.05	240-249	2	0	0.00
390-399	15	0	0.00	250-259	1	0	0.00
400-409	--	--	--	260-269	1	0	0.00
410-419	6	0	0.00				
420-429	--	--	--				
430-439	--	--	--				
440-449	--	--	--				
450-459	--	--	--				
460-469	5	1	0.20				
470-479	8	0	0.00				
480-489	2	1	0.50				
490-499	--	--	--				
500-509	4	0	0.00				
510-519	--	--	--				
520-529	2	0	0.00				
530-539	--	--	--				
540-549	1	0	0.00				
>550	4	0	0.00				

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

1 September when there was zero or near-zero spill. We also stopped radio-tagging steelhead at Bonneville Dam for almost 2 weeks in late July/early August when river temperatures exceeded 21º 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.

Steelhead were recorded falling back at John Day Dam throughout the steelhead migrations, with 55% of all fallback events in 1996 and 68% in 1997 before 1 November (Figure 36). Although we were not able to determine the exact time of all fallback events, we estimated that 76% of all fallbacks and 100% of fallback events within 24 h in 1996 occurred during spill. (Spill was approximately 1 to 1.5 kcfs in September and October, when 31% of all fallbacks and 58% of fallbacks within 24 h occurred.) It was more difficult to identify if fish tagged in 1997 fell back during spill. About 50% of all events in 1997 occurred in September and October, when mean daily spill alternated between 0 and about 1 kcfs. We believe at least half of the fallback events in September and October occurred during spill, but the proportion may have been higher because some fish likely fell back during spill and were detected downstream the following day during no-spill. Overall, we believe 50% of all fallbacks in 1997 were during possible spill, 24% were during definite spill, and 26% were during no spill (Figure 36). Of the 11 events within 24 h of passage, we believe 64% were during definite spill and 36% were during possible spill in September and October.

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 passing the dam 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 John Day Dam by steelhead. (See Bjornn et al., 2001 for complete migration history for steelhead tagged in 1996.)

In 1996, 12 steelhead with transmitters fell back within 24 h of passage at John Day Dam (11 before 31 October). Three events in late July and early August, when relatively few radio-tagged fish were passing the dam, produced the highest fallback ratios (Figure 37). The lowest ratios were in late September and early October during the peak counts of tagged fish. Flows decreased from July to September and was generally between 100 and 140 kcfs through September and October. Spill was between 30 and 40 kcfs in July and August, was at low levels (approximately 1 to 1.5 kcfs) in September and October, was at zero in November and December, and resumed in January, 1997. Water temperatures peaked in early September then decreased, and Secchi disk visibility increased gradually during the fall and winter period of the migration. The higher fallback ratios were during the period of highest flow and spill during the 1996 portion of the migration, and coincided with water temperatures > 20º C (Figure 38).

Eleven steelhead outfitted with transmitters in 1997 fell back within 24 h of passage at John Day Dam, all before 31 October. Six of the eleven events were before 1 September, when mean daily spill ranged from 30 to 80 kcfs (Figure 39). Peak fallback ratios were in the second half of August, when relatively few steelhead with transmitters were passing the dam, but three fell back within 24 h of passage. Five steelhead fell back within 24 h during September/October, when spill alternated between zero and ~1 kcfs. Fallback ratios during that time of near-

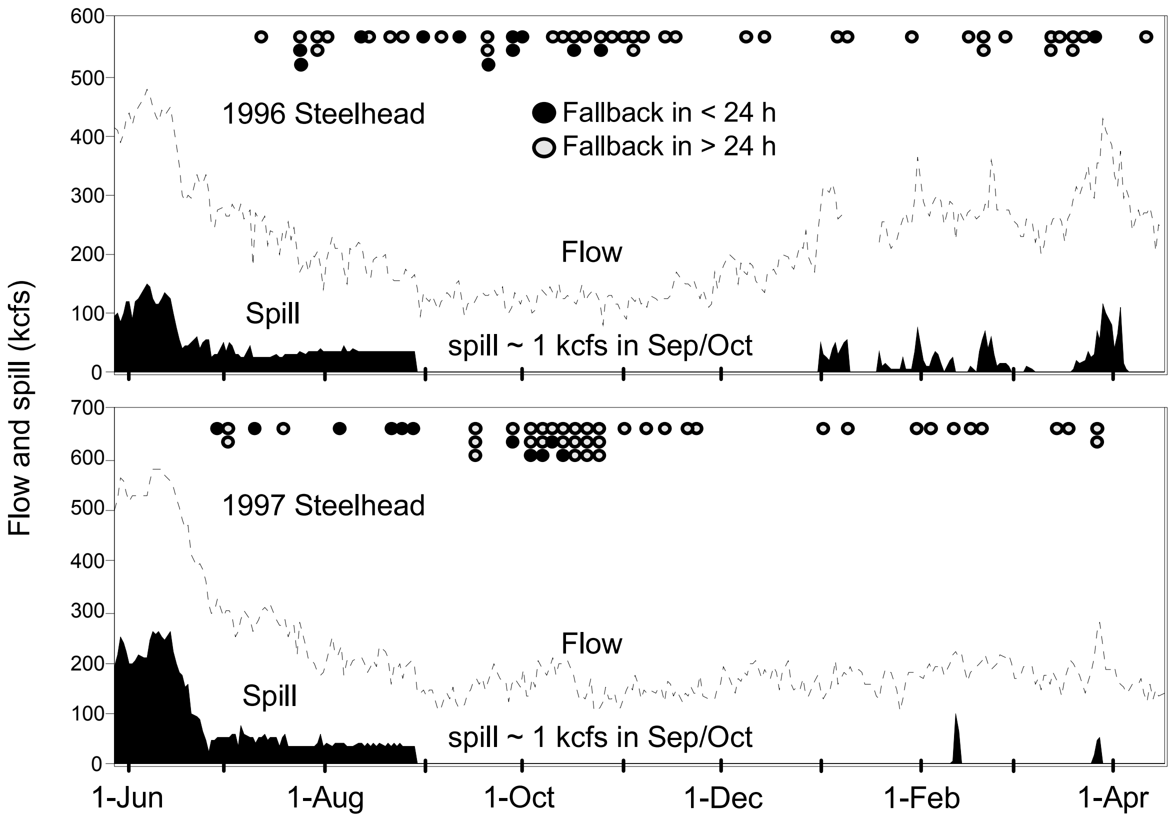

Figure 36. Flow, spill, and distribution of fallback events by steelhead with transmitters at John Day Dam in the run-years 1996-1997 and 1997-1998.

peak passage were relatively low (Figure 39). As in 1996, the highest 5-d moving average fallback ratios coincided with forced spill > 30 kcfs and with water temperatures > 20º C (Figure 38).

We also created a binary data set that included every known-date passage of John Day 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 462 known passages by steelhead before 31 December at John Day Dam by fish tagged in 1996. Following passage, 11 fell back within 24 h and 451 did not (Table 11). Although flow, spill, and water temperature were higher for fish that fell back within 24 h, differences were not significant (P > 0.67). We found no difference in mean Secchi visibility. Sixteen fish fell back within 5 d of passage. Flow on the date of passage was 166 kcfs for fish that fell back and 152 for fish that did not fall back, a difference that was not significant (P = 0.25). Spill was also higher on the date of passage for fish that fell back within 5 d (15 kcfs) than for fish that did not fall

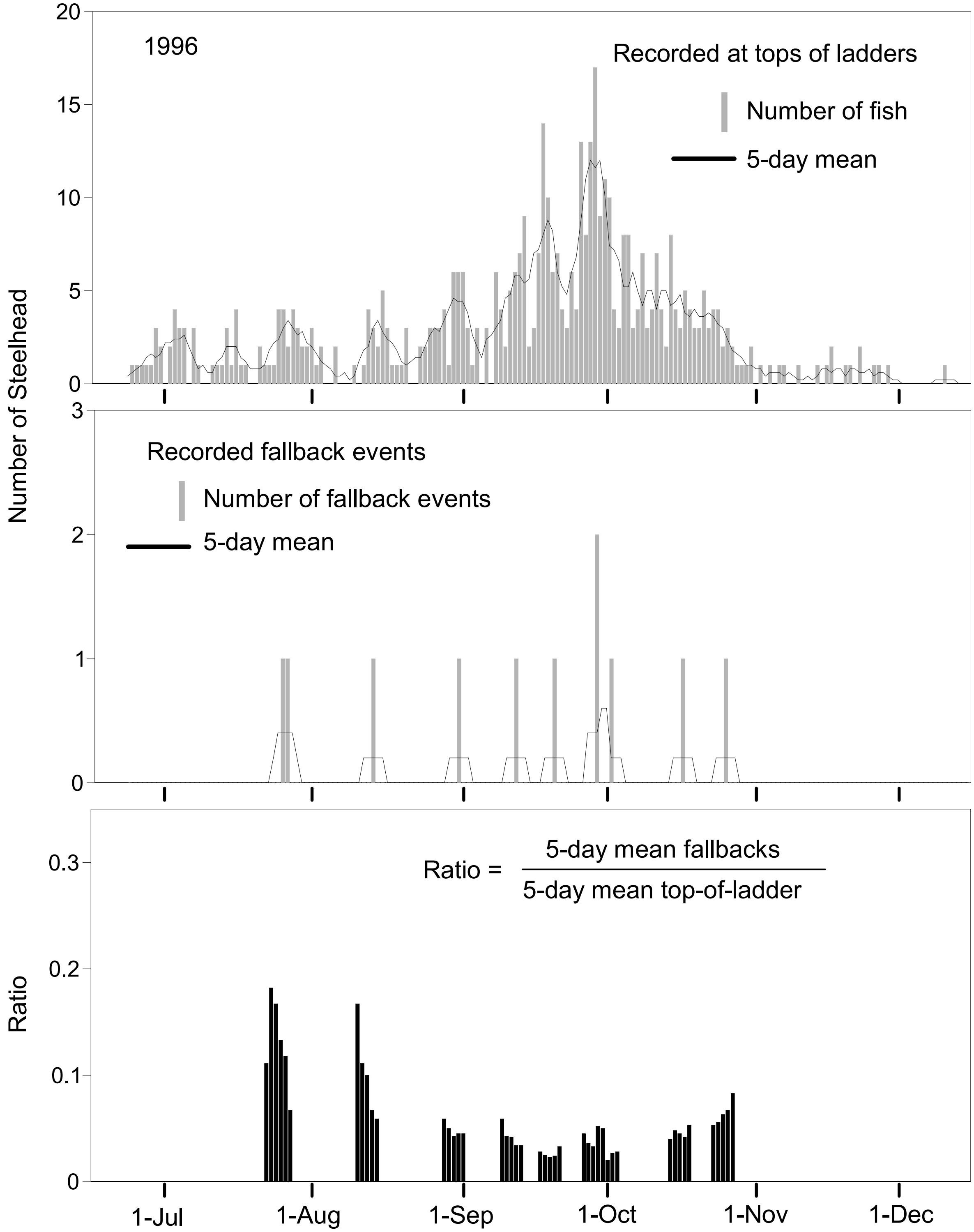

Figure 37. Daily number and 5-d moving average of recorded passages at John Day Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for steelhead outfitted with transmitters in 1996.

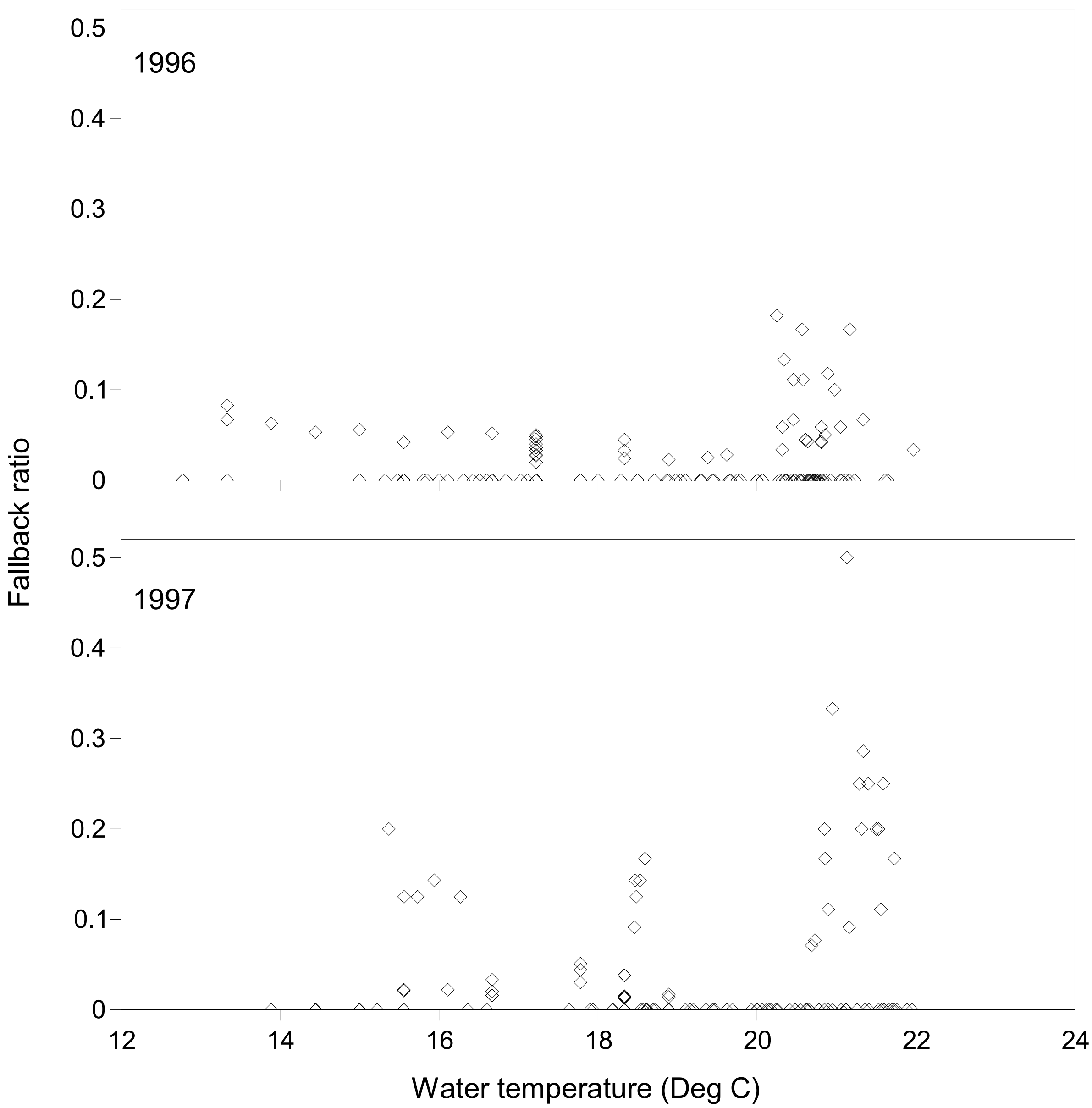

Figure 38. Water temperature in the forebay with 5-d moving average fallback ratios for steelhead with transmitters at John Day Dam from 23 June to 31 October, 1996.

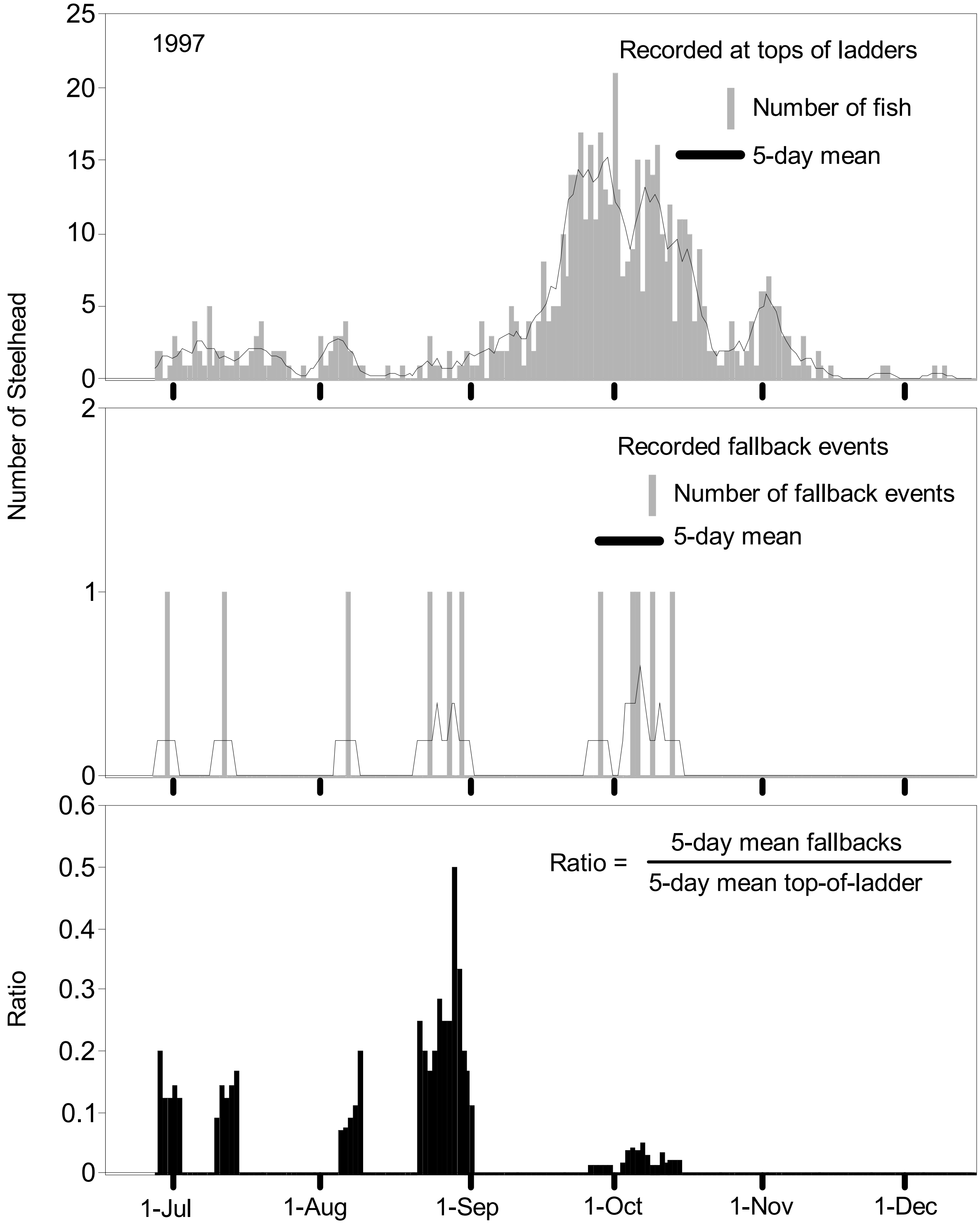

Figure 39. Daily number and 5-d moving average of recorded passages at John Day Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for steelhead outfitted with transmitters in 1997.

back (11 kcfs), and water temperatures were also higher for fallback fish, but differences were not significant (P = 0.39 for spill, P = 0.33 for water temperature).

There were 571 known passages before 31 December by steelhead tagged in 1997. Following passage, 11 fell back within 24 h and 560 did not (Table 11). Spill was significantly higher at the time of passage for fish that fell back (29 kcfs) than for fish that did not fall back (8 kcfs) (P < 0.001). Flow was also significantly higher for fish that fell back (212 kcfs) than for fish that did not fall back (178 kcfs) (P = 0.03). We found little difference in Secchi visibility (P = 0.61). Water temperatures were higher for fallback fish, but differences were not significant (P = 0.28) (Table 11). Twenty-two fish fell back within 5 d of passage (Table 12). Spill and flow were significantly higher for fallback fish (P = 0.001 for spill, P = 0.02 for flow). We found no significant differences in Secchi visibility (P = 0.63) or water temperature (P = 0.38) for fallback fish (Table 12).

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. All radio-tagged fish passed John Day Dam after 1 September, during the period of no spill. In addition, < 5% of the radio-tagged fall chinook salmon fell back at John Day Dam in 1998, and only 4 fish fell back within 24 h of passage.

Fall chinook salmon were recorded falling back at John Day Dam starting in the third week of September with the highest number of events in early October following peak counts at the dam (Figure 40). Four fish fell back late in October or in November after most fish had passed the dam.

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 John Day Dam by fall chinook salmon tagged in 1998.

Four fall chinook salmon with transmitters fell back within 24 h of passage at John Day Dam in 1998. We observed no clear patterns in the fallback ratios based on 5-d moving averages (Figure 41). Nine fall chinook salmon fell back within 5 d of passage. Moving-average fallback ratios using those fallbacks peaked in the second half of September (Figure 42). Fallback ratios were positively correlated with flow ($r^2 \sim 0.16$) and water temperature ($r^2 \sim 0.13$). The 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.

We also created a binary data set that included every known-date passage of John Day Dam by fall chinook salmon with transmitters in 1998. Fish that fell back within 5 d of passage were coded ‘1,’ and fish that did not fall back within

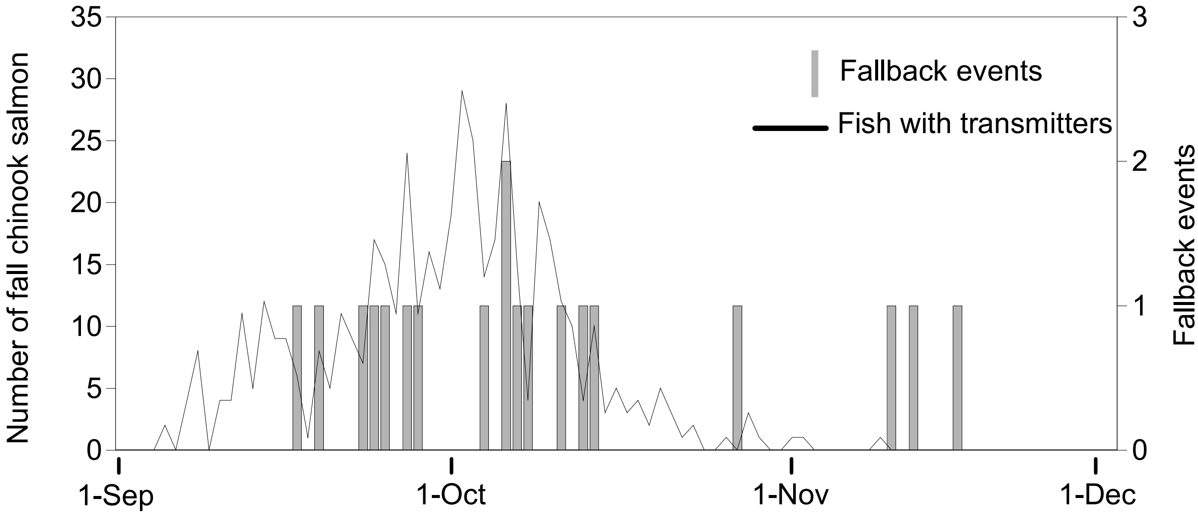

Figure 40. Number of fall chinook salmon with transmitters recorded passing John Day Dam in 1998, and the number of fish that fell back at the dam; date of fallback event is shown, not date of passage.

5 d 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 5 d in each year. There were 482 known-date passages by fall chinook salmon at John Day Dam by fish tagged in 1998. Following passage, 9 fell back within 5 d and 473 did not (Table 12). We found no significant differences in flow or spill for fish that fell back within 5 d ($P > 0.87$). Water temperatures were higher for fallback fish, but not significantly higher ($P = 0.16$). Secchi visibility at the time of passage was significantly lower for fallback fish than for fish that did not fall back within 5 d ($P = 0.005$) (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 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 John Day 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 and spill were highly correlated ($r > 0.95$), and dissolved gas was positively correlated with both flow and spill ($r > 0.51$) (Figure

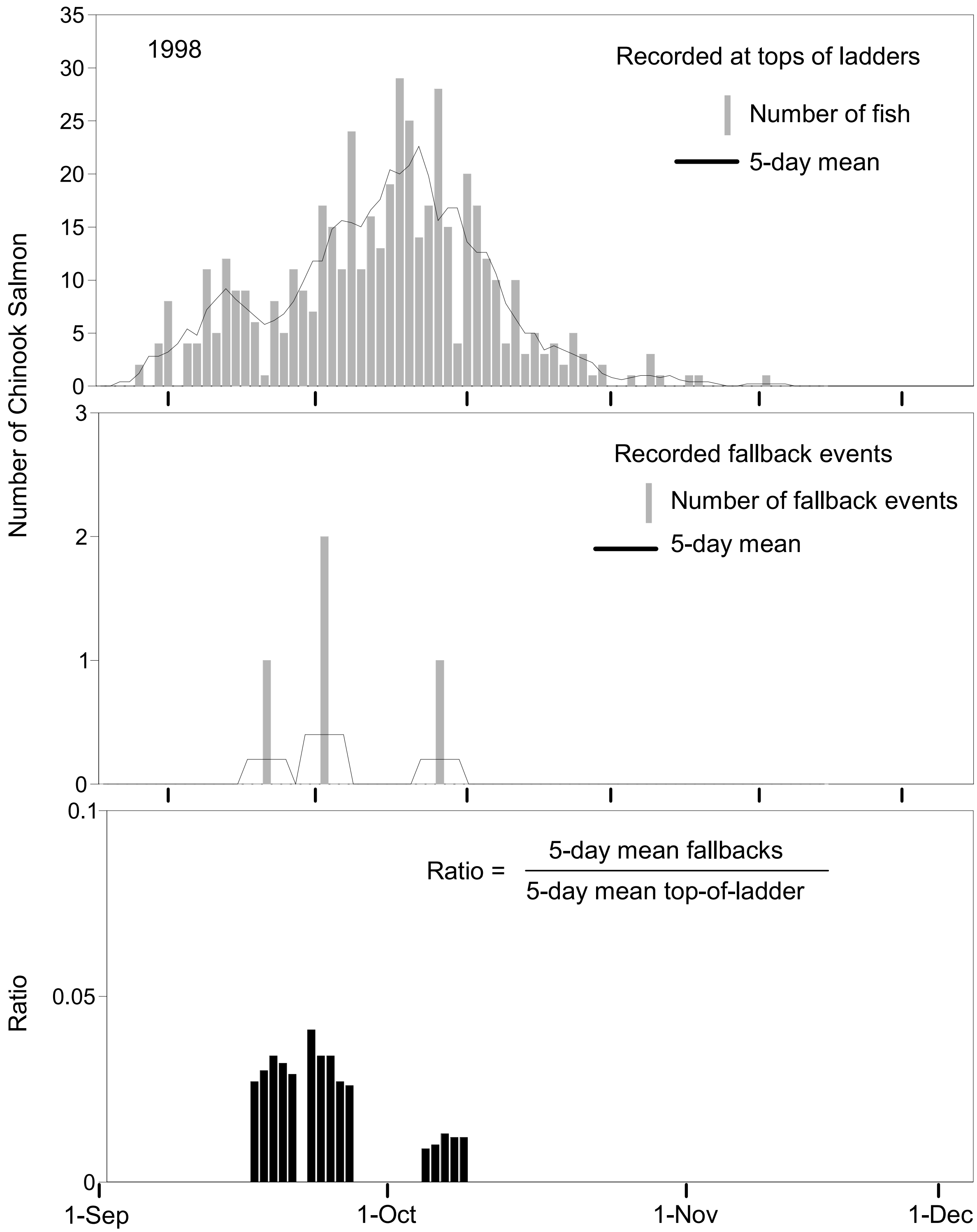

Figure 41. Daily number and 5-d moving average of recorded passages at tops of the fishways at John Day Dam, daily number and 5-d mean fallbacks within 24 h of passage, and the 5-d moving average ratio of fallbacks to passages for fall chinook salmon outfitted with transmitters in 1998.

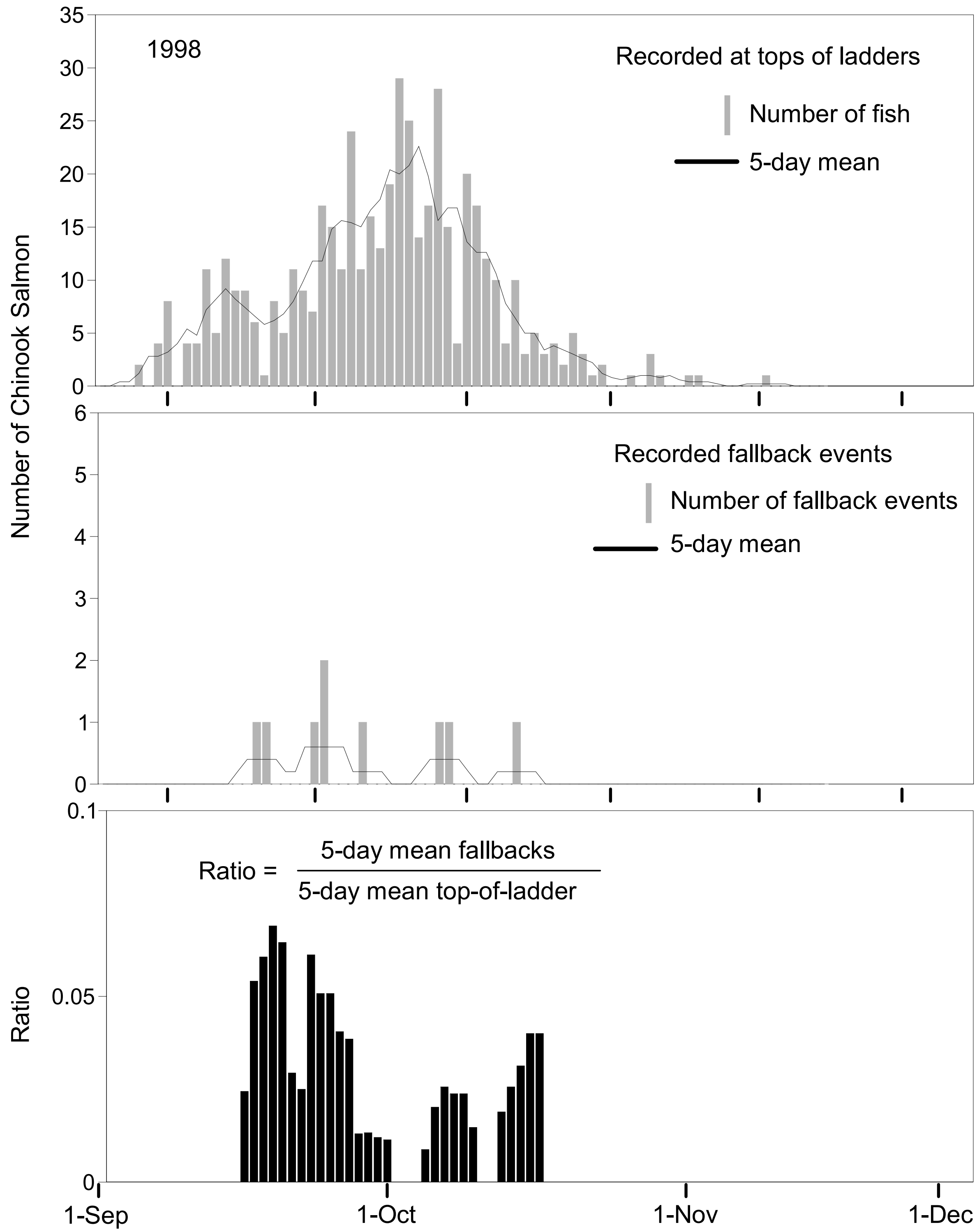

Figure 42. Daily number and 5-d moving average of recorded passages at tops of the fishways at John Day Dam, daily number and 5-d mean fallbacks within 5 d of passage, and the 5-d moving average ratio of fallbacks to passages for fall chinook salmon outfitted with transmitters in 1998.

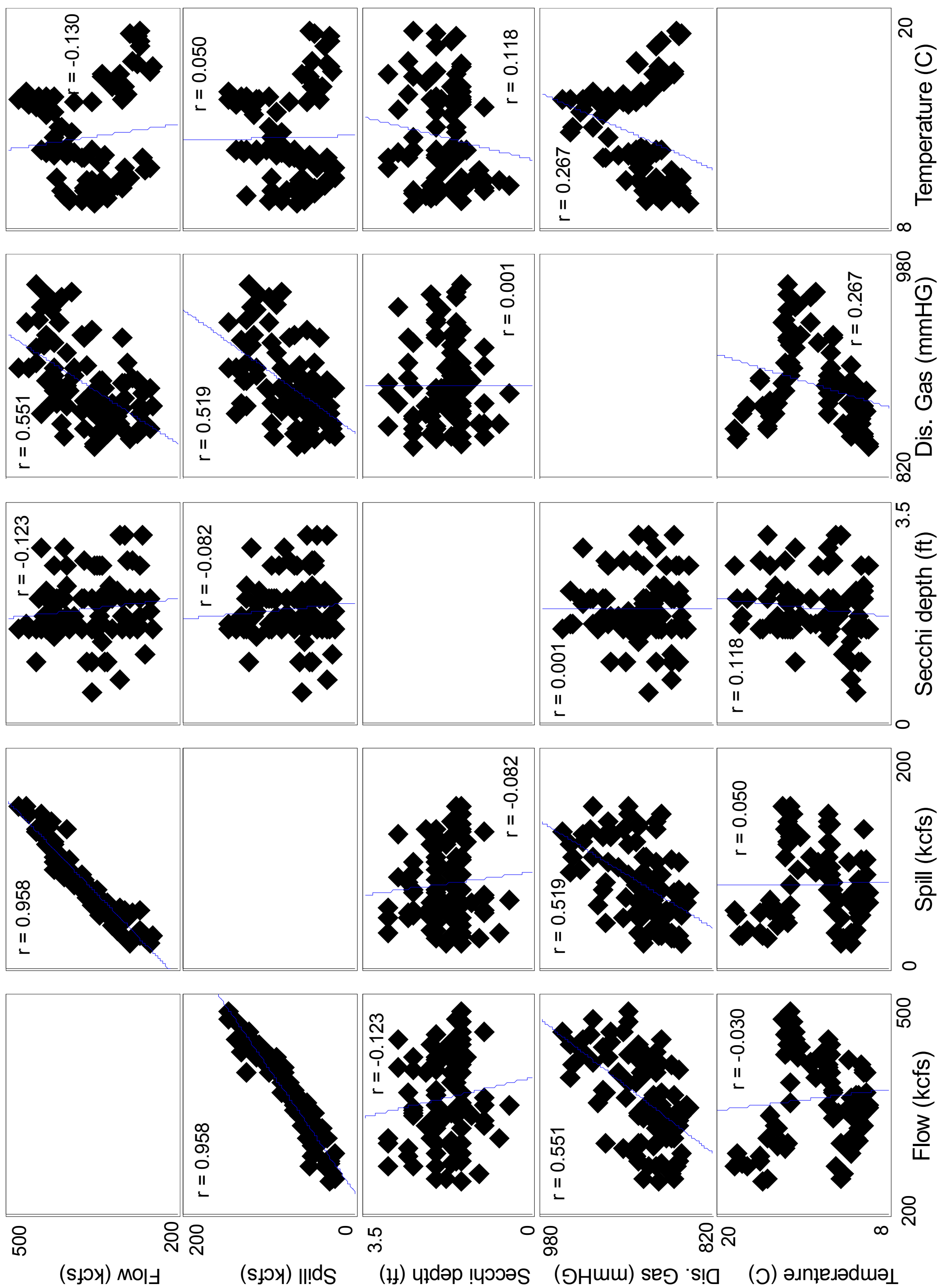

Figure 43. Scatter plots and correlation coefficients for environmental variables used in multiple regression models, based on daily mean values during the spring/summer chinook salmon migration at John Day Dam in 1996.

43). Secchi disk visibility was weakly correlated with other variables (r < 0.13). Water temperatures had a parabolic relationship with flow, spill, and dissolved gas: 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 43).

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, no variables met the 0.10 significance level for inclusion in the model (Table 14). When we used the fallback ratios from the consecutive 5-d block method as the dependent variable, no variables were selected at P < 0.10 (Table 14).

We tested multiple regression models on two versions of the 1997 spring and summer chinook salmon fallback data at John Day Dam. The first set included the entire range of dates that chinook salmon with transmitters were passing the dam (12 April to 30 July); the second set included about 65% of all passages (12 April to 15 June).

Over the entire date range, flow, spill, and dissolved gas were highly correlated (r > 0.81) (Figure 44). Secchi disk depth was negatively correlated with flow, spill, and dissolved gas levels (r ~ 0.35 to 0.46) and water temperature had parabolic relationships with the other variables (Figure 44). In general, correlations among environmental variables in the truncated data set (12 April to approximately 15 June) were similar to those for the entire date range.

With the entire 1997 spring and summer chinook salmon data set, dissolved gas level was the first and only variable selected using the variable-day-bin data (r^2 = 0.16), and spill was the only variable selected using the consecutive 5-d block data (r^2 = 0.25) (Table 15). With the truncated data set (through mid June), no variables were selected using the variable-day-bin data. With the 5-d block data, water temperature was first selected (r^2 = 0.36), followed by dissolved gas and Secchi visibility for an overall model r^2 of 0.71. When we removed temperature from the model, spill was selected (r^2 = 0.19) and no additional variables met the 0.10 selection criteria for inclusion in the model.

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 12 April to 10 July						
a. No variables selected						
Model 2, Consecutive 5-d block model with all variables included from 12 April to 10 July						
a. No variables selected						

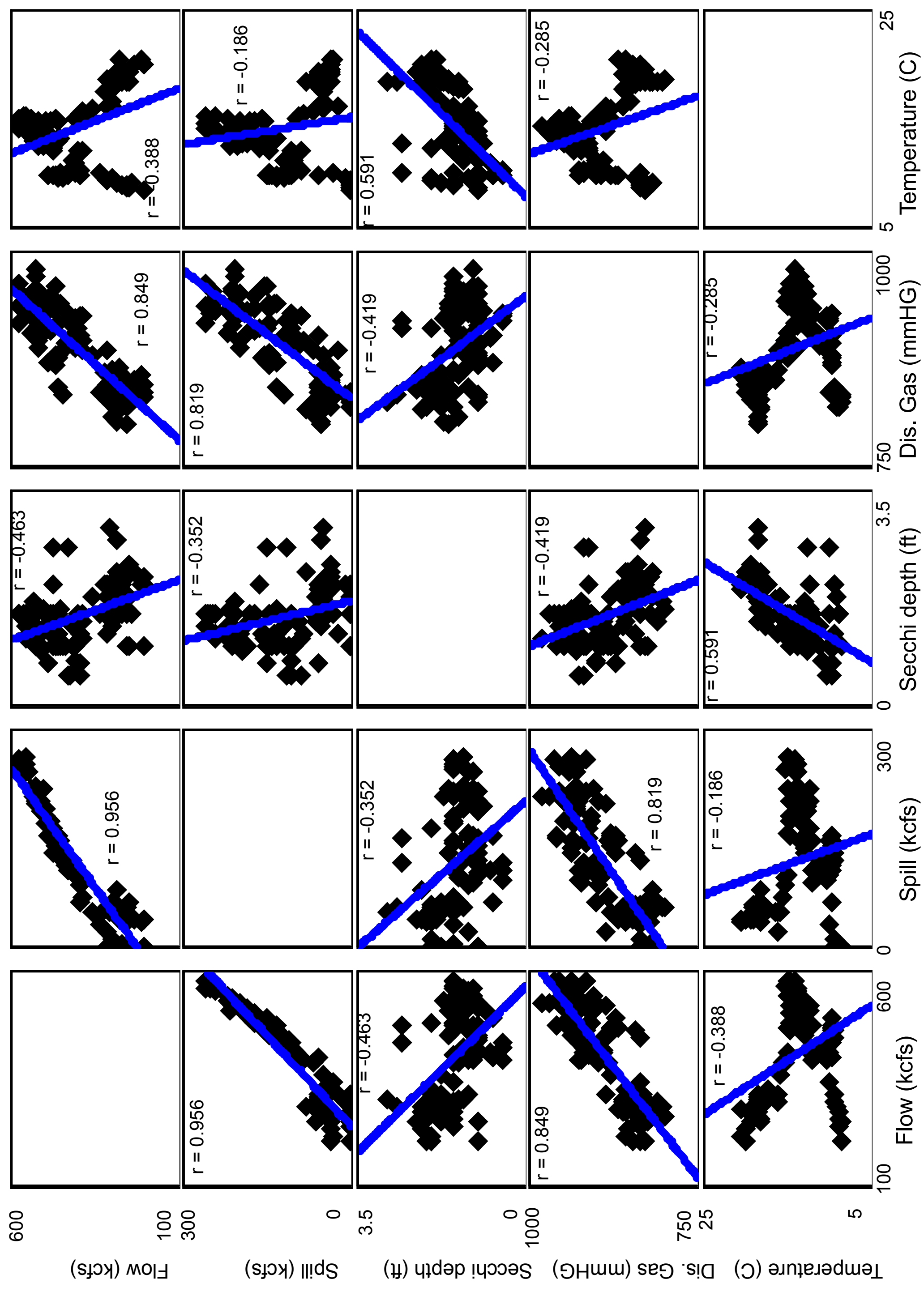

Figure 44. Scatter plots and correlation coefficients for environmental variables used in multiple regression models, based on daily mean values during the spring and summer chinook salmon migration in 1997.

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 12 April to 30 July						
	a. Dissolved gas		0.1560	0.1560	3.70	0.0689
Model 2, Variable-day-bin model with all variables included from 12 April to 9 June						
	a. No variables selected					
Model 3, Consecutive 5-d block model with all variables included from 12 April to 30 July						
	a. Spill		0.2483	0.2483	6.61	0.0183
Model 4, Consecutive 5-d block model with all var. included from 12 April to 15 June						
	a. Water temperature		0.3639	0.3639	6.86	0.0224
	b. Dissolved gas		0.4987	0.1349	2.96	0.1133
	c. Secchi visibility		0.7103	0.2116	7.30	0.0222

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 9 April to 1 August						
	a. No variables selected					
Model 2, Consecutive 5-d block model with all var. included from 9 April to 1 August						
	a. No variables selected					

During the 1998 chinook salmon migration, flow and spill were highly correlated (r = 0.93), and dissolved gas was also correlated with flow and spill (r ~ 0.61) (Figure 45). 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 (and to a lesser extent Secchi visibility) that we observed in previous years (Figure 45).

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). With both datasets, spill was selected at P ~ 0.20. Truncating the datasets had little impact on model fit.

During the 1997 sockeye salmon migration from 16 June through 14 August, flow and spill were highly correlated (r = 0.93), as were flow and dissolved gas (r = 0.90), and spill and dissolved gas (r = 0.82) (Table 17). (Also see Figure 44 for 1997 coefficients.) Secchi disk visibility

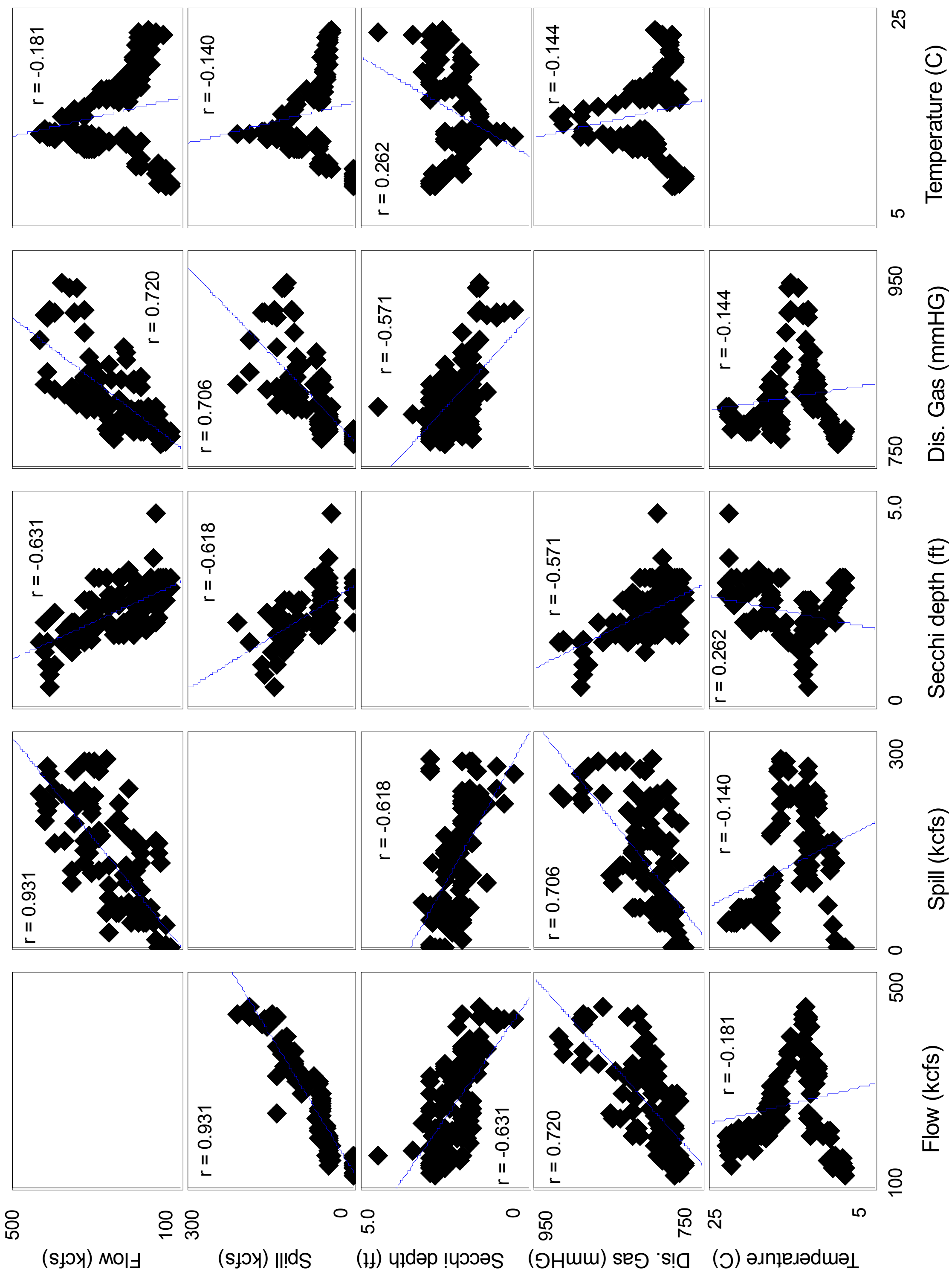

Figure 45. Scatter plots and correlation coefficients for environmental variables used in multiple regression models, based on daily mean values during the spring and summer chinook salmon migration in 1998.

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 John Day Dam from 16 June to 14 August, 1997

	Water temp	Flow	Spill	Secchi disk	Dissolved gas
Water temp	---	-0.896	-0.728	0.747	-0.828
Flow	-0.896	---	0.925	-0.657	0.896
Spill	-0.728	0.925	---	-0.507	0.816
Secchi	0.747	-0.657	-0.507	---	-0.636
Gas	-0.828	0.896	0.816	-0.636	---

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 18 June to 27 July						
a. No variables selected						
Model 2, Consecutive 5-d block model with all var. included from 18 June to 27 July						
a. No variables selected						

was negatively correlated with flow, spill, and dissolved gas (r > -0.63) and positively correlated with water temperature (r = 0.75) (Table 17).

We limited fallback data included in stepwise models to between 16 June and 20 July. With all environmental variables included and the variable-day-bin fallback ratio as the dependent variable for 1997 sockeye salmon, no variables were selected in the stepwise procedure (Table 18). Likewise, no variables met the P = 0.10 criteria for model using the consecutive 5-d block data (Table 18). Truncating the data used had little impact on model fit.

Final Distribution of Fish that Fell Back at John Day 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 John Day 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 John Day Dam was 74.5% in 1996, 83.1% in 1997, and 71.6% in 1998 (Table 19). Steelhead survival was 56.5% for fish tagged in 1996 and 63.6% for fish tagged in 1997. About 77.8% of sockeye salmon and 52.6% of fall chinook salmon that fell back at John Day Dam survived using our limited criteria (Table 19).

Of 47 spring and summer chinook salmon that fell back at John Day Dam in 1996, 2 (4%) were later recorded in tributaries downstream from Bonneville Dam, 2 (4%) were in tributaries between Bonneville and The Dalles dams, 7 (15%) were in the Deschutes or John Day rivers, 2 (4%) were in the Umatilla River, and 1 (2%) was in the Yakima River (Table 19). One fish 2 (2%) was in the Tucannon River, and 18 (38%) were in Snake River tributaries upriver from Lower Granite Dam or in the Lower Granite Trap (Table 19). Two (4%) were last recorded at the top of Priest Rapids Dam. Twelve fish (26%) fell back and were not recorded in tributaries or at the top of Priest Rapids Dam, of which 10 were last recorded in the Bonneville Dam pool or at The Dalles or John Day dams. Nineteen of 47 fish (40%) that fell back did not reascend, of which 9 (47%) were recorded entering downstream tributaries (Table 20).

Of 59 spring and summer chinook salmon that fell back at John Day Dam in 1997, 1 (2%) was later recorded in the Sandy River, 4 (7%) were last recorded in tributaries between Bonneville and The Dalles dams, 10 (17%) were in the Deschutes River, 4 (7%) were in the Yakima River, 5 (8%) were in the Icicle River, 2 (3%) were at Wells Dam or trap, 1 was in the Tucannon River, and 22 (37%) were in Snake River tributaries upriver from Lower Granite Dam (Table 19). Ten fish (26%) fell back and were not recorded in tributaries or at Wells Dam, of which 9 were last recorded at lower Columbia River dams or in their reservoirs. Nineteen of 59 fish (32%) that fell back did not reascend, of which 14 (74%) were recorded entering downstream tributaries (Table 20).

Of 67 spring and summer chinook salmon that fell back at John Day Dam in 1998, 1 (1%) was later recorded in the Sandy River downstream from Bonneville Dam, 8 (12%) were in tributaries between Bonneville and The Dalles dams, 8 (12%) were in the Deschutes or John Day rivers, 4 (6%) were in the Yakima or Icicle rivers, and 21 (31%) were in Snake River tributaries upriver from Lower Granite Dam or in the Lower Granite Trap (Table 19). Nineteen fish (28%) fell back and were not recorded in tributaries or the uppermost sites, of which 13 were last recorded at lower Columbia River dams or in their reservoirs. Twenty-four of 67 fish (36%) that fell back did not reascend, of which 15 (63%) were recorded entering downstream tributaries (Table 20).

Of 46 steelhead tagged in 1996 that fell back at John Day Dam, 2 (4%) were later recorded in tributaries between Bonneville and The Dalles dams, 14 (30%) were in the Deschutes or John Day rivers, 1 (2%) was in the Umatilla River, and 8 (17%) were in Snake River tributaries upriver from Lower Granite Dam (Table 19). Twenty fish (43%) fell back and were not recorded in tributaries, of which 15 were last recorded at lower Columbia River dams or in their reservoirs. Twenty-five of 46 fish (54%)

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 John Day 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	**47**	**59**	**67**	**46**	**44**	**18**	**19**
Final location							
Cowlitz River	1						
Sandy River	1		1				
Wind River			2				
Little White Salmon River				1			
White Salmon River	1						2
Hood River		1					
Klickitat River	1	3	6	1	1	1	1
Deschutes River	5	10	6	10	4		6
John Day River	2		2	4	1		
Umatilla River	2		1	1	2		
Walla Walla River					1		
Yakima River	1	4	3		1		
Hanford Reach			1			1	1
Wenatchee/Tumwater Dam						8	
Okanogan River						3	
Icicle River		5	1				
Methow River						1	
Tucannon River	1	1					
Clearwater River	4	11	8	3	9		
Snake River above Asotin	2	1	1	2	3		
Grande Ronde River				2	1		
Imnaha River			1				
Salmon River	5	10	10	1	3		
Total:	**26**	**46**	**43**	**25**	**26**	**14**	**10**
Percent that survived to tributaries:	**55.3**	**78.0**	**64.2**	**54.3**	**59.1**	**77.8**	**52.6**
Additional fish that survived to relevant non-tributary sites:							
L. Granite trap: to hatchery	4		1				
L. Granite trap, no trans.	3						
At/Near Ringold trap		1	3		2		
Top of Pr. Rapids Dam[a]	2			1			
At Wells Dam/trap[b]		2	1				
Percent that survived to tributaries, traps, top of Pr. Rapids (1996) or Wells dams:	**74.5**	**83.1**	**71.6**	**56.5**	**63.6**	**77.8**	**52.6**

[a] 1996 only

[b] includes fish at Chief Joseph Dam

that fell back did not reascend, of which 12 (48%) were recorded entering downstream tributaries (Table 20).

Of 44 steelhead tagged in 1997 that fell back at John Day Dam, 1 (2%) was later recorded in the Klickitat River, 5 (11%) were in the Deschutes or John Day

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 John Day Dam in 1996 to 1998 that did not reascend John Day 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	19	10	9 (47%)	Deschutes (5), White Salmon (1), Klickitat (1), Cowlitz (1), Sandy (1)
1997 CK	19	5	14 (74%)	Deschutes (10), Klickitat (3), Hood (1)
1998 CK	24	9	15 (63%)	Deschutes (6), Klickitat (6), Wind (2), Sandy (1)
1996 SH	25	13	12 (48%)	Deschutes (10), Little White Salmon (1), Klickitat (1)
1997 SH	11	6	5 (45%)	Deschutes (4), Klickitat (1)
1997 SK	2	1	1 (50%)	Klickitat (1)
1998 FCK	18	9	9 (50%)	Deschutes (6), White Salmon (2), Klickitat (1)
All species combined	118	53	65 (55%)	Deschutes (41), Klickitat (14), White Salmon (3), Wind (2), Sandy (2), Little White Salmon (1), Hood (1), Cowlitz (1)

rivers, 2 (5%) were in the Umatilla River, 1 (2%) each was in the Walla Walla and Yakima rivers, and 16 (36%) were in Snake River tributaries upriver from Lower Granite Dam (Table 19). Sixteen fish (36%) fell back and were not recorded in tributaries, of which 9 were last recorded at lower Columbia River dams or in their reservoirs. Eleven of 44 fish (25%) that fell back did not reascend, of which 5 (45%) were recorded entering downstream tributaries (Table 20).

Of 18 sockeye salmon that fell back at John Day Dam in 1997, 1 (6%) was later recorded in the Klickitat River, 8 (44%) were in the Wenatchee River, 3 (17%) were in the Okanogan River, and 1 (6%) was in the Methow River (Table 19). Four fish (22%) fell back and were not recorded in tributaries, all of which were last recorded at dams. Two of 18 fish (11%) that fell back did not reascend, one of which (50%) was recorded entering in a downstream tributary (Table 20).

Of 19 fall chinook salmon that fell back at John Day Dam in 1998, 3 (16%) were later recorded in tributaries or at hatcheries between Bonneville and The Dalles dams, 6 (32%) were in the Deschutes River, and 1 (5%) was in the Hanford Reach of the Columbia River (Table 19). Nine fish (47%) fell back and were not recorded in tributaries, all of which 18 were last recorded at dams or in reservoirs downstream from John Day Dam. Eighteen of 19 fish (95%) that fell back did not reascend, of which 9 (50%)

were recorded entering downstream tributaries (Table 20).

Between 45% and 74% of radio-tagged fish that fell back at John Day Dam and did not reascend entered downstream tributaries (Table 20). Results suggest that many fallbacks at John Day 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 Deschutes River; 40% to 71% of spring and summer chinook salmon, 83% of steelhead, and 66% of fall chinook salmon that fell back and entered downstream tributaries entered the Deschutes River. When we considered all fish that fell back at John Day Dam, 9% to 17% of spring and summer chinook salmon, 9% to 22% of steelhead, and 32% of fall chinook salmon eventually entered the Deschutes River.

Discussion

We monitored fallback behavior for more than 3,600 adult salmon and steelhead at John Day Dam using radio-telemetry equipment during the years 1996 to 1998. Significant proportions of the radio-tagged spring and summer chinook salmon and steelhead fell back in each year they were monitored; fallback proportions for sockeye salmon in 1997 and fall chinook salmon in 1998 were relatively low compared to proportions for chinook salmon and steelhead.

The percentage of spring and summer chinook salmon (9.4% to 12.3%) that fell back over the dam and fallback rates (11.4% to 14.4%) were highest in 1996. Fallback percentages were 4.9% for sockeye salmon, between 7.9% and 10.0% for steelhead, and 4.0% for fall chinook salmon. Fallback rates were 4.1% for sockeye salmon, 9.0% to 11.1% for steelhead, and 4.0% for fall chinook salmon. Percentages and rates were less than 7.0% 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. We expect that fallback percentages and rates for fall chinook salmon would have been higher had we sampled the portion of the run that passed during forced spill conditions prior to 1 September.

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 40% of spring and summer chinook salmon, steelhead, and fall chinook salmon fell back within 24 h of passage. About 40% percent of spring and summer chinook salmon, 25% of steelhead, and 40% of fall chinook salmon were recorded at upstream sites (mostly at McNary Dam) before they fell back at John Day 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 John Day 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 tended to increase with flow and spill, and decreased with lower turbidity levels. Similar trends were observed for 1997 sockeye salmon. Few steelhead or fall chinook salmon fell back within 24 h of passage during periods of zero spill. We found some evidence that water temperatures > 18^{o} C were associated with higher fallback ratios for sockeye salmon, steelhead, and fall chinook salmon, but sample sizes were relatively low at the highest temperatures.

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 steelhead in 1996 that fell back within 24 h, but differences were not significant at ($P < 0.05$). Flow and spill were significantly higher for steelhead tagged in 1997 that fell back within 24 h.

Extending the time horizon for fallbacks to 5 d produced more significant results. Some fish that were recorded more than 24 h after exiting from the top of a ladder may have fallen back within the 24 h period, but remained upstream of tailrace receivers and downstream of fishway receivers for a day or more. Other that fell back within 5 d were recorded at upstream sites before falling back and we suspect others migrated upstream out of the John Day Dam forebay prior to fallback, but were not recorded upstream. We believe environmental conditions at the time of passage would be less likely to affect fallback after fish migrated upstream, but uncertainty about fallback timing and upstream behavior limited interpretation. Spring and summer chinook salmon in 1997 and 1998 and steelhead in 1997 that fell back within 5 d of passage passed the dam under significantly higher flow and spill conditions than fish that did not fall back within 5 d ($P < 0.005$). Dissolved gas levels were also higher for fallback spring and summer chinook salmon in 1997 ($P < 0.005$), and water temperatures were significantly lower for fallback fish in 1996 and 1997 ($P < 0.05$). Secchi visibility was significantly lower ($P < 0.005$) for fall chinook salmon that fell back within 5 d of passage.

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. No variables were selected using stepwise regression models for 1996 or 1998 spring and summer chinook salmon or the 1997 sockeye salmon data. Dissolved gas and spill were selected for 1997 spring and summer chinook salmon, as was water temperature for a truncated version of the 1997 data. High correlations between flow, spill, and dissolved gas in all years made it difficult to separate effects, but overall we found little evidence that environmental conditions contributed significantly to fallback within 24 h of passage at the dam.

We believe most spring and summer chinook salmon and sockeye salmon that fell back at John Day Dam did so via the spillway. All fallbacks by spring and summer chinook salmon and sockeye salmon occurred on days with forced spill. About 76% of fallbacks by steelhead tagged in 1996, 46% of fallbacks by steelhead tagged in 1997 fell back on days with spill, although spill rates were < 1.5 kcfs for much of September and October in both years. All fall chinook salmon fallbacks in 1998 were 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 most fall chinook likely fell back through the navigation lock, and a smaller number via an ice and trash sluiceway, or though the juvenile bypass. We believe relatively few fish of any species fell back through powerhouses, but no potential fallback routes were monitored at John Day Dam in any year (except the juvenile bypass in 1998: 8% of spring and summer chinook salmon fallbacks and no fall chinook salmon fallbacks were via the juvenile bypass in 1998). 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.

More than 70% of radio-tagged spring, summer, and fall chinook salmon, more than 78% of steelhead, and 60% of sockeye salmon passed John Day Dam via the Oregon-shore ladder. We did not observe a pattern of higher fallback percentages or rates associated with either ladder for any species, although a significantly higher proportion of spring and summer chinook salmon fell back after passing the Washington-shore ladder in 1998.

A high percentage of the fish that fell back at John Day Dam reascended the dam (60% to 82% of spring and summer chinook salmon, 46% to 75% of steelhead, 89% of sockeye salmon, 5% of fall chinook salmon) and those extra passages at the dam (more than once for some fish) caused 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 0.871 in 1996, 0.889 in 1997, and 0.894 in 1998. The pooled adjustment factor was 0.961 for sockeye salmon in 1997, 0.895 for steelhead in 1996, 0.916 for steelhead in 1997, and 0.961 for fall chinook salmon in 1998. Positive biases due to fallback and reascenion by spring and summer chinook salmon were about 3,900 in 1996, 9,200 in 1997, and 4,000 in 1998. Positive biases were about 1,400 sockeye salmon in 1997, about 16,500 steelhead in 1996, 13,400 steelhead in 1997, and 3,100 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, summer, and fall chinook salmon and sockeye salmon, and were slightly higher for steelhead. Pooled adjustment factors indicated higher positive bias for steelhead because a relatively high number of radio-tagged steelhead fell back at John Day Dam early and late in migrations when relatively few fish were passing the dam.

We did not monitor navigation lock passage in any year, but passage through the lock would partially compensate for the positive bias in counts passing via ladders. We estimated that 1.4% to 3.6% of radio-tagged spring and summer chinook salmon, 1.3% to 1.7% of steelhead, 7.9% of sockeye salmon, and 1.9% of fall chinook salmon passed upstream via the lock. When we incorporated estimated lock passage into pooled adjustements factors, positive biases decreased by approximately 10% to 25% (~ 450 to 1,500 fish) for spring and summer chinook salmon. Biases decreased by about 13% for steelhead (~ 1,750 to 2,350 fish), and about 45% (~ 1,400 fish) for fall chinook salmon. Estimated lock passage by sockeye salmon would have more than compensated for positive ladder bias; we found a negative bias of about 1,400 sockeye salmon with inclusion of the lock passage term.

Complete migration summaries indicated that about 72% to 83% of spring and summer chinook salmon, 57% to 64% of steelhead, 78% of sockeye salmon, and 53% of fall chinook salmon that fell back at John Day 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: 19% to 24% of spring and summer chinook salmon, 6% of sockeye salmon, 14% to 28% of steelhead, and 47% of fall chinook salmon entered tributaries downstream from John Day Dam after falling back. Fish that fell back and subsequently entered downstream tributaries mostly entered the Deschutes River (63%), the Klickitat River (22%), and the White Salmon River (5%). One or two fish entered the Wind, Hood, Little White Salmon, Sandy, or Cowlitz rivers after falling back. The relatively high incidence of entering downstream tributaries after falling back indicated some fallbacks were likely caused by wandering, overshoot behavior, or other migration factors.

From 31% to 38% of spring and summer chinook salmon and 17% to 36% 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 67% of the sockeye salmon that fell back at John Day Dam were last recorded at tributaries to the upper Columbia, mostly in the Wenatchee and Okanogan rivers.

Fish not recorded in tributaries or the uppermost monitoring sites (17% to 28% of spring and summer chinook salmon and sockeye salmon, 36% to 47% of steelhead and fall chinook salmon) 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 John Day 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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