Survival Estimates of migrant Juvenile Salmonids in the Columbia River from John Day Dam through Bonneville Dam using Radio-Telemetry, 2000.

Annual Report of Research

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Prepared for:

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Contract No. W66QKZ00402095, W66QKZ00391980, and W66QKZ00381936

Submitted: September, 2002

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Executive Summary

During 2000, we estimated the survival of yearling chinook salmon at John Day, The Dalles and Bonneville dams, the survival of steelhead trout at John Day Dam, and the survival of sub-yearling chinook salmon at The Dalles Dam and from near Hood River, OR to below Bonneville Dam. The survival of releases of radio-tagged fish were evaluated using the paired release-recapture models of Burnham et al. (1987) that provide estimates of survival of treatment groups in relation to control groups and also using Cormack-Jolly-Seber models (Cormak 1964, Jolly 1965, Seber 1965) that express the absolute survival of the release groups. The objectives at John Day were to provide estimates of the relative survival of yearling chinook salmon and steelhead trout passing through the spillway and also through all routes at this project during two spill conditions that were comprised of 0% daytime spill/53% night spill and 30% day spill/53% night spill. The Dalles Dam study was conducted to provide comparisons of the estimates of relative survival from radio-tagged fish released directly through the spillway, ice and trash sluiceway, and through the powerhouse to estimates generated from concurrent releases of PIT-tagged fish. Our efforts at Bonneville Dam were designed to evaluate the feasibility of using the release and detection schemes employed in the impounded reaches of the Columbia River above Bonneville Dam to estimate the survival of migrating juvenile salmonids as they pass through Bonneville Dam and the un-impounded lower Columbia River.

The evaluation of the assumptions associated with the survival models used during these studies indicated that in general the assumptions were satisfied. Similar to the survival evaluation during 1999, the results of Burnham tests 2 and 3, that test the assumptions that upstream or downstream detections affect downstream survival and/or detection and whether upstream capture histories affect downstream survival and/or capture, were largely incalculable not only for the evaluation at John Day Dam but for the evaluations at The Dalles and Bonneville dams as well. While we will continue to evaluate Burnham tests 2 and 3 in future years, the utility of these tests to discern whether these assumptions have been met is constrained by the high capture probabilities now possible with the radio-telemetry detection arrays

Alterations to the timing of releases of yearling chinook salmon and steelhead trout near Rock Creek, WA alleviated, to a large extent, difficulties in matching up the time of passage of the treatment groups with releases of control groups in the tailrace of John Day Dam so that the assumption of mixing of the treatment and control groups was met for most releases during 2000. For spill passed fish, only 2 of 16 yearling chinook and 6 of 16 steelhead releases indicated that there were differences in the arrival times of the treatment and control groups at The Dalles Dam compared with 10 of 16 and 16 of 16 yearling chinook releases of yearling chinook and steelhead, respectively, made during 1999 (Counihan et al. 2001). Similar trends in the similarity of arrival times were observed at telemetry arrays downstream of The Dalles Dam. That significant differences in arrival times continued to persist during 2000 at John Day Dam is likely due to the delay in passage (e.g., arriving during the day and then passing at night) exhibited by steelhead, and to a lesser extent, yearling chinook, at John Day Dam (Beeman et al. 2001a).

Releases of dead radio-tagged yearling chinook salmon and steelhead trout at John Day and The Dalles dams indicated that there was no evidence at these projects that dead radio-tagged fish would have drifted downstream and be detected at the telemetry arrays used in the survival evaluation and thus, considered alive when in fact they were dead. However, dead radio-tagged steelhead trout, but no yearling chinook, were detected at arrays established below Bonneville Dam, indicating that there was the potential to violate the assumption that detections downstream of the release location are only of live fish. Differences in the channel morphology and hydraulic characteristics of the tailrace area of Bonneville Dam and also the Columbia River below the tailrace compared with the impounded reaches of the Columbia River below John Day and The Dalles Dams may account for the detection of dead radio-tagged steelhead in this area. The detection of dead radio-tagged steelhead at downstream telemetry arrays may also be caused by consumption of these fish and subsequent downstream movements of predators.

Significant differences in the survival of juvenile steelhead passing during spill blocks with 0% day/53 % night and 30% day/ 53% night spill conditions were detected for steelhead passing via the John Day Dam spillway, with survival being lower during the 30% day/53% night spill condition. This result suggests that since the major difference between the spill blocks was the 30% day spill condition, that this dam operation condition may have been the causative mechanism determining the differences in survival. While the results for the yearling chinook spillway evaluation, and for the yearling chinook and steelhead passing via all routes evaluation were not found to be statistically different, the similarity in the trends exhibited for the relative survival estimates (higher survival during the 0% day/53% night spill condition) further suggested that the 30% day spill condition may have been affecting the survival of fish passing this project. However, further examination of this hypotheses did not indicate that survival was negatively related to the proportion of fish passing during the day or positively related to the number of fish passing during the night. Our objective in evaluating survival at John Day Dam was to assess potential differences in survival given two different dam operation conditions. However, through an exploratory analysis of the conditions present during these two spill treatments, we found considerable variability in the conditions fish experienced as they passed this project within and between the two treatments. We demonstrated that the variability in total discharge, proportion of discharge as spill, and potentially tail water elevation may have affected the survival of both yearling chinook salmon and steelhead trout and confounded the original intent of the experiment.

Survival estimates of yearling chinook salmon and steelhead trout generated from releases made near Rock Creek, WA, that were also used in the evaluation of the passage behavior of these species at John Day Dam (Beeman et al. 2001a) and the paired release-recapture evaluation of spillway and total project survival (this report), also allowed us to generate estimates of survival from Rock Creek, WA to John Day Dam, survival of the release groups through various stretches in between Rock Creek, WA a to near Lyle, WA, and also overall survival over this river reach. In general, survival from Rock Creek to John Day Dam was high for both yearling chinook salmon and steelhead. Our evaluation of the relation between forebay residence time and survival did not indicate that increased residence time resulted in lower survival from Rock Creek, WA to John Day Dam. However, the estimates are not measuring survival in the forebay of John Day Dam only, but survival over the reach from Rock Creek, WA to John Day Dam. Thus, the estimates will incorporate all potential sources of mortality over this distance and may obscure or overwhelm the mortality that occurs directly in the forebay.

The yearling chinook survival evaluation at The Dalles Dam suggested that the survival estimates generated using two different tags that can be used to uniquely identify individual fish (e.g., radio- and PIT-tags) and two different methods for assessing survival (e.g., relative recoveries and paired release-recapture) were similar. In general, the differences between the point estimates of relative survival from PIT- and radio-tagged yearling chinook were small. Trends shown by the estimates between the routes evaluated were similar with relative survival being highest for fish released into the ice and trash sluiceway and lowest for fish released through the various turbine units at the powerhouse. The 95% confidence intervals for the relative survival estimates generated from the radio-tag release were smaller than for the estimates generated from PIT-tag estimates, despite the fact that less radio-tagged fish than PIT-tagged fish were used in the evaluation. The smaller error estimates associated with the radio-tag releases, given the number of releases evaluated, are likely a result of the high detection probabilities possible with radio-telemetry systems. In many instances, all fish released in the tailrace of The Dalles Dam (control group) were detected at the first array below this project. Similar to the results for PIT-tagged fish (Absalon et al. In review), the relative survival of yearling chinook through the spillway and powerhouse were not significantly related to either spill or total discharge. One marginally significant result was detected suggesting that the survival of sluiceway passed fish was positively related to total discharge.

The estimates generated from radio- and PIT-tagged sub-yearling chinook were not as comparable as those generated for yearling chinook salmon. In general, the estimates generated from release of radio-tagged fish had large confidence intervals and did not exhibit the same trends as those shown for PIT-tagged fish. The number of releases made was constrained by the availability of the small (nano-) coded radio-tags that were used to tag sub-yearling chinook. Consequently, we were only able to make 9 releases in conjunction with the NMFS. The small number of releases and the poor survival of our treatment and control groups compared to that of yearling chinook over the same distance, likely contributed to the variability in our relative survival estimates. Given the large confidence intervals associated with both the PIT- and radio-tag estimates, comparisons of the estimates generated from the two tagging methodologies seems questionable and of little value. However, the estimates generated during 2000 will be incorporated into the design of the work for 2001 and will provide a means to continue to improve our experiments in the future. No significant relations to total and spill discharge were detected.

We demonstrated that the release and detection schemes employed at John Day and The Dalles dams can be used to estimate survival through Bonneville Dam and in the lower Columbia River. Of particular interest were the high capture probabilities associated with radio-telemetry arrays in the un-impounded lower Columbia River, an area that we have had no prior experience working until 2000. Releases of yearling and sub-yearling chinook salmon have provided us with preliminary estimates of the survival and capture probabilities associated with conducting evaluations of the survival in this area of the lower Columbia River. As previously mentioned, dead radio-tagged steelhead were detected at array below Bonneville Dam indicating that the arrays used during 2000 will have to be moved further downstream to avoid the possibility of false positive detections in the future. During 2001,we will incorporate the information gathered during 2000 and continue our evaluation of survival through Bonneville Dam.

Introduction

As anadromous juvenile salmonids migrate from freshwater rearing habitats to the ocean, they are vulnerable to a host of factors that affect their survival. Direct effects associated with dam passage (e.g., instantaneous mortality, injury, loss of equilibrium, etc.) and indirect effects (e.g., predation, disease, and physiological stress) contribute to the total mortality of seaward migrating salmonids. Many studies have been conducted to determine the effects of hydroelectric dams on the survival of salmonid migrants (Raymond 1979, Stier and Kynard 1986, Iwamato et al. 1994, Muir et al. 1995, Smith et al. 1998). Based on this research and studies examining migrant salmonid behavior at dams in the Columbia River Basin, management actions are currently being implemented to improve the survival of salmonid migrants.

A primary objective of The National Marine Fisheries Service Federal Columbia River Power System (FCRPS) Biological Opinion is to increase survival of juvenile salmonid out migrants through the federal hydrosystem (NMFS 2000). To help meet this objective, specific water management scenarios have been specified for the hydropower system in general and also, specifically for each project. Based on past research, the NMFS has determined that measures that increase juvenile fish passage through spillways should be given the highest priority, while passing fish through turbines is the least preferred route of passage. Thus, various levels and configurations of spill are used to help meet the established survival and fish passage goals. While there is a consensus that survival is greater for fish diverted from turbines, questions regarding the effectiveness of different spill patterns and other passage scenarios remain (Dawley et al. 1998, NMFS 2000). To evaluate the efficacy of specified water management strategies, the FCRPS biological opinion stresses the importance of establishing a process to monitor, evaluate, and report on the efficacy of the specified measures to improve survival of juvenile migrants. Estimating the survival of migrant juvenile salmonids through projects and reservoirs in the lower Columbia River has been specified as a necessary step in this evaluation process.

New fish marking techniques and the development and acceptance of new statistical methodologies (see Leberton et al. 1992) have led scientists to reevaluate past techniques used to assess survival of migrant salmonids in the Columbia River Basin. For instance, the development of the passive integrated transponder (PIT) tag, which allowed for the unique identification of fish (Prentice et al. 1990), offered many advantages over previous marking techniques (fin-clipping, freeze branding) used in survival studies. Consequently, PIT-tag recoveries and release-recapture models (Burnham et al. 1987, Smith et al. 1996) have been used to assess the survival of migrant salmonid smolts through various reaches of the Columbia and Snake rivers (Iwamato et al. 1994, Muir et al. 1995, Skalski et al. 1998a, Smith et al. 1998, Dawley et al. 1998). However, the use of the PIT-tag technique relies on the availability of PIT tag detectors at hydroelectric dams and these detectors are not present at all locations in the Columbia River Basin. The absence of PIT tag detectors at certain projects (e.g., The Dalles Dam) and areas below Bonneville Dam has precluded survival estimation in some specific reaches of the Columbia River and fixed the spatial scale over which survival estimates can be made. Further, the relatively low detection probabilities associated with this technique requires that large numbers of fish be handled to obtain desired levels of precision in survival estimates (Skalski 1999b). Consequently, researchers have been motivated to examine the feasibility of using radio-telemetry to generate survival estimates (Normandeau Associates, Inc. et al. 1998, Skalski 1999a, Counihan et al. 2001).

Radio-telemetry has been used extensively to evaluate the survival of fish and wildlife populations (White 1983, Bell and Kynard 1985, Giorgi et al. 1985, Pollock et al. 1996, Normandeau Associates, Inc. et al. 1998) and to monitor the behavior of yearling and subyearling chinook salmon *Oncorhynchus tshawytscha* and juvenile steelhead *O. mykiss* through hydroelectric projects in the Columbia River Basin (Sheer et al. 1997, Hansel et al. 1998, Holmberg et al. 1998, Hensleigh et al. 1999, Vendetti et al. 2000). During 1999, the U. S. Army Corps of Engineers, Portland District requested that the USGS examine the feasibility of extracting juvenile salmonid survival information from radio-tagged fish. The results of this evaluation suggested that radio-telemetry could be used to evaluate survival of juvenile salmonids in the lower Columbia River, but that logistic adjustments were necessary to ensure that assumptions of the survival estimation procedure were necessary (Counihan et al. 2001).

During 2000, we evaluated the survival of radio-tagged yearling chinook salmon at John Day, The Dalles, and Bonneville dams and sub-yearling chinook salmon at The Dalles Dam. Our objectives during 2000 were to 1) evaluate the survival of yearling chinook salmon during different spill scenarios at John Day Dam 2) evaluate the survival of yearling and sub-yearling chinook salmon at The Dalles Dam and compare the estimates with concurrent releases of PIT-tagged fish made by the NMFS and, 3) assess the feasibility of assessing the survival of radio-tagged juvenile salmonids at Bonneville Dam.

Methods

Radio-telemetry detection arrays

Radio-telemetry detection arrays were set up at John Day, The Dalles, and Bonneville dams. Additional detection arrays were set up in Bonneville Reservoir near the town of Lyle, WA and also below Bonneville Dam at river kilometers 226, 217 and 211. Release and detection schemes used during 2000 are depicted in Figures 1-5. The arrays at each of the three dams spanned the breadth of the river channel and were set up so that passage through various routes of passage could be determined (Beeman et al. 2001a, Beeman et al. 2001b, Evans et al. 2001). The detection array in Bonneville Reservoir consisted of antennas placed only on the Washington shore. Each array below Bonneville Dam was comprised of multiple antenna and receiver locations typically placed on channel markers so that fish passing through most of the river channel could be detected. The arrays below Bonneville Dam were established to examine the feasibility of using arrays in this area of the Columbia River to facilitate survival estimation.

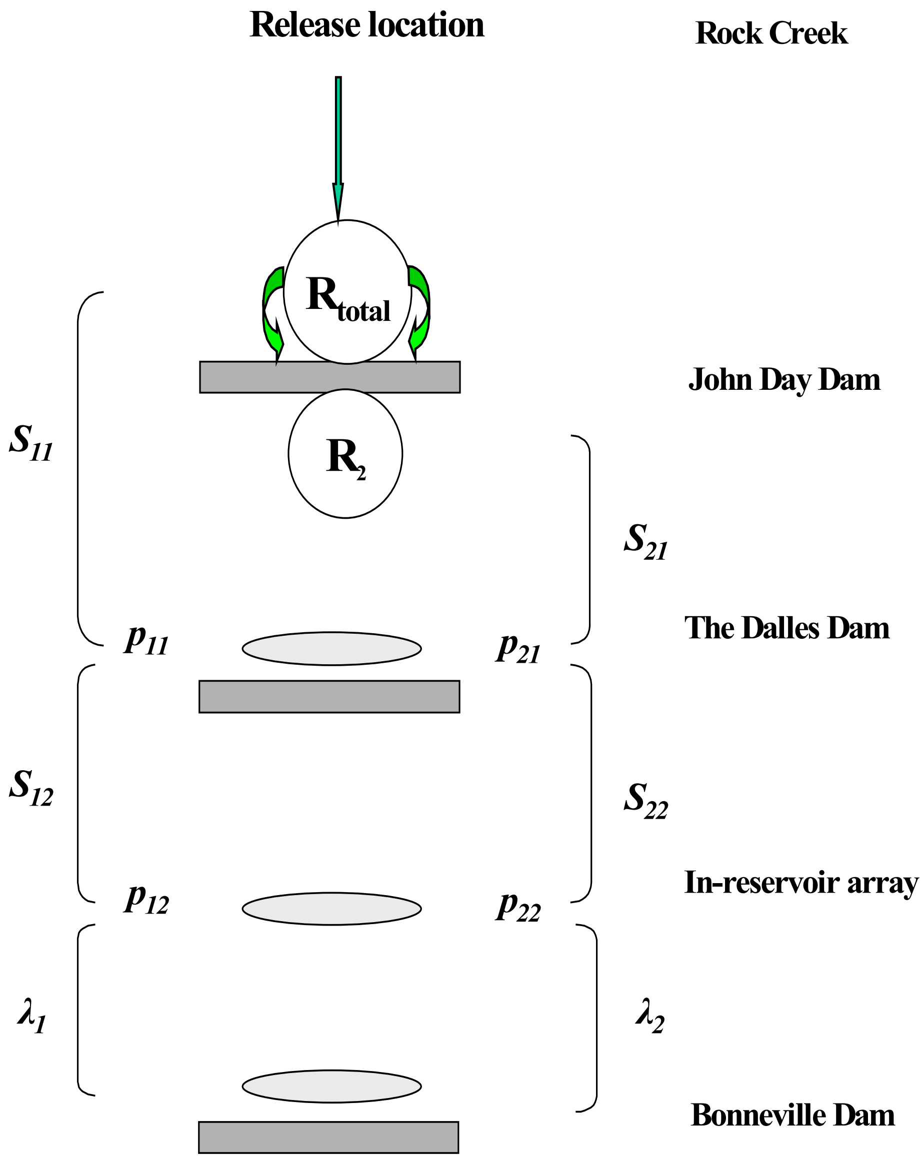


Figure 1. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from releases at Rock Creek and the John Day dam outfall. Dams are represented by rectangles and ovals represent detection arrays.

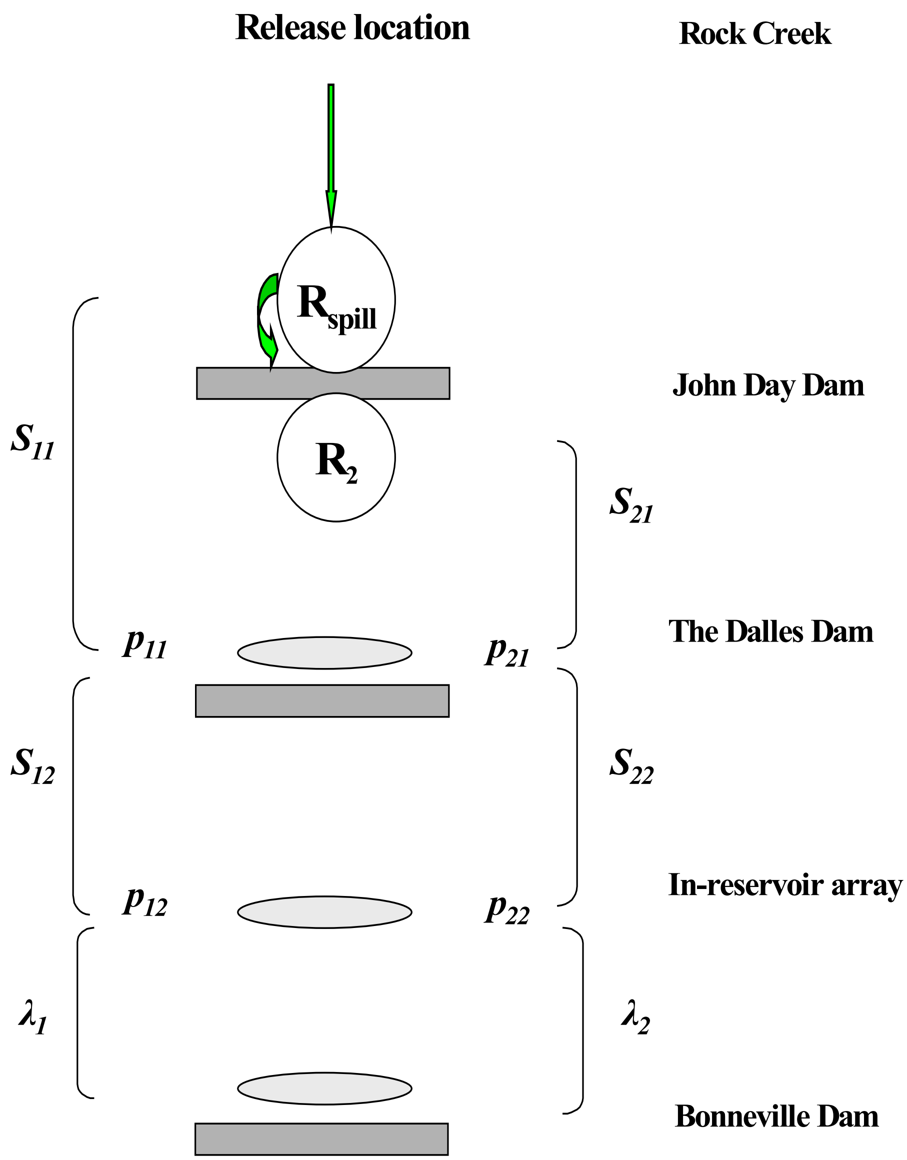


Figure 2. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from releases at Rock Creek and the John Day dam outfall. Dams are represented by rectangles and ovals represent detection arrays.

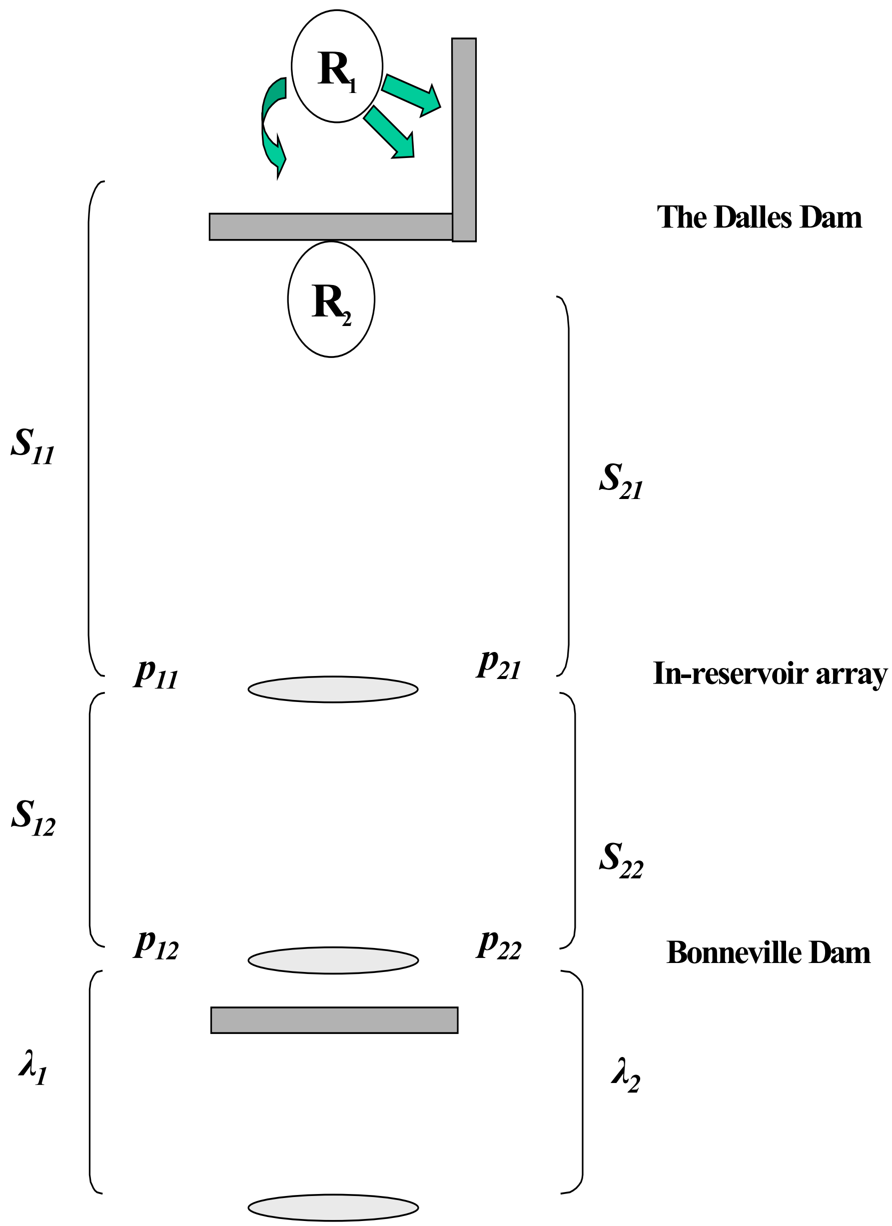


Figure 3. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and λ = S · p) from releases through various routes at The Dalles Dam and in the tailrace. Dams are represented by rectangles and ovals represent detection arrays.

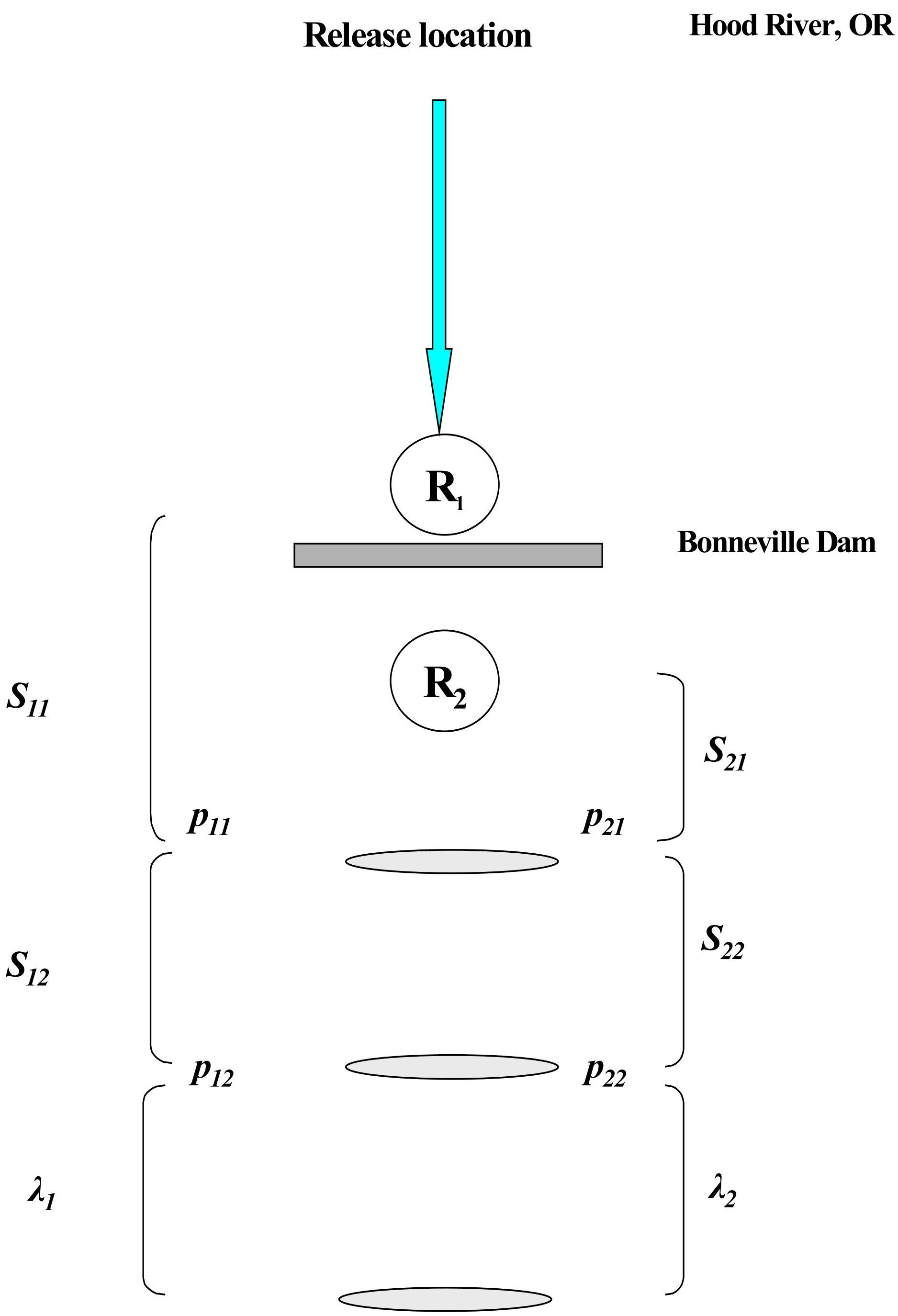


Figure 4. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from releases at Hood River, Oregon. Dams are represented by rectangles and ovals represent detection arrays.

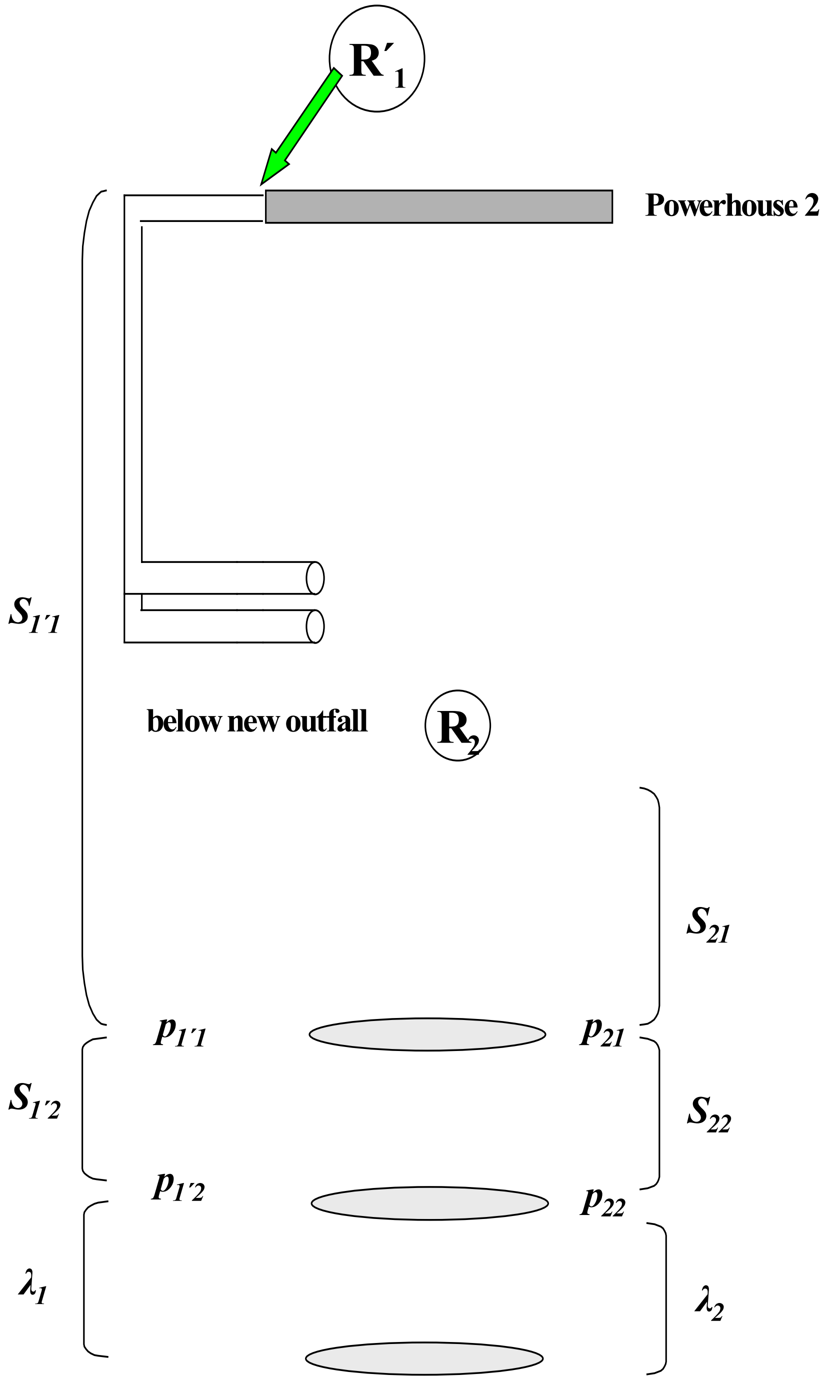


Figure 5. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from releases at Bonneville Dam Powerhouse 2. Dams are represented by rectangles and ovals represent detection arrays.

John Day Dam

Fish collection, transportation, tagging, holding, and release protocols are described in Beeman et al. (2001a). The releases at Rock Creek consisted of 32 separate releases that were evaluated using the single-release model and that were also grouped with 16 releases made in the John Day Dam tailrace to form 16 paired releases that were evaluated using the paired release recapture models (Table 1). A total of 424 yearling chinook salmon released at Rock Creek and 284 yearling chinook salmon released in the John Day Dam tailrace were included in these analyses (Tables 2 and 3). Similarly, 436 steelhead trout released at Rock Creek and 286 steelhead trout released in the John Day Dam tailrace were evaluated (Tables 4 and 5). For the releases made near Rock Creek, WA, fish were released and then interrogated at John Day Dam and based on these detections, we formulated release groups based on their presence or absence and also their route of passage at this project (Figures 1 and 2).

The Dalles Dam

All releases of radio-tagged fish at The Dalles Dam were made in conjunction with releases made by the National Marine Fisheries Service as part of as study examining the survival of PIT-tagged yearling chinook through various passage routes at The Dalles Dam. Fish collection, transportation, tagging, holding, and release protocols are described in Allen et al. (2001). The releases at The Dalles Dam consisted of 13 releases at each of three release sites above The Dalles Dam; upstream of the spillway, into the ice and trash sluiceway, and into various turbine units. Thirteen corresponding releases were made in The Dalles Dam tailrace to form the 13-paired releases evaluated (Table 6). Release locations and mechanisms are described in Absalon et al. (2002). A total of 236 yearling chinook salmon were released upstream of the Dalles Dam spillway, 216 yearling chinook salmon were released into the Dalles Dam ice and trash sluiceway, and 213 yearling chinook salmon released into various turbine units at the Dalles Dam. The Dalles Dam tailrace releases consisted of 222 yearling chinook salmon (Tables 7 and 8).

Releases of radio-tagged sub-yearling chinook salmon were also made in conjunction with releases of PIT-tagged fish at The Dalles Dam. Nine paired releases consisting of tailrace released fish combined with releases through the spillway, into the ice and trash sluiceway, and into various turbine units were made at The Dalles Dam (Tables 9 and 10).

Bonneville Dam

Fish collection, transportation, tagging, holding, and release protocols are described in Evans et al. 2001. The releases at Bonneville Dam consisted of 12 releases in Bonneville Reservoir near Hood River, OR and 12 releases into the Powerhouse 2 juvenile bypass at Bonneville Dam that were grouped with 12 releases made in the Bonneville Dam tailrace to form the 12 paired releases evaluated (Table 11). For the releases made near Hood River, OR fish were released and then interrogated at

Table 1. Release dates and times for the paired releases of yearling chinook salmon released at Rock Creek and at the John Day Dam tailrace during 2000.

	Rock Creek release A		Rock Creek release B		John Day Tailrace release	
Paired release	Release date	Release time	Release date	Release time	Release date	Release time
1	05/01	2120	05/02	0901	05/02	2055
2	05/03	0830	05/03	1945	05/04	0815
3	05/04	1955	05/05	0810	05/05	2030
4	05/06	0822	05/06	2020	05/07	0725
5	05/07	2007	05/08	0842	05/08	1900
6	05/09	0800	05/09	1932	05/10	0810
7	05/10	1937	05/11	0810	05/11	1916
8	05/12	0824	05/12	2016	05/13	0830
9	05/13	2010	05/14	0750	05/14	2039
10	05/15	0820	05/15	1951	05/16	0720
11	05/16	2016	05/17	0830	05/17	1929
12	05/18	0820	05/18	2010	05/19	0730
13	05/19	2025	05/20	0814	05/20	2105
14	05/21	0810	05/21	1955	05/22	0728
15	05/22	2016	05/23	0810	05/23	2000
16	05/24	0850	05/24	1938	05/25	0735

Table 2. The sample size (N) , mean, standard deviation (SD), and range of fork lengths (mm) of yearling chinook salmon released at Rock Creek and in the John Day Dam tailrace during 2000.

Paired release	Rock Creek release A				Rock Creek release B				John Day Tailrace release			
	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	14	155.5	19.6	128-187	14	172.0	20.6	142-205	17	153.5	12.9	125-176
2	12	163.2	18.6	142-196	15	164.6	17.9	143-195	17	157.6	10.5	142-187
3	15	162.1	19.6	138-212	16	162.0	18.7	137-198	15	162.5	16.7	125-190
4	15	159.1	15.3	141-194	15	163.9	19.6	140-198	16	174.6	12.8	150-199
5	14	175.7	19.0	131-197	16	159.8	16.6	131-189	19	177.9	24.0	146-222
6	13	169.3	17.0	145-197	10	166.7	16.3	143-192	18	184.2	18.9	156-218
7	15	175.7	16.5	155-208	15	166.3	19.7	131-203	16	173.8	21.9	145-220
8	18	188.1	15.1	166-214	14	191.1	17.1	165-225	18	183.5	15.8	151-207
9	17	185.8	18.7	140-215	16	184.4	18.5	143-218	19	176.7	19.2	141-210
10	17	182.9	18.3	130-204	16	172.9	16.0	138-197	19	177.6	23.7	140-215
11	16	177.1	17.9	142-202	6	177.2	21.6	144-198	9	184.1	19.4	146-218
12	19	184.7	10.5	164-200	16	183.2	12.9	153-205	19	176.5	20.2	140-207
13	13	184.1	13.8	158-204	14	185.1	10.3	165-201	19	181.9	12.3	162-206
14	15	189.3	14.0	165-218	15	187.7	11.7	165-210	14	174.6	15.1	147-195
15	15	179.2	14.4	153-198	16	184.4	16.7	148-206	24	185.1	12.7	156-205
16	18	190.1	10.1	161-204	24	182.7	16.7	140-210	25	182.0	15.7	143-220

Table 3. The sample size (N) , mean, standard deviation (SD), and range of weights (g) of yearling chinook salmon released at Rock Creek and in the John Day Dam tailrace during 2000.

Paired release	Rock Creek release A				Rock Creek release B				John Day Tailrace release			
	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	14	40.1	16.1	21.8-71.5	14	52.1	19.1	30.2-84.3	17	36.5	9.1	21.5-56.5
2	12	44.1	16.3	25.4-71.7	15	45.3	17.6	27.0-76.5	17	38.2	10.7	23.9-70.7
3	15	42.9	21.4	25.1-104.2	16	43.8	15.3	25.1-78.3	12	48.5	14.3	29.7-71.4
4	15	41.6	14.4	28.8-80.0	15	44.7	16.7	25.0-75.8	16	55.7	13.5	32.6-86.1
5	14	56.5	17.4	22.3-81.2	16	42.5	13.1	22.8-66.4	19	58.8	23.4	28.9-102.6
6	13	50.2	15.9	33.2-76.1	10	49.3	14.0	28.9-72.9	18	65.1	21.3	36.2-104.0
7	15	57.0	17.4	36.4-98.8	15	48.3	18.5	22.3-92.5	16	54.4	21.9	30.2-108.3
8	18	67.9	17.8	37.7-102.8	14	72.5	21.8	45.2-125.1	18	64.8	17.7	31.8-94.7
9	17	65.3	19.4	24.0-103.5	16	65.3	19.7	26.7-99.1	19	58.4	18.3	29.0-92.6
10	17	62.3	17.8	21.4-87.8	16	54.5	16.2	27.9-91.8	19	58.8	22.4	24.5-91.8
11	16	57.2	17.9	25.6-89.3	6	54.7	20.1	26.8-77.4	9	65.4	17.9	33.9-97.1
12	19	63.3	12.3	41.0-85.5	16	62.7	13.8	34.1-86.5	19	55.3	20.1	21.1-85.2
13	13	60.1	12.1	42.7-79.9	14	64.4	11.7	44.2-86.4	19	59.1	12.4	40.3-81.8
14	15	63.4	13.7	42.8-89.9	15	54.7	9.4	37.1-73.8	14	42.8	10.7	22.8-58.1
15	15	48.0	11.2	30.4-61.6	16	42.8	10.2	21.2-57.5	24	45.8	9.7	26.1-63.0
16	18	66.6	9.7	40.3-77.6	24	60.2	15.7	24.6-93.7	25	60.9	13.5	33.3-98.7

Table 4. The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of juvenile steelhead released at Rock Creek and in the John Day Dam tailrace during 2000.

Paired release	Rock Creek release A				Rock Creek release B				John Day Tailrace release			
	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	11	227.4	42.6	121-285	13	220.4	13.8	191-253	19	221.9	30.0	122-263
2	13	221.8	14.9	195-245	14	223.6	18.5	185-254	16	220.8	24.8	183-273
3	13	221.2	18.1	195-265	14	229.3	15.9	194-258	17	221.9	15.3	190-250
4	15	219.3	19.8	180-250	16	223.7	21.0	197-262	19	221.8	18.2	190-255
5	15	217.9	17.8	187-260	15	221.9	16.4	197-252	18[a]	220.8	14.9	189-240
6	13	219.6	15.9	187-246	15	221.5	24.1	186-262	18	216.2	17.9	178-252
7	14	215.9	18.2	191-252	19	222.7	15.2	200-261	18	222.2	22.4	188-288
8	15	226.1	20.2	205-270	20	223.6	22.5	188-262	19	216.8	11.9	199-243
9	14	230.7	17.6	199-263	13	218.4	16.7	187-248	20	219.4	24.1	178-268
10	11	221.0	19.8	182-247	10	212.6	20.5	185-246	19	210.5	15.8	186-240
11	20	214.9	19.1	185-247	15	213.3	18.4	191-256	15	211.3	12.5	190-240
12	16	225.5	20.4	200-276	20	224.4	14.4	202-258	18	215.7	9.7	198-233
13	20	211.8	14.3	193-253	20	216.0	19.2	189-267	20	218.5	23.5	188-290
14	19[a]	214.7	19.2	187-257	16	215.7	15.0	189-246	14	222.6	22.5	175-255
15	14	228.9	19.7	195-260	14	225.7	21.0	197-257	19	214.2	15.0	190-248
16	16	217.8	21.6	183-276	12	214.8	21.4	183-250	16	223.3	20.3	195-270

[a] One fish was excluded from the calculation because an incorrect length value was recorded.

Table 5. The sample size (N) , mean, standard deviation (SD), and range of weights (g) of juvenile steelhead released at Rock Creek and in the John Day Dam tailrace during 2000

Paired release	Rock Creek release A				Rock Creek release B				John Day Tailrace release			
	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	11	116.7	41.9	69.7-200.5	13	89.3	15.4	62.1-127.5	19	100.3	24.9	63.0-153.8
2	13	91.2	18.8	62.0-127.2	14	93.6	24.4	54.5-136.9	16	92.7	32.4	48.1-173.2
3	13	88.5	23.6	61.7-147.0	14	104.3	24.1	56.4-155.1	14	95.2	20.8	55.7-130.7
4	15	88.8	25.3	45.6-148.5	16	93.6	29.1	60.5-162.2	19	93.4	23.1	54.9-139.5
5	15	83.8	22.3	48.1-138.5	15	90.7	23.0	58.0-125.3	19	91.0	18.7	54.1-126.6
6	13	92.2	19.7	57.5-125.7	15	95.8	35.0	49.9-163.0	18	84.4	22.3	45.8-134.9
7	14	85.2	20.8	55.4-121.3	19	94.7	21.9	63.5-158.7	18	93.8	35.7	53.6-204.2
8	15	96.5	27.7	67.2-170.6	20	94.4	29.6	54.4-166.4	19	89.5	16.8	60.4-132.5
9	14	99.2	18.8	68.8-132.6	14	90.9	22.4	50.6-132.2	20	90.3	29.7	46.0-165.2
10	11	92.2	23.1	52.9-126.1	10	83.4	25.4	49.7-128.3	19	79.0	19.0	54.3-114.6
11	20	83.7	22.9	52.0-125.5	15	83.2	26.6	56.9-161.4	15	78.7	12.8	59.5-104.2
12	16	95.8	28.5	63.6-175.0	20	93.0	18.5	70.2-144.8	18	81.3	12.6	59.2-103.3
13	20	74.9	19.0	56.6-144.4	20	83.7	22.3	47.5-148.0	20	88.6	34.8	49.2-205.4
14	20	82.3	29.0	51.3-164.0	16	74.5	18.4	46.4-122.0	14	75.5	22.4	36.5-112.0
15	14	80.7	24.9	44.5-127.5	14	65.5	17.4	43.5-98.4	19	54.6	11.7	37.7-79.2
16	16	84.4	34.1	46.4-197.7	12	83.4	26.8	46.6-128.7	16	95.7	31.5	60.3-183.0

Table 6. Release dates and times for paired release of yearling Chinook salmon at The Dalles Dam spring 2000.

	Spillway		Sluiceway		Turbine		Tailrace	
Release #	Date	Time Span	Date	Time Span	Date	Time Span	Date	Time Span
1	4/29	2347-2350	4/29	2339-2343	4/29	2315-2319	4/30	0010-0028
2	5/03	0037-0042	5/03	0027-0031	5/03	0008-0012	5/03	0103-0117
3	5/04	2347-2350	5/04	2330-2333	5/04	2316-2319	5/05	0018-0031
4	5/07	0019-0026	5/07	0005-0007	5/06	2344-2349	5/07	0051-0104
5	5/09	1158-1201	5/09	1143-1146	5/09	1125-1132	5/09	1224-1234
6	5/11	1700-1702	5/11	1644-1646	5/11	1629-1632	5/11	1732-1744
7	5/13	1216-1218	5/13	1201-1203	5/13	1144-1149	5/13	1246-1256
8	5/16	1257-1259	5/16	1238-1240	5/16	1221-1226	5/16	1323-1341
9	5/19	0019-0022	5/19	0003-0005	5/18	2348-2352	5/19	0052-0105
10	5/20	2319-2322	5/20	2305-2307	5/20	2249-2253	5/21	0003-0015
11	5/23	1220-1223	5/23	1205-1208	5/23	1139-1143	5/23	1248-1301
12	5/25	1216-1218	5/25	1203-1205	5/25	1146-1150	5/25	1243-1303
13	5/27	1156-1158	5/27	1142-1144	5/27	1116-1125	5/27	1224-1233

Table 7. The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of yearling chinook salmon released at The Dalles Dam during 2000.

Paired	Spillway				Sluiceway				Turbine				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	19	168.5	15.5	145-198	17	161.4	14.6	136-193	17	157.8	16.4	134-192	19	159.0	16.2	138-190
2	18	160.8	19.3	129-203	18	161.7	19.1	120-194	15	159.5	16.1	128-192	19	159.9	13.3	133-187
3	18	173.0	19.8	142-212	14	179.1	18.3	138-197	17	173.8	16.6	153-201	15	175.5	18.9	151-213
4	18	166.0	18.2	137-194	18	161.1	18.2	135-190	13	169.7	15.5	150-198	19	161.7	17.0	132-195
5	19	183.3	11.9	158-198	13	179.0	15.2	155-202	17	178.5	15.7	151-200	15	178.9	18.8	148-204
6	15	180.0	18.8	155-213	17	170.2	20.9	137-205	17	167.1	24.2	137-202	18	166.3	23.0	135-206
7	18	170.3	23.7	140-204	19	182.2	24.4	132-215	19	182.5	25.9	132-218	15	175.2	23.9	139-211
8	19	180.3	19.3	144-210	18	171.5	19.0	145-205	19	175.9	22.5	138-209	19	175.5	17.2	146-203
9	18	183.6	14.2	143-202	14	183.9	20.5	135-204	17	185.6	19.8	145-209	18	181.4	16.1	153-212
10	20	189.3	12.6	167-219	20	187.9	9.6	173-204	15	185.6	15.6	162-208	17	180.9	7.5	166-196
11	20	193.7	12.2	152-213	20	186.6	21.0	150-229	18	179.6	16.1	154-206	18	179.4	23.1	112-213
12	19	185.1	11.2	156-201	19	182.9	15.3	152-208	20	177.8	18.1	119-210	19	182.4	12.3	160-202
13	15	184.3	13.8	160-207	9	187.2	16.5	152-206	9	186.7	19.8	159-216	11	181.1	10.1	160-195
Overall	236	178.5	18.7	129-219	216	176.2	20.4	120-229	213	175.2	20.6	119-218	222	173.1	19.0	112-213

Table 8. The sample size (N), mean, standard deviation (SD), and range of weights (g) of yearling chinook salmon released at The Dalles Dam during spring 2000.

Paired Release	Spillway				Sluiceway				Turbine				Tailrace			
	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	19	44.7	13.6	28-76	17	38.9	12.6	24-69	17	37.7	12.6	23-69	19	38.1	13.6	22-67
2	18	40.2	15.1	23-77	18	43.2	14.0	18-71	15	37.5	12.6	15-63	19	39.5	10.1	22-63
3	18	50.8	18.2	27-93	14	55.5	16.5	25-76	17	50.8	16.2	34-77	15	52.7	19.1	30-95
4	18	44.8	15.4	24-70	18	41.2	14.1	25-67	13	46.9	14.1	28-77	19	40.1	13.9	23-71
5	19	59.0	10.4	37-75	13	56.5	15.5	33-83	17	55.9	15.0	33-80	15	55.7	17.8	29-79
6	15	57.9	19.9	36-98	17	49.2	18.6	23-84	17	47.2	22.4	23-81	18	46.4	19.7	23-83
7	18	48.2	20.3	24-82	19	60.4	23.2	24-104	19	62.0	25.5	18-111	15	54.5	21.0	25-93
8	19	57.5	19.2	26-90	18	48.3	16.9	27-86	19	55.8	21.1	25-94	19	52.7	16.0	29-79
9	18	59.7	13.8	24-79	14	60.0	17.3	27-85	17	62.0	19.7	27-89	18	59.5	16.9	33-94
10	20	64.7	14.0	39-100	20	64.1	11.4	47-93	15	62.0	14.7	38-88	17	56.9	8.1	41-76
11	20	68.5	13.8	30-91	20	61.4	20.8	31-118	18	53.5	13.7	37-79	18	59.9	17.3	27-93
12	19	58.6	11.4	32-75	19	54.3	14.2	31-87	20	57.6	15.6	38-101	19	55.9	12.2	35-81
13	15	58.9	15.0	36-86	9	59.6	15.5	29-80	9	63.6	20.4	39-94	11	54.0	8.9	36-65
Overall	236	55.0	17.3	23-100	216	53.1	18.1	18-118	213	53.2	19.1	15-111	222	50.9	16.9	22-95

Table 9. The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of sub-yearling chinook salmon released at The Dalles Dam during fall 2000.

Paired Release	Spillway				Sluiceway				Turbine				Tailrace			
	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	20	119.4	4.0	112-129	20	118.4	4.5	110-130	16	120.7	3.0	116-126	20	119.4	4.4	112-129
2	18	118.3	4.9	112-133	19	119.6	4.6	111-131	20	119.2	3.7	111-127	17	119.4	3.3	115-126
3	20	120.0	3.9	114-129	19	117.8	3.9	111-125	20	122.7	7.4	116-148	20	119.8	5.7	113-129
4	20	122.0	5.4	114-131	19	121.4	4.8	115-130	19	120.6	4.4	113-127	19	121.2	4.7	114-129
5	19	121.4	5.2	114-130	19	120.9	3.3	115-126	19	119.9	4.4	113-129	20	119.6	4.0	112-126
6	20	121.4	5.7	114-136	19	121.2	4.5	115-129	20	118.7	3.5	113-125	19	119.2	5.0	113-129
7	19	119.3	5.2	114-132	19	115.5	3.6	111-125	18	118.3	6.1	112-133	19	120.4	8.5	111-140
8	20	115.2	4.2	110-126	19	118.1	5.8	111-130	19	118.4	5.0	112-130	20	116.1	4.9	111-131
9	20	118.6	2.8	114-124	20	117.5	3.0	113-122	20	117.7	2.8	113-123	20	117.3	2.7	113-122
Overall	176	119.5	5.0	110-136	173	118.9	4.6	110-131	171	119.6	4.8	111-148	174	119.1	5.1	111-140

Table 10. The sample size (N), mean, standard deviation (SD), and range of weights (g) of sub-yearling chinook salmon released at The Dalles Dam during fall 2000.

Paired Release	Spillway				Sluiceway				Turbine				Tailrace			
	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	20	16.8	1.6	14-20	20	16.6	1.8	14-20	16	17.8	1.5	15-21	20	17.4	2.3	14-24
2	18	16.8	2.3	15-23	19	17.6	2.4	15-23	20	17.3	1.7	14-21	17	17.0	1.4	15-20
3	20	17.8	1.9	15-22	19	17.2	2.0	14-22	20	19.7	4.3	16-34	20	18.1	2.8	14-23
4	20	19.0	2.6	15-24	19	18.4	2.2	14-23	19	18.4	2.4	15-22	19	18.3	1.9	16-23
5	19	18.3	2.9	14-24	19	18.4	1.6	15-20	19	18.2	2.2	14-23	20	18.0	1.9	15-22
6	20	19.2	3.2	14-28	19	18.5	2.1	15-22	20	17.6	2.0	14-20	19	18.5	2.8	15-24
7	19	17.4	3.0	14-23	19	15.7	1.9	13-21	18	16.8	2.3	14-22	19	19.3	5.5	15-33
8	20	16.2	1.9	14-22	19	17.6	2.5	14-24	19	18.0	2.6	15-24	20	16.9	2.4	14-24
9	20	18.0	1.5	16-21	20	17.7	1.6	15-21	20	17.7	1.6	15-20	20	17.2	1.5	14-20
Overall	176	17.8	2.5	14-28	173	17.5	2.2	13-24	171	17.9	2.5	14-34	174	17.9	2.8	14-33

Table 11. Release dates and times for paired release of yearling Chinook salmon at Bonneville Dam spring 2000.

	Reservoir		JBS		Tailrace	
Release #	Date	Time	Date	Time	Date	Time
1	5/03/00	00:45	5/03/00	11:30	5/03/00	12:45
2	5/05/00	11:15	5/05/00	22:48	5/06/00	00:05
3	5/07/00	11:50	5/07/00	22:57	5/08/00	00:15
4	5/09/00	23:15	5/10/00	11:15	5/10/00	12:10
5	5/11/00	22:45	5/12/00	11:20	5/12/00	11:45
6	5/14/00	11:03	5/14/00	22:45	5/15/00	00:00
7	5/16/00	23:10	5/17/00	11:59	5/17/00	11:45
8	5/19/00	11:15	5/19/00	21:30	5/20/00	00:00
9	5/21/00	11:00	5/21/00	23:30	5/22/00	00:20
10	5/23/00	23:10	5/24/00	11:10	5/24/00	12:00
11	5/25/00	23:00	5/26/00	10:45	5/26/00	12:20
12	5/27/00	10:45	5/27/00	22:45	5/28/00	00:00

Bonneville Dam and based on these detections, we formulated release groups based on their presence or absence and also their route of passage at this project (Figure 4). A total of 252 yearling chinook salmon released in the Bonneville Reservoir at Hood River, 300 yearling chinook salmon released into the Powerhouse 2 juvenile bypass at Bonneville Dam, and 300 yearling chinook salmon released into the Bonneville Dam tailrace were included in these analyses (Tables 12 and 13).

Statistical methods

We used the single-release model at John Day Dam (Skalski et al. 1998b) and the paired-release recapture models of Burnham et al. (1987) to estimate the survival of juvenile yearling chinook salmon and steelhead trout through the lower Columbia River. There are assumptions associated with using the single release and paired release-recapture (PR) model to estimate survival, some are biological and some pertain to the statistical models (Burnham et al. 1987, Skalski 1998b, Skalski 1999a). The validity of some of the assumptions listed below can be evaluated using statistical tests and others can be met through careful consideration of fish collection, holding, tagging, and detection techniques. The assumptions are the following:

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and capture probabilities are not affected by tagging or sampling (i.e., tagged animals have the same probabilities as untagged animals).

A3. All sampling events are "instantaneous" (i.e., sampling occurs over a short time relative to the length of the intervals between sampling events).

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All individuals alive at a sampling location have the same probability of surviving until the end of that event.

A6. All tagged individuals alive at a sampling location have the same probability of being detected on that event.

A7. All tags are correctly identified and the status of fish (i.e., alive or dead) is correctly identified.

We conducted statistical tests to evaluate assumptions A5 and A6 using tests developed by Burnham et al. (1987). Burnham et al. (1987) presents a series of tests of assumptions named Test 2 that examine whether upstream or downstream detections affect downstream survival and/or detection. To examine whether upstream capture histories affect downstream survival and/or capture, Burnham et al. (1987) present a series of tests called test 3.

Table 12. The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of yearling Chinook salmon released at Bonneville Dam during spring 2000.

Paired	Reservoir				JBS				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	19	146.6	7.0	137-162	22	158.5	16.3	131-194	24	148.0	8.2	124-160
2	20	164.8	9.5	152-188	22	174.6	24.0	151-225	20	163.8	14.6	145-192
3	18	166.8	19.7	148-215	24	169.4	14.5	146-196	24	166.5	15.2	150-204
4	25	155.0	16.8	124-187	27	158.5	21.7	122-200	28	156.0	17.0	125-185
5	18	162.4	15.3	143-189	21	153.8	19.1	125-196	25	151.6	20.9	120-220
6	21	155.3	19.0	125-188	27	153.0	23.2	123-205	24	152.4	28.4	124-267
7	20	152.2	20.2	132-215	26	146.5	16.2	124-190	25	148.0	17.5	125-190
8	19	148.4	18.6	124-188	24	156.1	21.0	125-203	23	160.2	21.0	135-200
9	21	149.7	16.7	125-185	25	153.4	19.9	124-186	23	151.6	18.8	127-189
10	24	156.0	22.9	133-208	26	158.7	22.0	130-202	25	153.3	19.3	128-202
11	19	146.6	11.0	132-174	29	149.1	13.7	130-184	29	146.3	11.9	131-183
12	29	146.7	18.1	126-201	27	153.9	19.7	129-212	30	151.6	19.1	126-205
Overall	253	153.9	18.0	124-215	300	156.8	20.6	122-225	300	153.8	18.9	120-267

Table 13. The sample size (N), mean, standard deviation (SD), and range of weights (g) of yearling Chinook salmon released at Bonneville Dam during spring 2000.

Paired	Reservoir				JBS				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
1	19	33.4	4.4	28-43	22	44.0	14.2	24-80	24	34.7	6.1	21-52
2	20	47.9	8.1	34-64	22	60.4	30.1	34-130	20	47.8	14.6	30-77
3	18	50.4	26.3	32-131	24	50.7	15.6	32-88	24	49.4	15.4	34-85
4	25	40.9	14.4	22-68	27	42.9	18.4	20-88	28	40.8	14.1	22-71
5	18	46.9	12.7	33-69	21	42.6	15.7	23-79	25	41.1	22.0	23-129
6	21	43.2	16.6	24-75	27	41.8	24.8	18-112	24	35.6	12.4	19-70
7	20	39.8	23.1	23-118	26	33.5	13.0	22-71	25	34.4	14.2	20-75
8	19	36.4	16.7	21-73	24	42.0	20.4	22-97	23	46.2	19.7	26-87
9	21	36.5	14.2	21-66	25	39.5	18.5	19-80	23	37.6	15.3	22-72
10	24	42.2	20.7	24-94	26	44.6	20.3	22-85	25	39.9	18.3	23-88
11	19	32.9	7.9	22-53	29	35.4	12.2	22-67	29	32.6	10.7	24-71
12	29	35.1	17.0	22-95	27	39.9	17.4	24-90	30	38.4	16.5	21-88
Overall	253	40.3	16.9	21-131	300	42.8	19.7	18-130	300	39.6	16.0	19-129

Survival was estimated from paired releases by the expression:

$$\hat{S} = \frac{\hat{S}_{11}}{\hat{S}_{21}} \qquad (1)$$

with a variance estimate based on the Delta method (Seber 1982) of:

$$\begin{aligned} V\hat{a}r\left(\hat{S}_W\right) &\doteq \left(\frac{\hat{S}_{11}}{\hat{S}_{21}}\right)^2 \left[\frac{Var\left(\hat{S}_{11}\right)}{\hat{S}_{11}^2} + \frac{Var\left(\hat{S}_{21}\right)}{\hat{S}_{21}^2}\right] \\ &\doteq \hat{S}_W^2\left[\hat{C}V\left(\hat{S}_{11}\right)^2 + \hat{C}V\left(\hat{S}_{21}\right)^2\right] \end{aligned} \qquad (2)$$

where $\hat{S}_{11}$ = survival estimates for fish released above the project of interest or in the case, and $\hat{S}_{22}$ = fish released below the project.

and where

$$\hat{C}V\left(\hat{\theta}\right) = \frac{\sqrt{Var\left(\hat{\theta}\right)}}{\theta}$$

In order to estimate S, the survival S_{11} is assumed to be of the form:

$$S_{11} = S \cong S_{21}$$

leading to the relationship

$$\frac{S_{11}}{S_{21}} = \frac{S \cdot S_{21}}{S_{21}} = S. \qquad (3)$$

The equality (3) suggests two additional assumptions for valid survival estimation using the paired release-recapture protocol.

A8. Survival in the upriver segment (S) is conditionally independent of survival in the lower river segment.

A9. Releases (R_1) and (R_2) have the same survival probability in the lower river segment (S_{21}).

The assumption of downstream mixing was tested at each downstream array. An R x C contingency table test of homogenous recoveries over time was performed using a table of the form:

Day of detections		Release R_1	Release R_2
	1		
	2		
	3		
	⋮		
	D		

For each paired-release (R_1 and R_2) and evaluation at each project, a chi-square test of homogeneity was performed at each downstream array. Tests were performed at ∀ = 0.10. Because there were multiple releases and tests across paired releases, the Type I error rates were adjusted for an overall experimental-wise error rate of $\forall_{EW} = 0.10$ pertaining specifically to each evaluation conducted at John Day, The Dalles, and Bonneville Dams.

Inferences regarding mixing will be largely based on the sequential use of likelihood ratio tests. In any given survival estimation scenario, a number of potential models will be generated and subsequently evaluated (Burnham et al. 1987, Leberton et al. 1992). Forward-sequential and reverse-sequential procedures will be used to find the most parsimonious statistical model that adequately describes the downstream survival and capture processes of the paired-release. The most efficient estimate of survival will be based on the statistical model for the paired releases that properly share all common parameters between release groups.

A weighted average of the survival estimates from the replicated releases can be calculated according to the formula:

$$\hat{\bar{S}} = \frac{\sum_{i=1}^{k} W_i \hat{S}_i}{\sum_{i=1}^{k} W_i} \tag{4}$$

where k = number of replicate releases:

and where $\hat{S}_i$ = survival estimates from the ith release ($i = 1, ..., k$);

The weight W_i is calculated using the formula:

$$W_i = \frac{1}{\left(\frac{V\hat{a}r\left(\hat{S}_i\right)}{\hat{S}_i^2}\right)} = \frac{1}{CV\left(\hat{S}_i\right)^2} \tag{5}$$

with variance

$$Var\left(\hat{\bar{S}}\right) = \frac{\sum_{i=1}^{k} W_i \left(\hat{S}_i - \hat{\bar{S}}\right)^2}{(k-1)\sum_{i=1}^{k} W_i} \qquad (6)$$

If the average is estimating a mean over some static process then weighting would be inversely proportional to the variance. However, in the release-recapture models,

$$Var\left(\hat{S}\right) \propto S^2$$

Therefore, the variance is correlated with the point estimates of survival. The weight (5) eliminates this correlation yet weights in proportion to the sampling precision (i.e., *CV*). Unfortunately, while the weighted average has been applied by others examining the survival of PIT-tagged salmonids in the Columbia River Basin, the use of this methodology for estimating mean survival using radio-tagged fish has resulted in certain estimates (e.g., those that have survival and capture probabilities near 1) having highly disproportionate weights that invariably results in estimates of survival that are very near 1 despite the fact that very few of the survival estimates reflect this value. While weighted averages are designed to weight the average by certain observations with given qualities or other derived variables or quantities and thus cannot be expected to represent the value that would exist given an un-weighted estimator, the use of a weighted estimator that always skews the evaluation to indicate that the survival of fish passing a given project is 1, when as researchers we know this to not be the case, is unacceptable. The high capture probabilities possible with current radio-telemetry systems and the nature of the way the SURPH software calculates the variance of the survival estimates of the individual releases (e.g., analogous to the binomial variance formula) has resulted in this difficulty. Coordination between the USGS and the University of Washington, and subsequent efforts by University of Washington personnel have failed to resolve this computational difficulty. Consequently, we will evaluate the use of the weighted average, but will use the arithmetic mean to represent the survival of yearling chinook salmon and steelhead trout at the various projects if it appears that the use of the weighted estimator results in estimates that are disproportionately influenced by the aforementioned computational difficulty.

We evaluated Analysis of Variance models to test for differences in the survival of yearling chinook and steelhead trout passing via the spillway at John Day Dam and also for yearling chinook and steelhead passing via all routes at John Day Dam under two spill treatments. Since no a priori information was available to suggest that the survival of fish passing during either of the treatments would be greater than another so all of the tests conducted were two-tailed. The specific hypotheses addressed were as follows:

<u>Yearling Chinook</u>

$$H_0 : S_{30/53} = S_{0/53}$$

$$H_0 : S_{30/53} \neq S_{0/53}$$

<u>Steelhead trout</u>

$$H_0 : S_{30/53} = S_{0/53}$$

$$H_0 : S_{30/53} \neq S_{0/53}$$

We also evaluated linear regressions to examine the relation of the survival of our individual paired release groups at John Day and The Dalles dams to various environmental and dam operation conditions present at these projects during 2000. Environmental and dam operation data were obtained from the ACOE at http://www.nwd-wc.usace.army.mil/TMT/welcome.html. All linear regressions were examined for outliers using regression diagnostics (e.g., studentized deleted residuals, Cook's distance, DFFITS, as per Neter et al. 1989). Outlying observations were eliminated where appropriate and the fit and significance of the resulting models were examined.

Results

Burnham Tests

John Day Dam

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the yearling chinook released at Rock Creek and known to have passed the John Day Dam and their corresponding tailrace releases were inconclusive. For Test 2, 16 of the 32 possible tests were incalculable due to the presence of all zeroes in either rows or columns in the chi-square contingency tables (Table 14). Of the tests that were calculated, only 1 of the 32 tests was marginally significant ($P = 0.098$). For Test 3, similar results were obtained with 23 of the 32 tests incalculable with only 1 of the 32 tests calculated for Test 3 indicating significant differences ($P = 0.098$). For the yearling chinook released at Rock Creek and known to have passed the John Day Dam spillway and releases in the John Day Dam tailrace, the results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 were also inconclusive. For Test 2, 18 of the 32 possible tests were incalculable due to the presence of all zeroes in either rows or columns in the chi-square contingency tables (Table 15). Of the tests that were calculated, only 1 test was significant ($P < 0.10$). For Test 3, similar results were obtained with 23 of the 32 tests incalculable with only 1 test calculated for Test 3 indicating a significant difference ($P < 0.10$).

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6, for steelhead trout released at Rock Creek and known to have passed the John Day Dam and releases of steelhead in the John Day Dam tailrace were inconclusive. For Test 2, 22 of the 32 possible tests were incalculable due to the presence of all zeroes in either rows or columns in the chi-square contingency tables (Table 16). Of the tests that were calculated, only 1test was significant ($P < 0.10$). For Test 3, similar results were obtained with 26 of the 32 tests incalculable with only 1 test calculated for Test 3 indicating a significant difference ($P < 0.10$). For the steelhead trout released at Rock Creek and known to have passed the John Day Dam spillway and releases in the John Day Dam tailrace, similar results were obtained for the Burnham Tests 2 and 3. For Test 2, 26 of the 32 possible tests were incalculable due to the presence of all zeroes in either rows or columns in the chi-square contingency tables (Table 17). Of the tests that were calculated no tests were significant ($P < 0.10$). For Test 3, 27 of the 32 tests were incalculable with only 1test calculated indicating significant differences ($P < 0.10$).

The Dalles Dam

Similar to the results obtained for the releases at John Day Dam the results of the Burnham tests for releases through the spillway, ice and trash sluiceway, various turbine units and in the tailrace at The Dalles Dam were largely incalculable. For releases of yearling chinook salmon through the sluiceway and in the tailrace of The Dalles Dam, 21 of 26 test 2 and 13 of 26 test 3 results were incalculable (Table 18). Of the remaining tests, only 1 test 2 result was significant ($P < 0.10$), while none of the test 3 results were significant. For yearling chinook released through the spillway and their corresponding tailrace releases, 24 of 26 (test 2) and 18 of 26 (test 3) were incalculable (Table 19). None of the results of the remaining tests for test 2 were significant and only 4 test 3 results indicated significant differences. The results for the Burnham tests for yearling chinook released through turbine units at The Dalles Dam were similar to those for the releases through the other passage routes evaluated during 2000 (Table 20). Twenty of 26 test 2 results and 13 of 26 test 3 results were incalculable for the paired turbine releases of yearling chinook. Of the remaining tests 3 and 2 test 2 and test 3 results were significant, respectively.

During 2000, we also evaluated the results of the Burnham tests for releases of sub-yearling chinook salmon at The Dalles Dam. As was true for the yearling chinook releases, a large proportion of the Burnham tests were incalculable (Table 21). For sub-yearling chinook released through the ice and trash sluiceway and their corresponding tailrace releases, 8 of 18 test 2 results were incalculable with no significant differences found. For test 3, only 2 of 18 tests were incalculable and of these tests, no significant differences were detected. Similar results were obtained for releases through the spillway and the corresponding tailrace releases (Table 22). Nine of 18 results for test 2 were incalculable while only 1 of 18 test 3 results were incalculable. No significant differences were detected for either test 2 or test 3 for the spillway releases of sub-yearling chinook or the paired tailrace releases. For the paired turbine releases of sub-yearling chinook again 9 of 18 and only 1 of 18 results were incalculable for tests 2 and 3, respectively (Table 23). No significant differences were detected for the paired turbine releases at The Dalles Dam.

Table 14. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 16 paired releases of yearling chinook during 2000. Treatment fish were released above John Day Dam at Rock Creek and detected at John Day Dam and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control	1	2.730	0.098		[a]	[a]
2	treatment		[a]	[a]		[a]	[a]
	control	1	0.242	0.623	1	0.625	0.429
3	treatment	1	2.363	0.124	1	1.621	0.203
	control	1	0.442	0.506	1	0.625	0.429
4	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
5	treatment	1	1.891	0.169		[a]	[a]
	control		[a]	[a]		[a]	[a]
6	treatment		[a]	[a]		[a]	[a]
	control	1	0.603	0.438		[a]	[a]
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
8	treatment		[a]	[a]		[a]	[a]
	control	1	0.439	0.507	1	0.059	0.809
9	treatment	1	0.014	0.905	1	1.094	0.296
	control		[a]	[a]		[a]	[a]
10	treatment		[a]	[a]		[a]	[a]
	control	1	0.684	0.408	1	2.730	0.098
11	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
12	treatment		[a]	[a]		[a]	[a]
	control	1	0.059	0.809	1	0.997	0.318
13	treatment	1	2.246	0.134		[a]	[a]
	control	1	1.371	0.242		[a]	[a]
14	treatment	1	0.273	0.601	1	1.371	0.242
	control	1	0.749	0.387		[a]	[a]
15	treatment		[a]	[a]		[a]	[a]
	control	1	2.055	0.152		[a]	[a]
16	treatment	1	0.018	0.892	1	1.506	0.220
	control		[a]	[a]		[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 15. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 16 paired releases of yearling chinook during 2000. Treatment fish were released at Rock Creek detected at John Day Dam spillway and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	0.873	0.350
2	treatment		[a]	[a]		[a]	[a]
	control	1	0.242	0.623	1	0.625	0.429
3	treatment	1	0.143	0.706	1	1.371	0.242
	control	1	0.442	0.506	1	0.625	0.429
4	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
5	treatment	1	0.356	0.551		[a]	[a]
	control		[a]	[a]		[a]	[a]
6	treatment		[a]	[a]		[a]	[a]
	control	1	0.603	0.438		[a]	[a]
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
8	treatment		[a]	[a]		[a]	[a]
	control	1	0.439	0.507	1	0.059	0.809
9	treatment	1	0.327	0.568	1	1.122	0.290
	control		[a]	[a]		[a]	[a]
10	treatment		[a]	[a]		[a]	[a]
	control	1	0.684	0.408	1	2.730	0.098
11	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
12	treatment		[a]	[a]		[a]	[a]
	control	1	0.059	0.809	1	0.997	0.318
13	treatment	1	4.488	0.034		[a]	[a]
	control	1	1.371	0.242		[a]	[a]
14	treatment		[a]	[a]		[a]	[a]
	control	1	0.749	0.387		[a]	[a]
15	treatment		[a]	[a]		[a]	[a]
	control	1	2.055	0.152		[a]	[a]
16	treatment	1	0.033	0.855	1	2.371	0.124
	control		[a]	[a]		[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 16. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 16 paired releases of juvenile steelhead during 2000. Treatment fish were released above John Day Dam at Rock Creek and detected at John Day Dam and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
2	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
3	treatment	1	4.110	0.043		[a]	[a]
	control		[a]	[a]		[a]	[a]
4	treatment	1	1.258	0.262		[a]	[a]
	control		[a]	[a]		[a]	[a]
5	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
6	treatment	1	1.258	0.262	1	4.488	0.034
	control	1	1.496	0.221	1	1.371	0.242
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
8	treatment	1	0.730	0.393		[a]	[a]
	control		[a]	[a]	1	1.621	0.203
9	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
10	treatment	1	0.522	0.470		[a]	[a]
	control	1	1.496	0.221		[a]	[a]
11	treatment	1	1.746	0.186	1	1.496	0.221
	control		[a]	[a]		[a]	[a]
12	treatment	1	0.765	0.382		[a]	[a]
	control		[a]	[a]		[a]	[a]
13	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
14	treatment		[a]	[a]		[a]	[a]
	control	1	0.749	0.387	1	1.723	0.189
15	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
16	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	2.730	0.098

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 17. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 16 paired releases of steelhead trout during 2000. Treatment fish were released at Rock Creek detected at John Day Dam spillway and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
2	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
3	treatment	1	0.652	0.419		[a]	[a]
	control		[a]	[a]		[a]	[a]
4	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
5	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
6	treatment		[a]	[a]		[a]	[a]
	control	1	1.496	0.221	1	1.371	0.242
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
8	treatment	1	0.603	0.438		[a]	[a]
	control		[a]	[a]	1	1.621	0.203
9	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
10	treatment		[a]	[a]		[a]	[a]
	control	1	1.496	0.221		[a]	[a]
11	treatment	1	1.247	0.264	1	0.997	0.318
	control		[a]	[a]		[a]	[a]
12	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
13	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
14	treatment		[a]	[a]		[a]	[a]
	control	1	0.749	0.387	1	1.723	0.189
15	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
16	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	2.730	0.098

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 18. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 13 paired releases of yearling chinook during 2000 through The Dalles Dam sluiceway and tailrace. Treatment fish were released through the sluiceway and control fish were released in the tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
2	treatment	1	3.233	0.072		[a]	[a]
	control	1	1.247	0.264	1	0.096	0.757
3	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	1.122	0.290
4	treatment	1	3.734	0.053	1	0.175	0.676
	control		[a]	[a]	1	0.059	0.809
5	treatment		[a]	[a]	1	1.122	0.290
	control		[a]	[a]	1	0.000	1.000
6	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	0.684	0.408
7	treatment	1	0.684	0.408	1	0.036	0.849
	control		[a]	[a]		[a]	[a]
8	treatment		[a]	[a]	1	0.022	0.881
	control		[a]	[a]		[a]	[a]
9	treatment		[a]	[a]	1	0.364	0.546
	control		[a]	[a]		[a]	[a]
10	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
11	treatment		[a]	[a]	1	1.746	0.186
	control		[a]	[a]		[a]	[a]
12	treatment	1	1.746	0.186	1	1.496	0.221
	control		[a]	[a]		[a]	[a]
13	treatment		[a]	[a]	1	1.723	0.189
	control		[a]	[a]		[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 19. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 13 paired releases of yearling chinook during 2000 through The Dalles Dam spillway and tailrace. Treatment fish were released through the spillway and control fish were released in the tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
2	treatment		[a]	[a]	1	0.997	0.318
	control	1	1.247	0.264	1	0.096	0.757
3	treatment		[a]	[a]	1	0.217	0.641
	control		[a]	[a]	1	1.122	0.290
4	treatment		[a]	[a]	1	0.684	0.408
	control		[a]	[a]	1	0.059	0.809
5	treatment		[a]	[a]	1	0.059	0.809
	control		[a]	[a]	1	0.000	1.000
6	treatment		[a]	[a]	1	0.242	0.623
	control		[a]	[a]	1	0.684	0.408
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	2.982	0.084
8	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	0.041	0.839
9	treatment		[a]	[a]	1	3.734	0.053
	control		[a]	[a]	1	3.734	0.053
10	treatment		[a]	[a]	1	3.484	0.062
	control		[a]	[a]		[a]	[a]
11	treatment	1	0.439	0.507	1	0.059	0.809
	control		[a]	[a]		[a]	[a]
12	treatment		[a]	[a]	1	2.479	0.115
	control		[a]	[a]		[a]	[a]
13	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	2.226	0.136

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 20. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 13 paired releases of yearling chinook during 2000 through various turbine units at The Dalles Dam and in the tailrace. Treatment fish were released through various turbine units and control fish were released in the tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
2	treatment		[a]	[a]	1	0.015	0.904
	control	1	1.247	0.264	1	0.096	0.757
3	treatment	1	2.730	0.098	1	2.479	0.115
	control		[a]	[a]	1	1.122	0.290
4	treatment		[a]	[a]	1	1.875	0.171
	control		[a]	[a]	1	0.059	0.809
5	treatment	1	2.226	0.136		[a]	[a]
	control		[a]	[a]	1	0.000	1.000
6	treatment	1	3.233	0.072	1	0.242	0.623
	control		[a]	[a]		[a]	[a]
7	treatment	1	3.233	0.072	1	2.982	0.084
	control		[a]	[a]		[a]	[a]
8	treatment	1	0.356	0.551	1	0.036	0.849
	control		[a]	[a]		[a]	[a]
9	treatment		[a]	[a]	1	5.304	0.021
	control		[a]	[a]		[a]	[a]
10	treatment		[a]	[a]	1	1.122	0.290
	control		[a]	[a]		[a]	[a]
11	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
12	treatment		[a]	[a]	1	3.734	0.053
	control		[a]	[a]		[a]	[a]
13	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 21. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 9 paired releases of sub-yearling chinook during 2000. Treatment fish were released into The Dalles Dam sluiceway and control fish were released in The Dalles Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment	1	0.024	0.876	1	0.750	0.386
	control	1	0.088	0.766	1	0.212	0.645
2	treatment		[a]	[a]	1	0.234	0.629
	control		[a]	[a]	1	0.179	0.673
3	treatment	1	0.703	0.402	1	0.043	0.836
	control		[a]	[a]	1	0.048	0.826
4	treatment		[a]	[a]	1	0.150	0.699
	control	1	0.263	0.608	1	0.750	0.386
5	treatment	1	0.381	0.537		[a]	[a]
	control		[a]	[a]	1	2.553	0.110
6	treatment	1	0.076	0.782	1	0.141	0.708
	control		[a]	[a]	1	0.134	0.714
7	treatment	1	0.006	0.936	1	0.563	0.453
	control		[a]	[a]	1	0.136	0.712
8	treatment	1	0.023	0.879	1	0.625	0.429
	control		[a]	[a]		[a]	[a]
9	treatment	1	0.274	0.600	1	0.017	0.895
	control	1	0.242	0.623	1	0.174	0.676

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 22. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 9 paired releases of sub-yearling chinook during 2000. Treatment fish were released into The Dalles Dam spillway and control fish were released in The Dalles Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment	1	0.502	0.479	1	0.000	1.000
	control	1	0.088	0.766	1	0.212	0.645
2	treatment		[a]	[a]	1	0.000	1.000
	control		[a]	[a]	1	0.179	0.673
3	treatment	1	0.000	1.000	1	0.039	0.843
	control		[a]	[a]	1	0.048	0.826
4	treatment	1	0.024	0.876	1	0.150	0.699
	control	1	0.263	0.608	1	0.750	0.386
5	treatment		[a]	[a]	1	0.076	0.783
	control		[a]	[a]	1	2.553	0.110
6	treatment	1	0.000	1.000	1	0.313	0.576
	control		[a]	[a]	1	0.134	0.714
7	treatment		[a]	[a]	1	0.030	0.863
	control		[a]	[a]	1	0.136	0.712
8	treatment	1	0.075	0.784	1	0.417	0.519
	control		[a]	[a]		[a]	[a]
9	treatment	1	2.479	0.115	1	0.088	0.766
	control	1	0.242	0.623	1	0.174	0.676

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Bonneville Dam

The evaluation of the Burnham tests for releases of yearling chinook salmon released near Hood River, OR and know to have passed Bonneville Dam, releases at Hood River and known to have passed via the Bonneville Dam spillway, releases into the new juvenile bypass system at Powerhouse 2, and the corresponding tailrace releases for these evaluations exhibited similar results as those for John Day and The Dalles dams. For the paired releases of yearling chinook into the Powerhouse 2 juvenile bypass and tailrace, 9 of 24 test 2 and 15 of 24 test 3 results were incalculable (Table 24). Of the remaining tests for the paired juvenile bypass releases, 2 each for test 2 and 3 indicated significant differences. Similar results were obtained for the paired releases of fish released near Hood River, OR and detected at Bonneville Dam with 15 of 24 test 2 and 18 of 24 test 3 results incalculable (Table 25). Of the calculable tests only 1 test 2 result indicated a significant result. For the releases of fish near Hood River, OR that were determined to have passed via the spillway at Bonneville Dam and their corresponding tailrace releases 17 of 24 test 2 and 21 of 24 test 3 results were incalculable with only 1 test 2 result indicating a significant difference.

Tests of the assumption of mixing of the treatment and control groups

John Day Dam

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of yearling chinook salmon and steelhead trout indicated that there were few significant differences in arrival times between the two release groups. Two of the 16 tests for yearling chinook salmon released at Rock Creek and detected at John Day Dam (e.g., release groups used in the evaluations of total project survival at this project) indicated significant differences in arrival times at The Dalles Dam between the paired releases (Table 27, $P < 0.007$). For steelhead trout that were detected at John Day Dam and their corresponding control releases in the tailrace, 6 of the 16 tests (Table 27) indicated significant differences in arrival times at The Dalles Dam ($P < 0.007$).

For the paired releases of yearling chinook salmon and steelhead trout that passed the spillway at John Day Dam , the chi-square tests of homogeneity testing for the similarity in arrival times also indicated that there were few significant differences in arrival times between the treatment and control groups. For the paired releases of yearling chinook salmon determined to have passed the John Day Dam spillway (e.g., release groups used in the evaluations of spillway survival at this project), 2 of the 16 tests (Table 28) indicated significant differences in arrival times at The Dalles Dam ($P < 0.007$). Four of the 16 tests for the paired juvenile steelhead releases at Rock Creek and known to have passed the John Day Dam spillway (Table 28) indicated significant differences in arrival times at The Dalles Dam between the paired releases ($P < 0.007$).

Table 23. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 9 paired releases of sub-yearling chinook during 2000. Treatment fish were released into The Dalles Dam turbines and control fish were released in The Dalles Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment	1	0.011	0.915	1	0.263	0.608
	control	1	0.088	0.766	1	0.212	0.645
2	treatment		[a]	[a]	1	0.017	0.895
	control		[a]	[a]	1	0.179	0.673
3	treatment		[a]	[a]	1	0.178	0.673
	control		[a]	[a]	1	0.048	0.826
4	treatment	1	0.000	1.000	1	0.056	0.813
	control	1	0.263	0.608	1	0.750	0.386
5	treatment	1	0.009	0.924	1	0.000	1.000
	control		[a]	[a]	1	2.553	0.110
6	treatment	1	0.749	0.387	1	0.502	0.479
	control		[a]	[a]	1	0.134	0.714
7	treatment	1	0.039	0.843	1	0.000	1.000
	control		[a]	[a]	1	0.136	0.712
8	treatment		[a]	[a]	1	0.000	1.000
	control		[a]	[a]		[a]	[a]
9	treatment	1	0.426	0.514	1	0.034	0.853
	control	1	0.242	0.623	1	0.174	0.676

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables..

Similar results were obtained for the tests of similarity in arrival times at the Bonneville Reservoir array of the paired releases of yearling chinook (Table 29; none significant) and steelhead trout (Table 29; Three of 16 significant; $P < 0.007$) detected at the John Day Dam. For the paired releases of yearling chinook known to have passed via the John Day Dam spillway the results were similar (Table 30; none significant), as well as for the paired releases of steelhead trout passing via the spillway (Table 30; Three of 16 significant; $P < 0.007$).

For the paired-release groups of yearling chinook salmon used in the total project survival evaluations, the chi-square tests for arrival times at Bonneville Dam indicated only one significant difference (Table 31; One of 16 significant; $P < 0.007$) and tow significant differences for the steelhead trout releases (Table 31; Two of 16 significant; $P < 0.007$). The arrival times of Rock Creek released yearling chinook salmon known to have passed the John Day Dam spillway showed similar results (Table 32; One of 16 significant; $P < 0.007$) as did the releases of steelhead trout (Table 32; Two of 16 significant; $P < 0.007$).

The Dalles Dam

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of yearling chinook salmon at The Dalles Dam sluiceway indicated no significant differences in arrival times between the two release groups at the Bonneville Reservoir array or at Bonneville Dam (Table 33 and 34, none significant). Similar results were obtained for arrival times of paired releases of yearling chinook salmon through various turbine units at The Dalles Dam (Table 33 and 34, none significant) and at The Dalles Dam spillway (Table 33 and 34, none significant). For the paired releases of sub-yearling chinook salmon through the spillway, ice and trash sluiceway, and through various turbine units at The Dalles Dam no significant differences were observed between the arrival times at any of the downstream arrays for any of the passage routes (Tables 35 & 36).

Bonneville Dam

The chi-square tests for the paired releases of yearling chinook salmon in the Bonneville Reservoir at Hood River indicated few significant differences in arrival times between the two release groups at the third array below Bonneville Dam. One of the 12 tests for yearling chinook salmon released in the Bonneville Dam Reservoir at Hood River and known to have passed the Bonneville Dam spillway showed a significant difference between the two release groups (Table 37). None of the tests for yearling chinook salmon released into the Powerhouse 2 juvenile bypass at Bonneville Dam indicated significant difference between the arrival times of the two release groups (Table 37).

Table 24. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 12 paired releases of yearling chinook during 2000. Treatment fish were released at the top of the juvenile bypass detected at Bonneville Dam and control fish were released in the Bonneville Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]	1	1.094	0.296
	control		[a]	[a]	1	2.246	0.134
2	treatment	1	1.175	0.278		[a]	[a]
	control	1	1.175	0.278		[a]	[a]
3	treatment	1	1.258	0.262		[a]	[a]
	control		[a]	[a]		[a]	[a]
4	treatment	1	5.376	0.020	1	4.488	0.034
	control	1	2.028	0.154		[a]	[a]
5	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
6	treatment	1	1.018	0.313	1	1.506	0.220
	control		[a]	[a]		[a]	[a]
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
8	treatment	1	2.246	0.134	1	2.121	0.145
	control	1	0.189	0.664	1	0.273	0.601
9	treatment	1	0.202	0.653		[a]	[a]
	control	1	0.035	0.852		[a]	[a]
10	treatment	1	2.121	0.145		[a]	[a]
	control	1	4.408	0.036		[a]	[a]
11	treatment	1	0.276	0.599	1	1.996	0.158
	control		[a]	[a]	1	0.001	0.978
12	treatment	1	2.496	0.114	1	5.238	0.022
	control	1	1.839	0.175		[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 25. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 12 paired releases of yearling chinook during 2000. Treatment fish were released above Bonneville Dam and were detected at Bonneville Dam and control fish were released in the Bonneville Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]	1	0.522	0.470
	control		[a]	[a]	1	2.246	0.134
2	treatment		[a]	[a]		[a]	[a]
	control	1	1.175	0.278		[a]	[a]
3	treatment	1	2.479	0.115	1	2.226	0.136
	control		[a]	[a]		[a]	[a]
4	treatment		[a]	[a]		[a]	[a]
	control	1	2.028	0.154		[a]	[a]
5	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
6	treatment	1	0.207	0.649		[a]	[a]
	control		[a]	[a]		[a]	[a]
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
8	treatment		[a]	[a]		[a]	[a]
	control	1	0.189	0.664	1	0.273	0.601
9	treatment		[a]	[a]		[a]	[a]
	control	1	0.035	0.852		[a]	[a]
10	treatment	1	0.592	0.442		[a]	[a]
	control	1	4.408	0.036		[a]	[a]
11	treatment		[a]	[a]	1	0.327	0.568
	control		[a]	[a]	1	0.001	0.978
12	treatment		[a]	[a]		[a]	[a]
	control	1	1.839	0.175		[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 26. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 12 paired releases of yearling chinook during 2000. Treatment fish were released above Bonneville Dam and were detected passing the Bonneville Dam spillway and control fish were released in the Bonneville Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	2.246	0.134
2	treatment		[a]	[a]		[a]	[a]
	control	1	1.175	0.278		[a]	[a]
3	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
4	treatment		[a]	[a]		[a]	[a]
	control	1	2.028	0.154		[a]	[a]
5	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
6	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
7	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
8	treatment		[a]	[a]		[a]	[a]
	control	1	0.189	0.664	1	0.273	0.601
9	treatment		[a]	[a]		[a]	[a]
	control	1	0.035	0.852		[a]	[a]
10	treatment	1	1.215	0.270		[a]	[a]
	control	1	4.408	0.036		[a]	[a]
11	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]	1	0.001	0.978
12	treatment		[a]	[a]		[a]	[a]
	control	1	1.839	0.175		[a]	[a]

[a] - Chi-square statistic was not calculable for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 27. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of total project spring chinook salmon and steelhead trout released at Rock Creek and detected at John Day Dam at The Dalles Dam.

	Spring chinook			Steelhead trout		
Release	DF	Chi-square	P	DF	Chi-square	P
1	3	8.57	0.036	2	5.18	0.075
2	2	1.90	0.388	2	10.88	0.004
3	1	5.91	0.015	2	7.00	0.030
4	2	7.97	0.019	1	0.13	0.714
5	2	1.82	0.403	3	4.62	0.202
6	1	7.32	0.007	4	13.66	0.008
7	1	1.59	0.207	3	6.64	0.084
8	1	3.78	0.052	4	14.40	0.006
9	1	0.78	0.378	3	6.62	0.085
10	1	9.29	0.002	3	3.82	0.282
11	1	2.79	0.095	2	6.96	0.031
12	2	2.03	0.362	2	12.00	0.002
13	2	3.99	0.136	2	19.65	<0.001
14	2	2.78	0.250	2	11.87	0.003
15	3	4.06	0.255	3	12.22	0.007
16	1	9.58	0.002	5	28.66	<0.001

Table 28. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of spillway spring chinook salmon and steelhead trout at The Dalles Dam.

	Spring chinook			Steelhead trout		
Release	DF	Chi-square	P	DF	Chi-square	P
1	1	4.11	0.043	2	2.55	0.279
2	1	0.27	0.601	0	0.00	[a]
3	1	5.53	0.019	2	5.76	0.056
4	1	7.27	0.007	1	0.91	0.339
5	1	1.22	0.269	1	1.09	0.296
6	1	8.61	0.003	2	8.81	0.012
7	1	0.97	0.325	1	2.93	0.087
8	1	2.06	0.151	1	5.10	0.024
9	0	0.00	[a]	2	4.73	0.094
10	1	5.91	0.015	2	14.84	<0.001
11	1	3.33	0.068	2	8.11	0.017
12	1	1.51	0.219	2	19.80	<0.001
13	1	2.62	0.106	2	15.61	<0.001
14	2	1.48	0.476	2	7.87	0.020
15	3	3.69	0.297	1	3.70	0.054
16	1	8.33	0.004	5	28.75	<0.001

[a] - All fish arrived on the same day at this detection array.

Table 29. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of total project spring chinook salmon and steelhead trout at the Bonneville Reservoir array.

	Spring chinook			Steelhead trout		
Release	DF	Chi-square	P	DF	Chi-square	P
1	2	1.86	0.395	2	3.90	0.142
2	3	4.03	0.259	2	2.25	0.324
3	1	5.19	0.023	1	5.76	0.016
4	2	6.15	0.046	1	0.73	0.393
5	1	2.28	0.131	2	3.44	0.179
6	1	2.50	0.114	6	16.67	0.011
7	1	0.29	0.588	3	5.87	0.118
8	1	7.20	0.007	4	14.61	0.006
9	1	2.34	0.126	3	6.59	0.086
10	2	5.01	0.082	3	6.88	0.076
11	1	1.68	0.195	2	6.98	0.030
12	3	3.13	0.372	4	19.11	<0.001
13	1	3.89	0.049	3	6.40	0.094
14	1	1.99	0.158	2	3.07	0.216
15	3	3.49	0.322	3	11.36	0.010
16	1	6.64	0.010	5	27.73	<0.001

Table 30. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of spillway spring chinook salmon and steelhead trout at a the Bonneville Reservoir array.

	Spring Chinook			Steelhead trout		
Release	DF	Chi-square	P	DF	Chi-square	P
1	2	4.16	0.125	2	3.19	0.203
2	1	1.37	0.242	1	0.15	0.703
3	1	4.88	0.027	1	4.28	0.038
4	2	5.66	0.059	1	0.54	0.461
5	1	1.38	0.240	1	1.17	0.279
6	1	3.17	0.075	4	12.69	0.013
7	1	0.38	0.537	1	1.91	0.167
8	1	4.57	0.033	3	13.38	0.004
9	1	2.30	0.129	3	5.33	0.149
10	1	0.51	0.475	2	12.63	0.002
11	1	2.12	0.145	2	6.19	0.045
12	1	1.75	0.186	3	10.91	0.012
13	1	3.35	0.067	3	5.07	0.167
14	1	0.64	0.422	2	2.19	0.334
15	3	3.25	0.354	1	3.47	0.063
16	1	6.06	0.014	5	28.95	<0.001

Table 31. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of total project spring chinook salmon and steelhead trout at Bonneville Dam.

	Spring chinook			Steelhead trout		
Release	DF	Chi-square	P	DF	Chi-square	P
1	3	0.97	0.808	3	3.28	0.350
2	3	3.53	0.316	2	2.33	0.313
3	3	4.09	0.252	2	7.38	0.025
4	3	7.26	0.064	2	2.71	0.258
5	3	2.34	0.505	3	5.22	0.157
6	2	2.05	0.359	7	12.64	0.081
7	2	1.73	0.421	3	8.00	0.046
8	1	3.59	0.058	5	17.82	0.003
9	3	4.55	0.208	4	4.27	0.371
10	3	15.13	0.002	4	5.22	0.265
11	1	1.12	0.290	2	6.13	0.047
12	2	0.77	0.680	4	11.84	0.019
13	4	4.97	0.290	3	6.31	0.098
14	2	2.42	0.298	2	3.54	0.171
15	3	3.53	0.317	3	12.19	0.007
16	4	6.73	0.151	5	17.82	0.003

Table 32. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of spillway spring chinook salmon and steelhead trout at Bonneville Dam.

	Spring chinook			Steelhead trout		
Release	DF	Chi-square	P	DF	Chi-square	P
1	3	4.19	0.242	2	1.42	0.492
2	2	0.10	0.949	1	0.41	0.524
3	3	3.03	0.387	2	6.59	0.037
4	3	6.10	0.107	1	1.93	0.164
5	1	1.03	0.309	1	1.17	0.279
6	2	1.30	0.522	5	13.84	0.017
7	2	0.97	0.617	1	3.24	0.072
8	1	2.05	0.152	3	6.61	0.085
9	3	4.90	0.179	4	4.15	0.386
10	3	13.19	0.004	3	13.39	0.004
11	1	1.36	0.243	2	5.06	0.080
12	1	0.03	0.854	2	9.40	0.009
13	3	4.19	0.242	3	5.04	0.169
14	2	1.16	0.561	2	1.69	0.430
15	3	3.40	0.334	2	4.62	0.099
16	3	5.22	0.157	5	21.36	<0.001

Table 33. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of The Dalles Dam spillway, turbine and sluiceway yearling chinook salmon at the Bonneville Reservoir array.

	Spillway			Turbine			Sluiceway		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	1.18	0.277	0	0	[a]	0	0	[a]
2	1	1.12	0.290	1	0.96	0.327	1	1.12	0.290
3	1	0.84	0.359	0	0	[a]	0	0	[a]
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	0	0	[a]	0	0	[a]
6	0	0	[a]	0	0	[a]	1	1.04	0.309
7	0	0	[a]	1	0.97	0.326	0	0	[a]
8	0	0	[a]	0	0	[a]	0	0	[a]
9	0	0	[a]	0	0	[a]	0	0	[a]
10	0	0	[a]	0	0	[a]	1	0.82	0.364
11	0	0	[a]	1	2.55	0.110	0	0	[a]
12	0	0	[a]	0	0	[a]	0	0	[a]
13	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array indicating treatment and control groups were mixed.

Table 34. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of The Dalles Dam spillway, turbine and sluiceway yearling chinook salmon at Bonneville Dam.

	Spillway			Turbine			Sluiceway		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	2	2.88	0.237	1	1.27	0.260	1	0.24	0.622
2	2	1.34	0.511	2	1.33	0.513	2	1.04	0.595
3	1	0.02	0.887	1	0.01	0.910	0	0	[a]
4	1	0.37	0.544	1	0.04	0.832	1	1.01	0.316
5	1	0.78	0.378	1	0.21	0.650	1	0.03	0.867
6	1	1.18	0.277	1	1.18	0.277	1	3.54	0.060
7	0	0	[a]	0	0	[a]	0	0	[a]
8	0	0	[a]	1	1.31	0.253	0	0	[a]
9	1	1.03	0.310	1	1.06	0.304	1	2.16	0.141
10	0	0	[a]	1	0.96	0.326	0	0	[a]
11	0	0	[a]	0	0	[a]	1	1.79	0.181
12	0	0	[a]	0	0	[a]	0	0	[a]
13	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array indicating treatment and control groups were mixed.

Table 35. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of spillway, turbine and sluiceway fall chinook salmon at the Sauter array.

	Spillway			Turbine			Sluiceway		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	1	1.37	0.242	0	0	[a]
2	1	1.20	0.274	0	0	[a]	0	0	[a]
3	0	0	[a]	0	0	[a]	0	0	[a]
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	0	0	[a]	1	1.20	0.274
6	0	0	[a]	0	0	[a]	0	0	[a]
7	0	0	[a]	0	0	[a]	0	0	[a]
8	0	0	[a]	0	0	[a]	0	0	[a]
9	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array indicating treatment and control groups were mixed.

Table 36. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of spillway, turbine and sluiceway fall chinook salmon at Bonneville Dam.

	Spillway			Turbine			Sluiceway		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	2	3.24	0.198	0	0	[a]
2	1	0.68	0.410	1	1.59	0.208	1	0.51	0.476
3	0	0	[a]	1	1.71	0.191	0	0	[a]
4	0	0	[a]	0	0	[a]	0	0	[a]
5	0	0	[a]	0	0	[a]	0	0	[a]
6	1	0.42	0.517	1	1.74	0.187	0	0	[a]
7	0	0	[a]	1	5.29	0.021	0	0	[a]
8	1	0.02	0.892	0	0	[a]	1	0.95	0.330
9	1	1.21	0.271	1	1.23	0.267	1	1.96	0.162

[a] - All fish arrived on the same day at this detection array indicating treatment and control groups were mixed.

Table 37. The results of chi-square tests of homogeneity testing for similarity in arrival times of releases of yearling chinook salmon released through the new juvenile bypass system at powerhouse 2 (PH2 bypass), near Hood River, OR and detected at Bonneville Dam (Total project), and near Hood River, OR and known to have passed via the spillway (Spillway) and their corresponding tailrace releases at the downstream most detection array below Bonneville Dam.

	PH2 Bypass			Total project			Spillway		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	1	14.40	<0.001	1	10.98	<0.001
2	1	0.005	0.945	1	1.47	0.225	0	0	[a]
3	2	1.92	0.384	1	4.48	0.034	0	0	[a]
4	0	0	[a]	2	2.34	0.311	0	0	[a]
5	2	3.44	0.179	3	6.22	0.101	3	11.94	0.008
6	2	2.59	0.274	0	0	[a]	0	0	[a]
7	0	0	[a]	1	1.37	0.243	0	0	[a]
8	1	0.98	0.323	0	0	[a]	0	0	[a]
9	0	0	[a]	0	0	[a]	0	0	[a]
10	1	1.12	0.291	1	1.17	0.280	0	0	[a]
11	0	0	[a]	2	3.64	0.162	0	0	[a]
12	1	1.27	0.259	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array indicating treatment and control groups were mixed.

Sequential evaluation of log-likelihood tests

A sequential evaluation of log-likelihood tests testing for significant difference in the survival model parameters was also performed to further evaluate the assumption of mixing and evaluate assumption A9 (e.g., Releases R_1 and R_2 have the same survival probability in the lower river segment S_{21}, see figures 1 and 2). For yearling chinook salmon and steelhead trout known to have passed the John Day Dam (Total Project survival evaluation), the majority of models selected did not suggest that the survival of treatment and control groups were significantly different in the river reaches evaluated below John Day Dam (Table 38; $P > 0.10$). Similarly, the evaluation of the log-likelihood tests did not suggest differential survival of the treatment and control groups downstream of John Day Dam for the majority of paired releases (Table 39; $P > 0.10$). At The Dalles Dam, the majority of models selected for the evaluation of survival of yearling chinook salmon through the spillway, ice and trash sluiceway, and turbine releases also did not suggest differential survival of the treatment and control groups for the river segments evaluated (see Figure 3) downstream of The Dalles Dam (Table 40; $P > 0.10$). Similar results were obtained for the sub-yearling chinook salmon releases at The Dalles Dam with the majority of models selected indicating similar survival probabilities for the treatment and control groups downstream of The Dalles Dam (Table 41; $P > 0.10$). For the evaluation of the survival of yearling chinook through Bonneville Dam, the Bonneville Dam spillway, and through the juvenile bypass system at Powerhouse 2, again the evaluation of the log-likelihood tests did not indicate differential survival between the treatment and control groups in the river reaches (see figures 4 and 5) evaluated below Bonneville Dam (Table 42; $P > 0.10$).

Releases of dead radio-tagged fish

Dead radio-tagged yearling chinook salmon and steelhead trout were released in the tailrace releases locations below John Day, The Dalles, and Bonneville dams to explore the likelihood of obtaining false-positive detections (e.g., detections of dead fish that would suggest they were alive) at arrays downstream of these projects. None of the dead radio-tagged fish released below John Day or The Dalles dams were detected at any radio-telemetry array below these projects. Similarly, no dead radio-tagged yearling chinook were detected at arrays below Bonneville Dam. However, three dead radio-tagged steelhead trout were detected at every downstream array below Bonneville Dam; suggesting that there was a possibility to have false-positive detections of steelhead at these arrays.

Table 38. Frequency of models selected as a result of evaluating log-likelihood ratio tests that test for differences in survival and capture probabilities between control and treatment groups. Model designations indicate the parameters that control and treatment groups have in common. For instance, model designation lambda p2 s2 p1 indicates that all the survival and capture probabilities were found not to be significantly different between the control and release groups. Model designation CJS refers to Cormack-Jolly-Seber model estimates that assume all parameters were different. In all cases, use of the CJS models resulted from computational constraints (e.g., variance estimates incalculable) associated with the SURPH software program and do not indicate that all parameters were tested and found to be significantly different.

	John Day Dam Total Project	
	Frequency	
Model	Yearling chinook salmon	Steelhead trout
Lambda p1	1	0
Lambda p2 S2 p1	7	6
Lambda s2	1	0
Lambda s2 p1	1	4
Lambda p2 S2	2	0
p2 s2 p1	2	1
p1 p2	1	0
CJS	1	5

Table 39. Frequency of models selected as a result of evaluating log-likelihood ratio tests that test for differences in survival and capture probabilities between control and treatment groups. Model designations indicate the parameters that control and treatment groups have in common. For instance, model designation lambda p2 s2 p1 indicates that all the survival and capture probabilities were found not to be significantly different between the control and release groups. Model designation CJS refers to Cormack-Jolly-Seber model estimates that assume all parameters were different. In all cases, use of the CJS models resulted from computational constraints (e.g., variance estimates incalculable) associated with the SURPH software program and do not indicate that all parameters were tested and found to be significantly different.

	John Day Dam Spillway	
	Frequency	
Model	Yearling chinook salmon	Steelhead trout
lambda p1	1	0
lambda p2 S2	3	0
lambda p2 S2 p1	7	11
lambda p2 p1	0	1
lambda s2 p1	0	3
p2 s2 p1	2	1
CJS	3	0

Table 40. Frequency of models selected as a result of evaluating log-likelihood ratio tests that test for differences in survival and capture probabilities between control and treatment groups. Model designations indicate the parameters that control and treatment groups have in common. For instance, model designation lambda p2 s2 p1 indicates that all the survival and capture probabilities were found not to be significantly different between the control and release groups. Model designation CJS refers to Cormack-Jolly-Seber model estimates that assume all parameters were different. In all cases, use of the CJS models resulted from computational constraints (e.g., variance estimates incalculable) associated with the SURPH software program and do not indicate that all parameters were tested and found to be significantly different.

	The Dalles Dam (yearling chinook salmon)		
	Frequency		
Model	Spillway	Sluiceway	Turbine
lambda p2	1	0	0
lambda p2 S2 p1	8	10	11
lambda p2 p1	2	1	0
lambda p2 S2	0	1	0
p2 s2 p1	1	0	2
p1 s2	0	1	0
CJS	1	0	0

Table 41. Frequency of models selected as a result of evaluating log-likelihood ratio tests that test for differences in survival and capture probabilities between control and treatment groups. Model designations indicate the parameters that control and treatment groups have in common. For instance, model designation lambda p2 s2 p1 indicates that all the survival and capture probabilities were found not to be significantly different between the control and release groups. Model designation CJS refers to Cormack-Jolly-Seber model estimates that assume all parameters were different. In all cases, use of the CJS models resulted from computational constraints (e.g., variance estimates incalculable) associated with the SURPH software program and do not indicate that all parameters were tested and found to be significantly different.

	The Dalles Dam (sub-yearling chinook salmon)		
	Frequency		
Model	Spillway	Sluiceway	Turbine
lambda p2 S2 p1	7	3	5
lambda s2 p1	0	3	2
lambda p2 S2	0	1	1
p2 s2 p1	1	2	0
p2s2	1	0	0
CJS	0	0	1

Table 42. Frequency of models selected as a result of evaluating log-likelihood ratio tests that test for differences in survival and capture probabilities between control and treatment groups. Model designations indicate the parameters that control and treatment groups have in common. For instance, model designation lambda p2 s2 p1 indicates that all the survival and capture probabilities were found not to be significantly different between the control and release groups. Model designation CJS refers to Cormack-Jolly-Seber model estimates that assume all parameters were different. In all cases, use of the CJS models resulted from computational constraints (e.g., variance estimates incalculable) associated with the SURPH software program and do not indicate that all parameters were tested and found to be significantly different.

	Bonneville Dam (yearling chinook salmon)		
	Frequency		
Model	Total Project	Spillway	Juvenile Bypass
lambda p2 S2 p1	8	9	9
lambda p2 p1	0	1	0
lambda s2 p1	1	0	1
lambda p2 S2	1	2	1
CJS	2	0	1

Survival Probability Assessment

John Day Dam

We generated survival probabilities and survival, capture, and lambda probabilities for each of the treatment and control groups for the river reaches shown in figures 1 and 2 for yearling chinook salmon and steelhead trout during two different spill scenarios. Of primary interest is the comparison of the survival probabilities of yearling chinook salmon (Table 43) and steelhead trout (Table 44) passing via the John Day Dam spillway and passing through all routes at John Day Dam during the two different spill conditions tested during 2000. The two spill scenarios planned at John Day Dam were: 0% spill during the day/ 60% spill during the night and 30% spill during the day/ 60% spill during the night. Evaluation of the actual spill levels at John Day Dam indicated that the conditions were approximately 0% day/53% night and 30% day/ 53% night on average. The survival of both yearling chinook salmon and steelhead trout passing via the John Dam spillway were both higher during the 0% day/53% night spill condition than the 30% day/53% night condition (Figure 6). Evaluation of an ANOVA indicated statistically significant differences in the survival of steelhead trout during the two spill conditions (ANOVA, $P = 0.036$). For yearling chinook salmon, the differences in survival were not statistically significant (ANOVA; $P = 0.28$) however, the power associated with this test was low ($1-\beta =$ 0.183 for the observed difference $\hat{S}_{SPILL\,30/53} - \hat{S}_{SPILL\,0/53}$ at $\alpha = 0.05$, two-tailed).

When yearling chinook and steelhead survival passing via all routes at John Day Dam were evaluated, similar trends were shown with survival being higher during the 0% day/53% night spill condition than the 30%/60% condition (Figure 7). However, the differences in survival between the two different spill conditions were not statistically significant (yearling chinook, ANOVA, $P = 0.37$; steelhead trout, ANOVA, $P = 0.20$). While no significant differences were detected, the power of the tests for yearling chinook ($1-\beta = 0.14$ for the observed difference $\hat{S}_{PROJECT\,30/53} - \hat{S}_{PROJECT\,0/53}$ at $\alpha = 0.05$, two-tailed) and for steelhead ($1-\beta =$ 0.24 for the observed difference $\hat{S}_{PROJECT\,30/53} - \hat{S}_{PROJECT\,0/53}$ at $\alpha = 0.05$, two-tailed) were low.

The nature of the evaluation of the different spill conditions at John Day Dam suggest that the primary difference between the two test conditions were the daytime spill percentages (i.e., 0% and 30%) and that reduced survival observed during the 30%day/53%night spill conditions was due to lower survival of fish passed during the day or increased survival of fish passed during the night. To explore this hypothesis, we evaluated linear regressions depicting the relation of the survival estimates of each individual release to the proportion of fish passing during the hours of the 30% daytime spill condition and also further examined the hypotheses of increased survival during nighttime hours by examining the relation of the survival estimates to the proportion of fish passing during the approximate nighttime hours present during the study (2100 to 0600 h). Essentially, we wished to examine whether daytime or nighttime passage was related to the survival of steelhead and yearling chinook at John Day Dam. The

Table 43. Survival estimates (S) and associated standard errors (SE) for yearling chinook salmon based on fish released at Rock Creek and determined to have passed via the John Day Dam spillway (Spillway), fish released at Rock Creek and determined to have passed John Day Dam (Total project), and releases of fish in the tailrace of John Day Dam during Spring 2000.

		Total Project		Spillway	
Paired Release	Spill Conditions	S	SE	S	SE
1	0/53	0.893	0.095	0.930	0.124
2	0/53	0.875	0.109	1.000	0.162
3	30/53	0.917	0.103	0.904	0.113
4	30/53	1.067	0.098	1.066	0.118
5	0/53	0.963	0.091	1.000	0.127
6	0/53	1.144	0.133	1.126	0.140
7	30/53	0.854	0.102	0.853	0.110
8	30/53	0.833	0.101	0.840	0.105
9	0/53	0.975	0.091	0.948	0.098
10	0/53	0.885	0.116	0.839	0.127
11	30/53	0.875	0.151	0.844	0.157
12	30/53	0.946	0.106	1.009	0.104
13	0/53	1.074	0.095	1.067	0.098
14	0/53	1.000	0.062	0.979	0.099
15	30/53	1.000	0.092	0.996	0.066
16	30/53	0.988	0.055	0.982	0.057

Table 44. Survival estimates (S) and associated standard errors (SE) for steelhead trout based on fish released at Rock Creek and determined to have passed via the John Day Dam spillway (Spillway), fish released at Rock Creek and determined to have passed John Day Dam (Total project), and releases of fish in the tailrace of John Day Dam during Spring 2000.

		Total Project		Spillway	
Paired Release	Spill condition	S	SE	S	SE
1	0/53	0.967	0.106	0.931	0.072
2	0/53	0.857	0.114	1.000	0.182
3	30/53	1.063	0.097	1.063	0.106
4	30/53	0.963	0.091	0.952	0.094
5	0/53	0.983	0.072	0.997	0.078
6	0/53	0.937	0.085	0.983	0.092
7	30/53	0.903	0.097	0.905	0.103
8	30/53	0.943	0.091	0.949	0.098
9	0/53	1.053	0.092	1.053	0.109
10	0/53	1.000	0.140	1.000	0.175
11	30/53	0.771	0.115	0.751	0.124
12	30/53	0.908	0.104	0.882	0.111
13	0/53	0.928	0.075	1.013	0.066
14	0/53	0.929	0.097	0.930	0.105
15	30/53	0.895	0.104	0.917	0.112
16	30/53	0.782	0.095	0.823	0.099

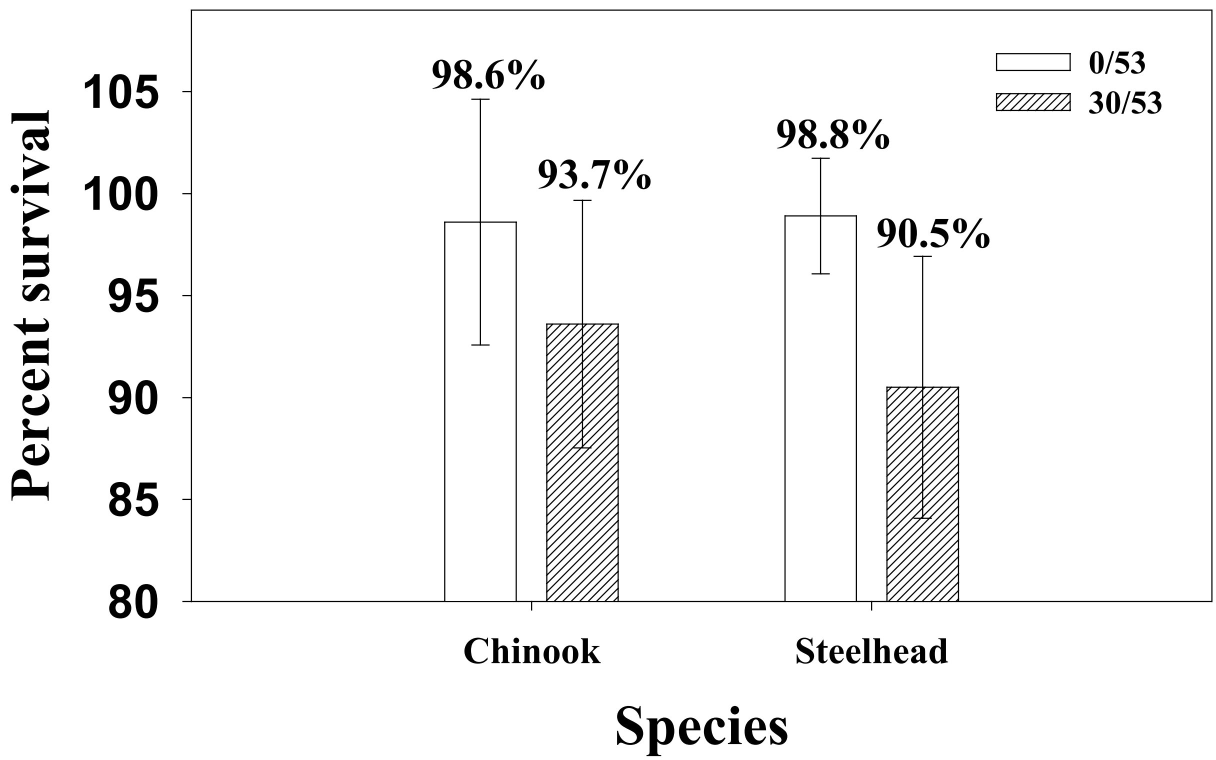


Figure 6. The survival probabilities based on 16 paired releases, expressed as percent survival, of yearling chinook salmon and steelhead trout passing via the John Day Dam spillway during 0% day/53% night and 30% day/53% night spill patterns. Error bars represent approximate 95% confidence intervals.

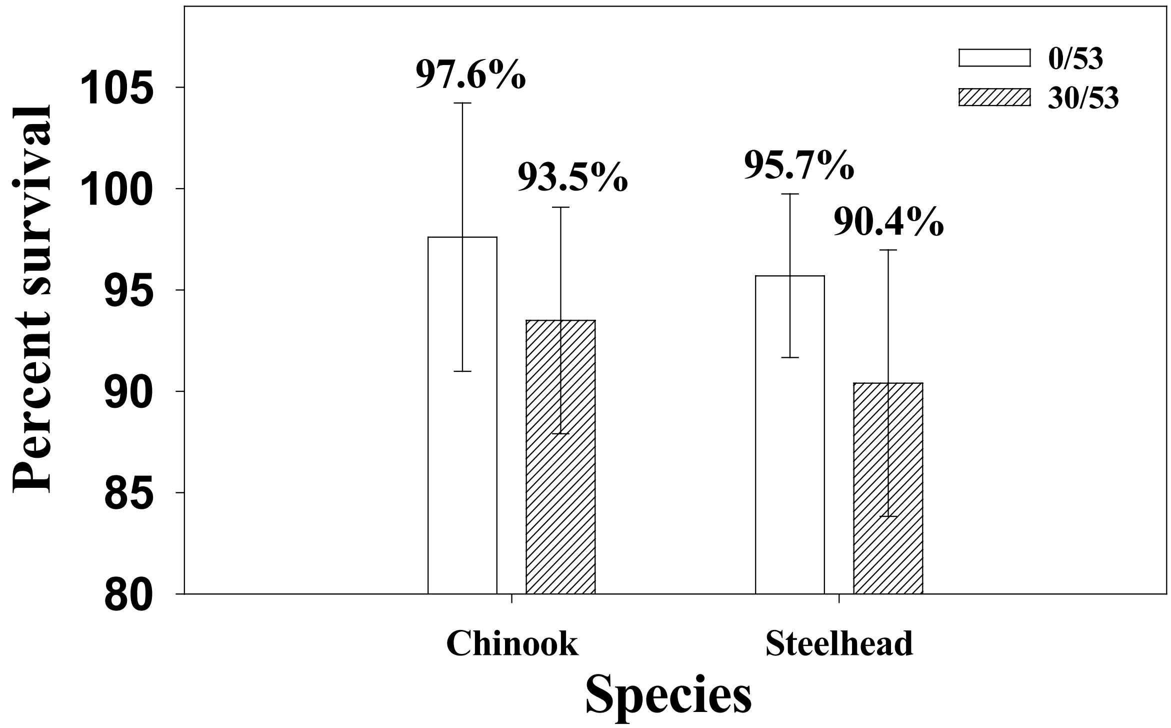


Figure 7. The survival probabilities based on 16 paired releases, expressed as percent survival, of yearling chinook salmon and steelhead trout passing John Day Dam via all routes during 0% day/53% night and 30% day/53% night spill patterns. Error bars represent approximate 95% confidence intervals.

proportion of fish passing during these hours were arcsine transformed and these values were used in the regression analyses (Sokal and Rohlf 1995). For yearling chinook salmon, no relation was detected between the survival estimates for fish passing via the John Day Dam spillway and the proportion of fish passing during 2100 to 0600 h (Figure 8, $P = 0.99$) or the proportion of fish passing during 0700 to 1800 h (Figure 8, $P = 0.90$). Similarly, no significant relation was found between the survival of steelhead trout passing via the spillway during the hours of 2100 to 0600 h (Figure 9, $P = 0.51$) or the proportion of fish passing during 0700 to 1800 h (Figure 9, $P = 0.30$). For yearling chinook passing through all routes at John Day Dam, no relations between the proportion of fish passing during 2100 to 0600 h (Figure 10, $P = 0.44$) or during 0700 to 1800 h (Figure 10, $P = 0.68$) were detected. The survival of steelhead trout passing all routes at John Day Dam was significantly related to the proportion (Figure 11, $P = 0.08$) however, the steelhead trout survival estimates were negatively correlated with the proportion of fish passing during the hours of 2100 to 0600 ($r = -0.45$, $P = 0.08$). No significant relation was detected between the survival of steelhead passing all routes at John Day Dam and the proportion of fish passing during the hours of 0700 to 1800 h (Figure 11, $P = 0.62$).

From these analyses we have evidence that the hypothesis of decreased survival of daytime passed fish is not supported by our data. Thus, we sought to examine what other environmental variables might account for the differences we observed between the survival of yearling chinook salmon and steelhead trout during each of the spill conditions tested at John Day Dam during 2000. Using an option in the Statistical Analysis Software package (SAS) that evaluates all potential models given a dependent variable and a set of independent variables, we identified candidate variables for further examination. While few of the variables or potential models appeared to explain a significant amount of the variability in the survival estimates, we did identify three potential variables (i.e., total discharge, proportion of total discharge as spill, and tail water elevation) for further examination. The other variables that were not selected for further evaluation included: forebay residence time, numbers of yearling chinook salmon, coho salmon, and steelhead trout passing John Day Dam by day, the number of juvenile salmonids (i.e., sum of yearling, coho, steelhead, etc.) passing John Day dam by day, proportion of fish passing during high spill discharge levels, proportion of fish passing during low spill discharge levels, and the proportion of fish passing during crepuscular periods. Linear regressions relating the survival of yearling chinook salmon and steelhead trout passing via the John Day Dam spillway and passing all routes at John day Dam to the total discharge, proportion of discharge as spill, and tail water elevation were evaluated. The values of these three variables for each release were calculated as the mean conditions experienced by all treatment fish in a particular release (i.e., those fish released at Rock Creek and determined to have passed John Day Dam). All relations were examined for the presence of outliers using regression diagnostics. For the relation of yearling chinook to total discharge, proportion of discharge as spill, and tail water elevation release 6 was designated as an outlier observation and was not included in the analyses; for steelhead trout release 10 was identified as an outlying observation and was also not included in the analyses.

For yearling chinook passing via the John Day Dam spillway, the relation of the survival estimates to total discharge was not significant (Table 45). However, the relation between survival and proportion of discharge as spill was marginally insignificant (Table 45, $P = 0.106$) and the relation of survival to tail water elevation was marginally significant (Figure 13,

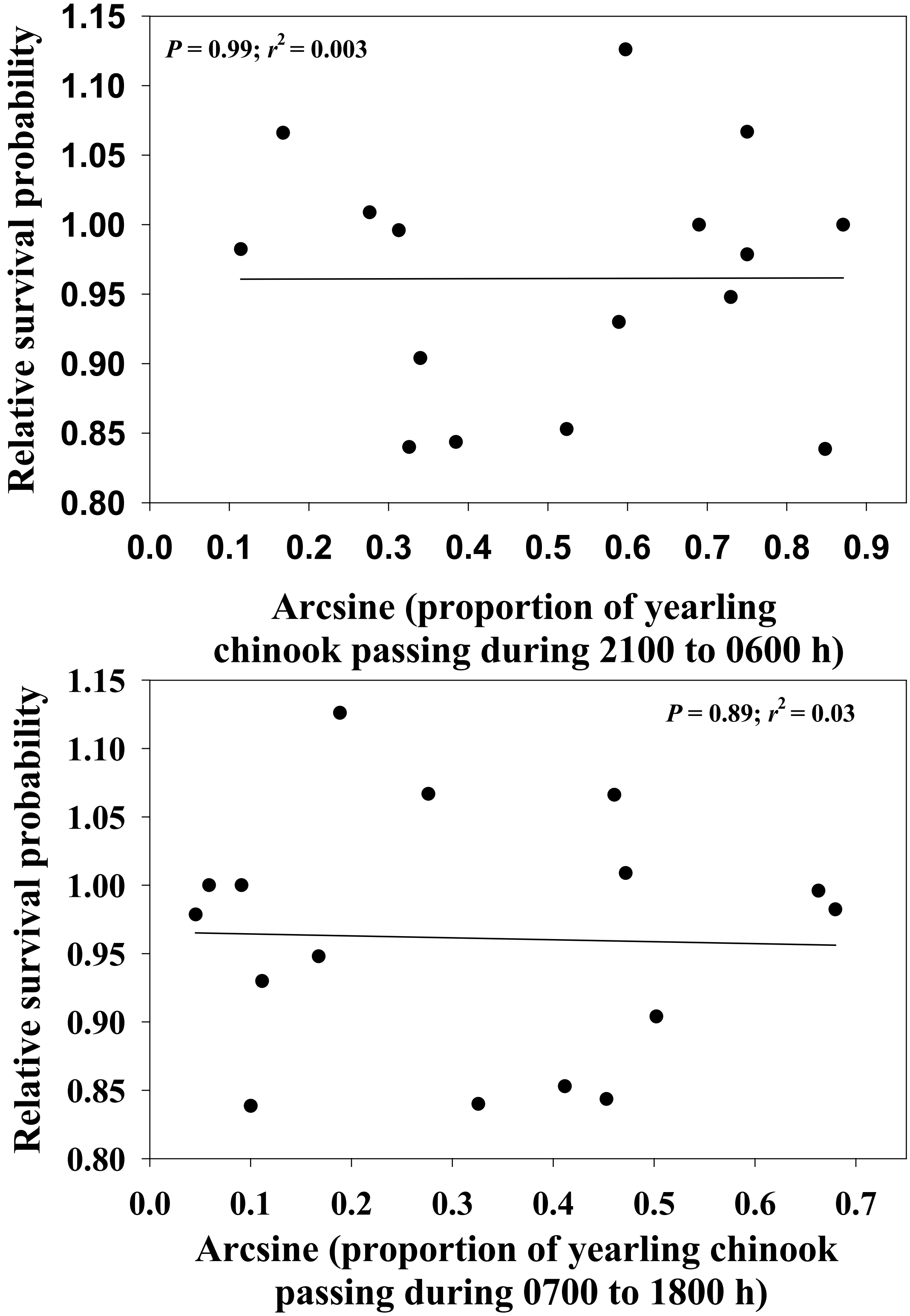


Figure 8. The relation of the arcsine transformed proportion of yearling chinook passing via the John Day Dam spillway during the hours of 2100 to 0600 (approximate nighttime hours) and during the hours of 0700 to 1600 h (approximate hours of the 30% daytime spill condition). The results of the linear regression analysis are presented on each graph.

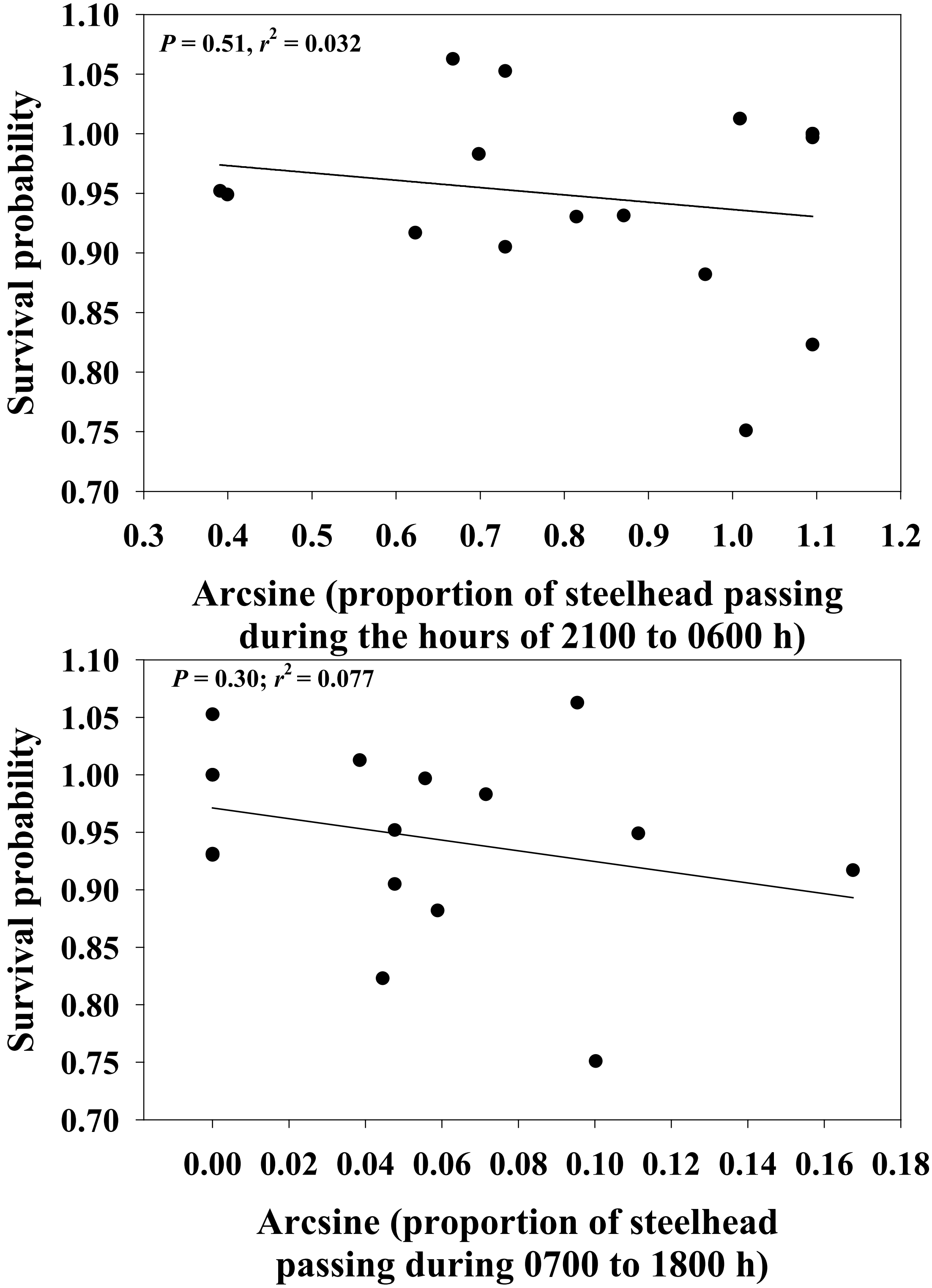


Figure 9. The relation of the arcsine transformed proportion of steelhead trout passing via the John Day Dam spillway during the hours of 2100 to 0600 (approximate nighttime hours) and during the hours of 0700 to 1600 h (approximate hours of the 30% daytime spill condition). The results of the linear regression analysis are presented on each graph.

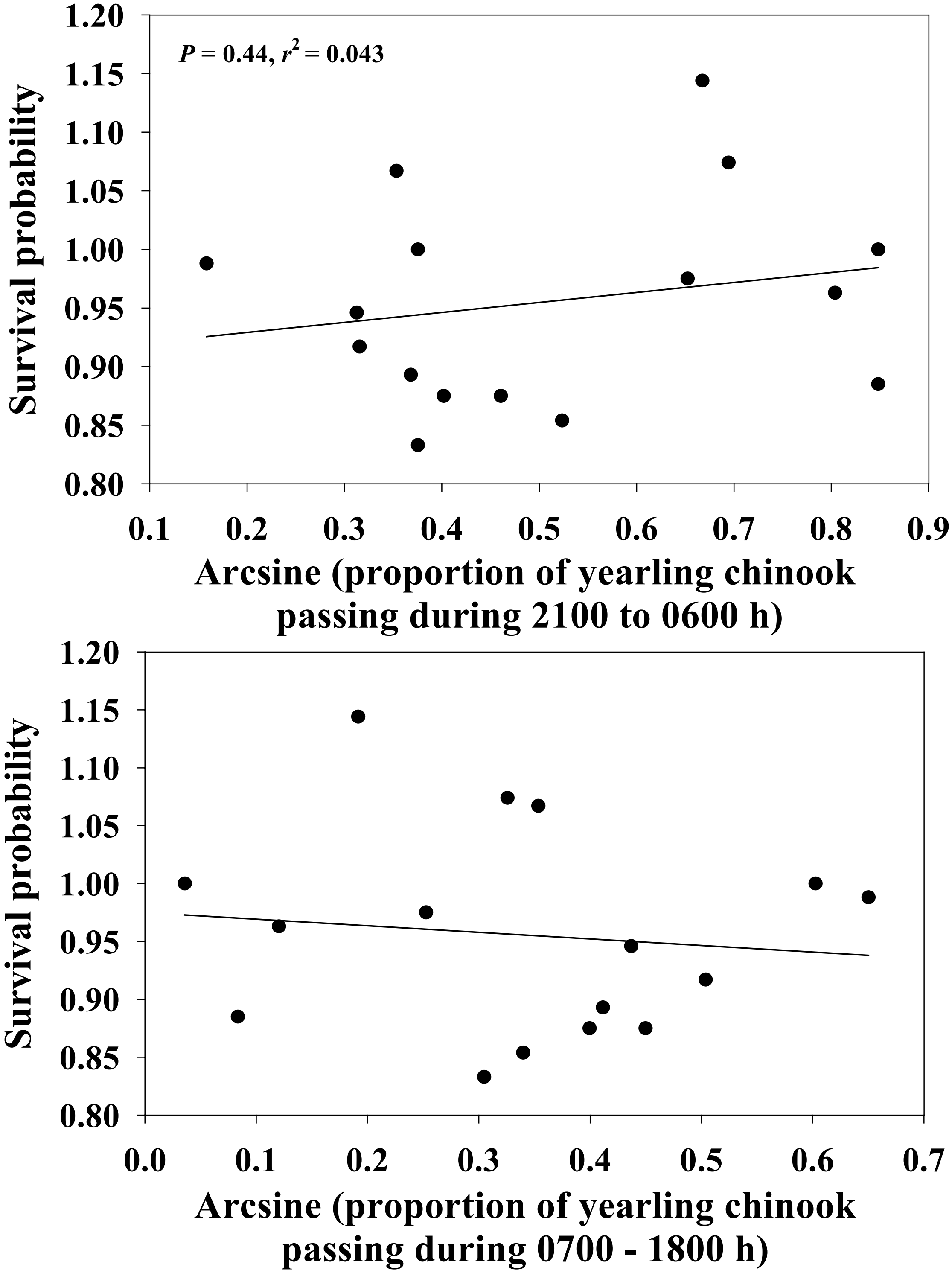


Figure 10. The relation of the arcsine transformed proportion of yearling chinook passing the John Day Dam during the hours of 2100 to 0600 (approximate nighttime hours) and during the hours of 0700 to 1600 h (approximate hours of the 30% daytime spill condition). The results of the linear regression analysis are presented on each graph.

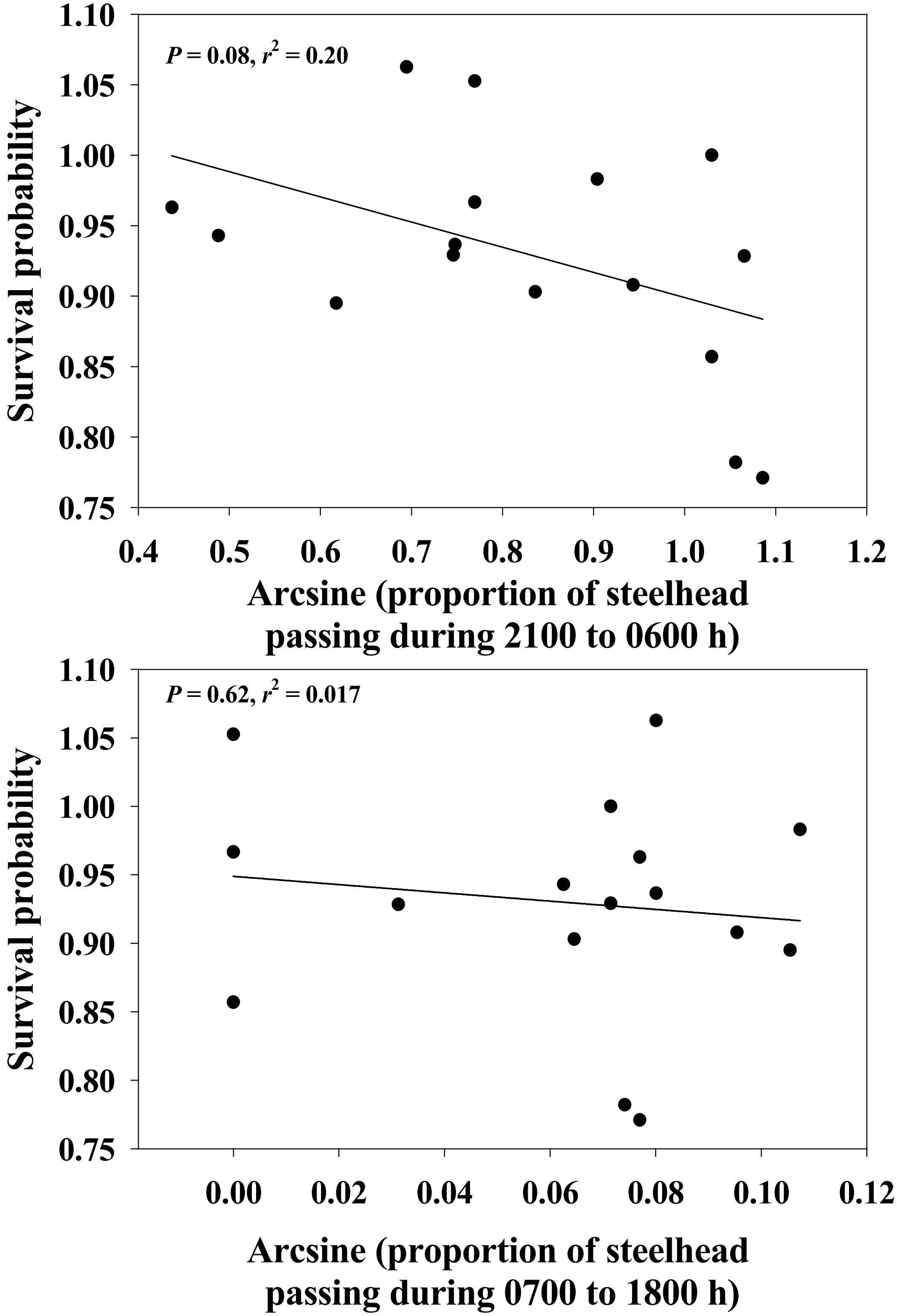


Figure 11. The relation of the arcsine transformed proportion of steelhead passing the John Day Dam during the hours of 2100 to 0600 (approximate nighttime hours) and during the hours of 0700 to 1600 h (approximate hours of the 30% daytime spill condition). The results of the linear regression analysis are presented on each graph.

Table 45. The sample size (n), significance (*P*), and fit (r^2) of simple linear regression models relating survival probabilities estimated from paired releases of radio-tagged yearling chinook and steelhead trout to various environmental parameters at John Day Dam during 2000. Estimates for the environmental parameters are based on average conditions experienced by radio-tagged fish given the time that they passed the dam. Significant relationships at $\alpha = 0.10$ are denoted by [A].

Independent variable in simple linear regression model (i.e., survival probability estimate = $\beta_o + \beta_1 \cdot$ (independent variable))	Species	Passage location	n	P	r^2
total discharge	yearling chinook	spill	15	0.19	0.13
proportion of discharge as spill	yearling chinook	spill	15	0.11	0.19
tail water elevation	yearling chinook	spill	15	0.09[A]	0.21
total discharge	yearling chinook	all passage routes	15	0.46	0.04
proportion of discharge as spill	yearling chinook	all passage routes	15	0.93	<0.01
tail water elevation	yearling chinook	all passage routes	15	0.46	0.04
total discharge during 0/53 spill blocks	yearling chinook	all passage routes	7	<0.01[A]	0.90
total discharge during 30/53 spill blocks	yearling chinook	all passage routes	7	0.43	0.13
proportion of discharge as spill during 0/53 spill blocks	yearling chinook	all passage routes	7	0.12	0.42
proportion of discharge as spill during 30/53 spill blocks	yearling chinook	all passage routes	7	0.03[A]	0.65
fish passage efficiency during 0/53 spill blocks	yearling chinook	all passage routes	7	0.02[A]	0.70
fish passage efficiency 30/53 spill blocks	yearling chinook	all passage routes	7	0.41	0.14
total discharge	Steelhead	spill	15	<0.01[A]	0.50
proportion of discharge as spill	Steelhead	spill	15	0.03[A]	0.32
tail water elevation	Steelhead	spill	15	<0.01[A]	0.53
total discharge	Steelhead	all passage routes	15	0.04[A]	0.30
proportion of discharge as spill	Steelhead	all passage routes	15	0.04[A]	0.28
tail water elevation	Steelhead	all passage routes	15	0.02[A]	0.33

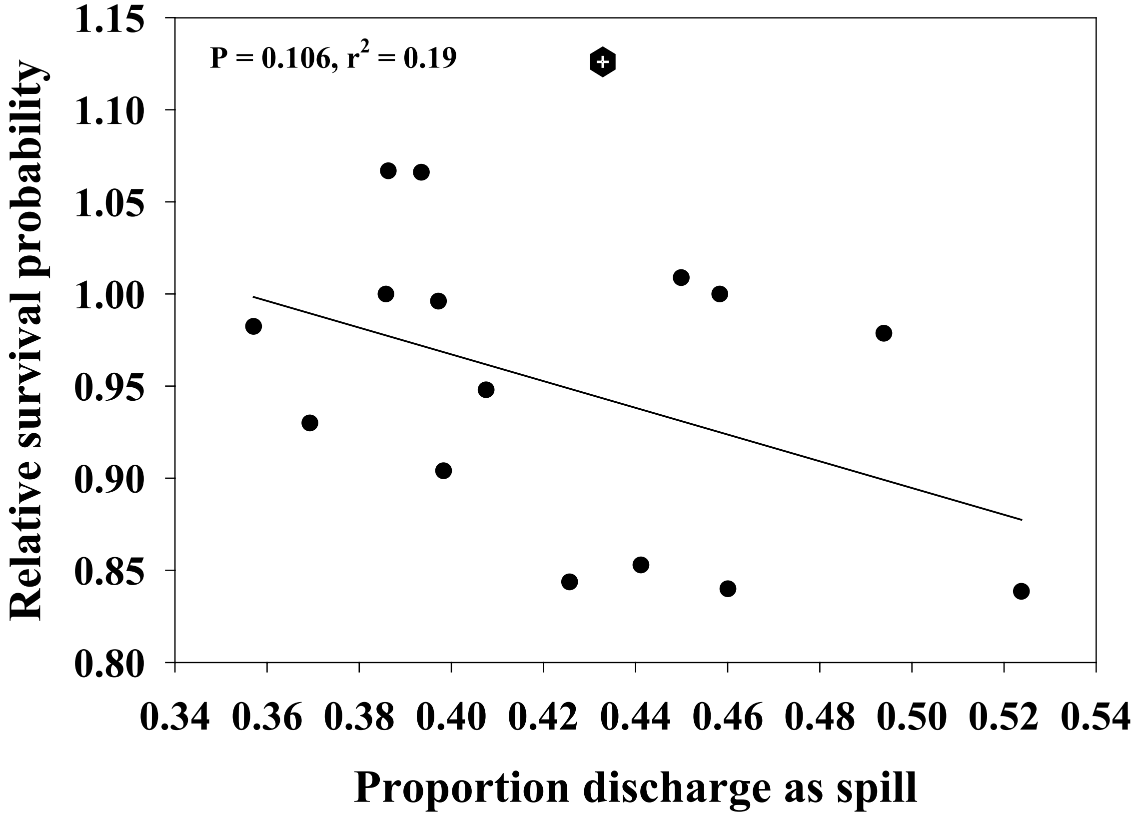


Figure 12. The relation of the percent of discharge as spill through John Day Dam present during passage times of spillway passed yearling chinook salmon during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 6 was designated as an outlier based on regression diagnostics and was deleted. The data for release 6 is represented as a hexagon on the plot.

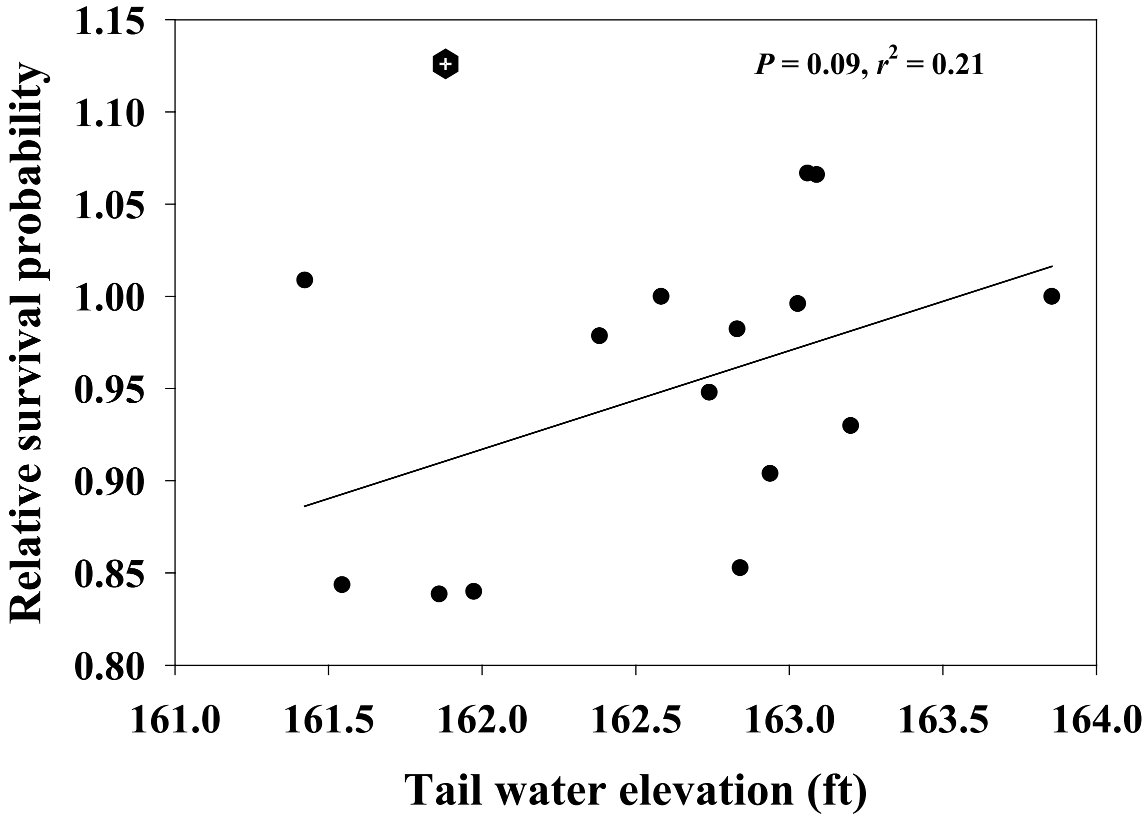


Figure 13. The relation of the tail water elevation (ft) in the tailrace of John Day Dam present during passage times of spillway passed yearling chinook salmon during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 6 was designated as an outlier based on regression diagnostics and was deleted. The data for release 6 is represented as a hexagon on the plot.

P= 0.09). For steelhead trout passing the John Day Dam spillway, the relation of survival to total discharge (Figure 14 , P = 0.003), proportion of discharge as spill (Figure 15, $P = 0.03$), and to tail water elevation (Figure 16, $P = 0.002$) were all found to be significant. The relation of the survival estimates for yearling chinook passing via all routes at John Day Dam to total discharge (Table 45, $P = 0.46$), proportion of discharge as spill (Table 45, $P = 0.93$), and tail water elevation (Table 45, $P = 0.46$) were not significant. Similar to the results for spillway passed steelhead, the relation of the survival of steelhead trout passing via all routes at John Day Dam to total discharge (Figure 17, $P = 0.035$), proportion of discharge as spill (Table 45, $P = 0.04$), and tail water elevation (Table 45, $P = 0.025$).

We also examined the correlations between total discharge, the proportion of discharge as spill, and tail water elevation present during passage of yearling chinook and steelhead passage and found that these variables were highly correlated with one another. For the conditions experienced by yearling chinook passing via the John Day Dam spillway, the proportion of discharge as spill was significantly negatively correlated with total discharge ($r = -0.64$, $P = 0.011$) and tail water elevation ($r = -0.66$, $P = 0.008$) and total discharge was positively correlated with tail water elevation ($r = -0.96$, $P < 0.001$). Similar results were obtained for the steelhead data where the proportion of discharge as spill was significantly negatively correlated with total discharge ($r = -0.85$, $P < 0.001$) and tail water elevation ($r = -0.79$, $P = 0.004$) and total discharge was positively correlated with tail water elevation ($r = -0.98$, $P < 0.001$). For the conditions experienced by yearling chinook passing via all routes at John Day Dam, the proportion of discharge as spill was significantly negatively correlated with total discharge ($r = -0.64$, $P = 0.01$) and tail water elevation ($r = -0.72$, $P = 0.002$) and total discharge was positively correlated with tail water elevation ($r = -0.94$, $P < 0.001$). The proportion of discharge as spill was significantly negatively correlated with total discharge ($r = -0.81$, $P = 0.0003$) and tail water elevation ($r = -0.76$, $P = 0.0009$) and total discharge was positively correlated with tail water elevation ($r = -0.97$, $P < 0.001$) for the conditions experienced by steelhead passing via all routes at John Day Dam.

Based on the exploratory analysis above, we then decided to examine the differences in these environmental variables that may have existed between the two spill conditions. We computed the average of these variables for the two test conditions based on the conditions experienced by the yearling chinook and steelhead released as part of the evaluation (Table 46) and also based on the entire set of conditions present during the spill blocks evaluated during 2000. In general, the total discharge was higher for fish passed during the 0% day/53% night spill condition than the 30% day/53% night spill condition. However, the differences between the two test conditions were higher for steelhead than for yearling chinook. The proportion of discharge as spill was higher during the 30% day/53% night spill condition than the 0% day/53% night spill condition in all cases except that for the spill passed yearling chinook (Table 46). Overall, the differences in the tail water elevation appeared to be minimal between the two test conditions. For the entire set of hourly environmental conditions present during the study, total discharge was higher during the 0% day/53% night spill condition during the night spill (0 = 285.4 $ft^3 \cdot s^{-1} \cdot 1000$, SE = 2.76 $ft^3 \cdot s^{-1} \cdot 1000$) than during the 30% day/53% night spill condition during the night spill (0 = 265.2 $ft^3 \cdot s^{-1} \cdot 1000$, SE = 2.49 $ft^3 \cdot s^{-1} \cdot 1000$). The total discharge during the 30% day/53% night spill condition during the day spill (0 = 272.5 $ft^3 \cdot s^{-1} \cdot 1000$, SE =

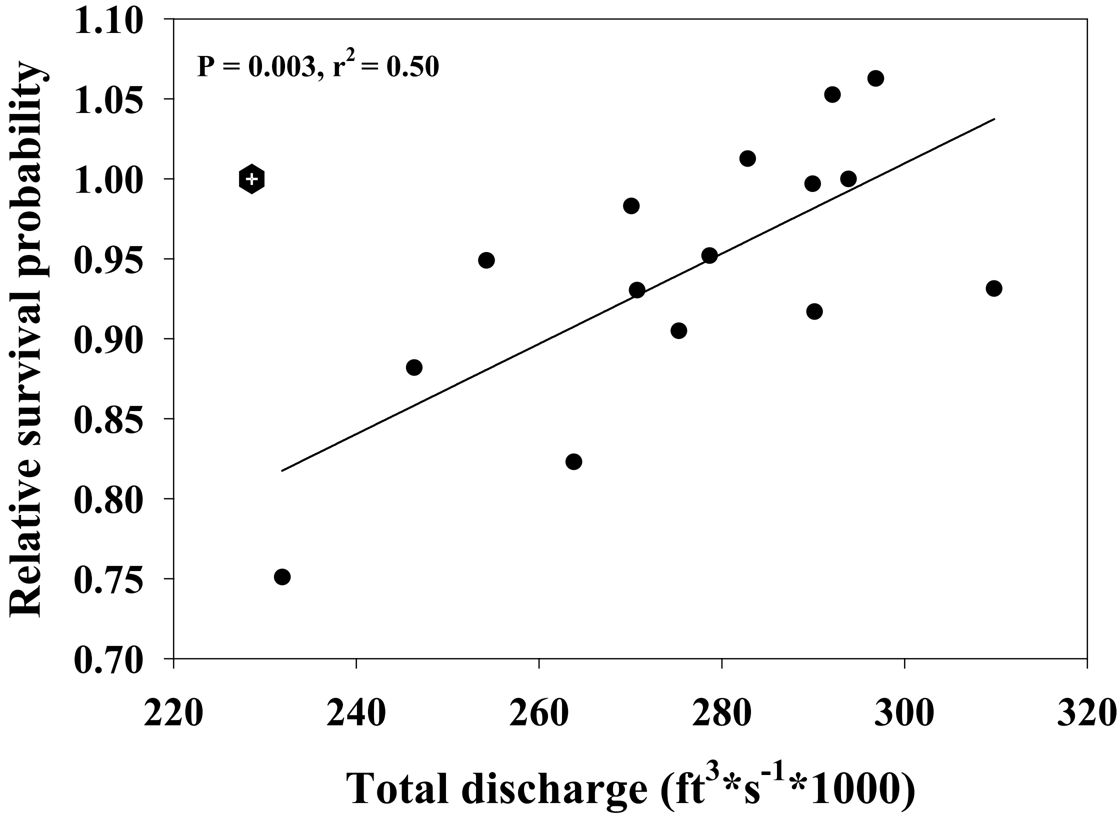


Figure 14. The relation of the total discharge ($ft^3*s^{-1}*1000$) through John Day Dam present during passage times of spillway passed steelhead trout during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 10 was designated as an outlier based on regression diagnostics and was deleted. The data for release 10 is represented as a hexagon on the plot.

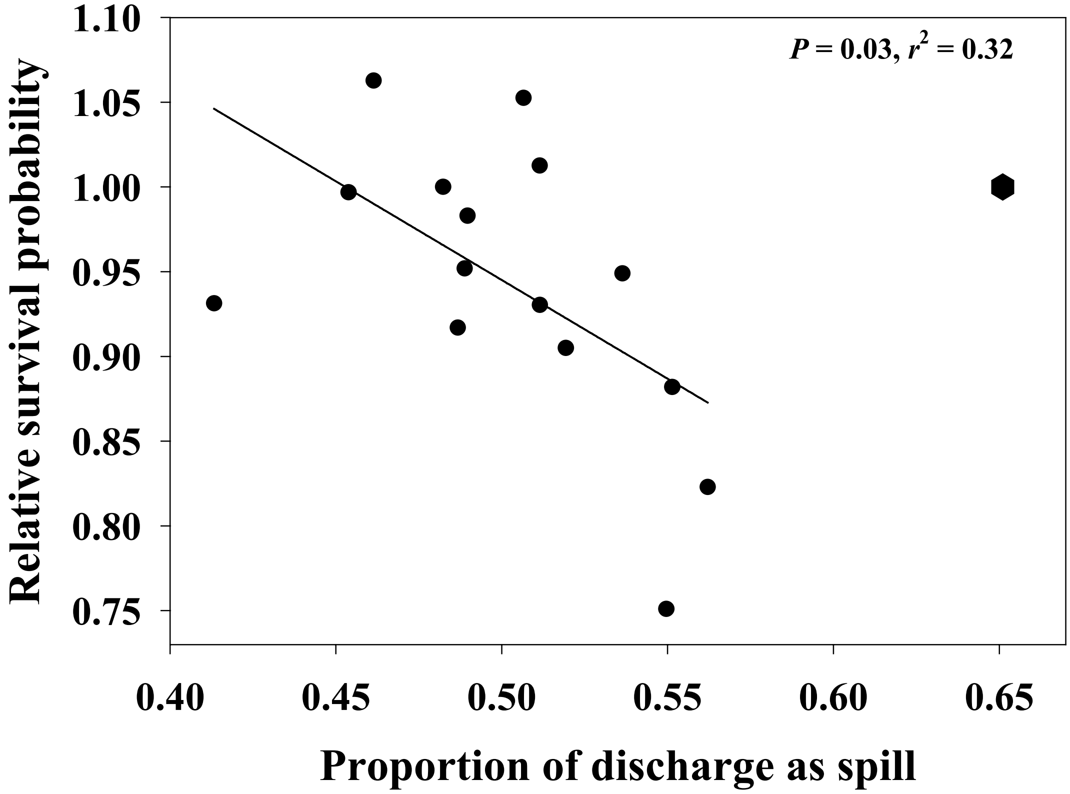


Figure 15. The relation of the percent of total discharge as spill through John Day Dam present during passage times of spillway passed steelhead trout during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 10 was designated as an outlier based on regression diagnostics and was deleted. The data for release 10 is represented as a hexagon on the plot.

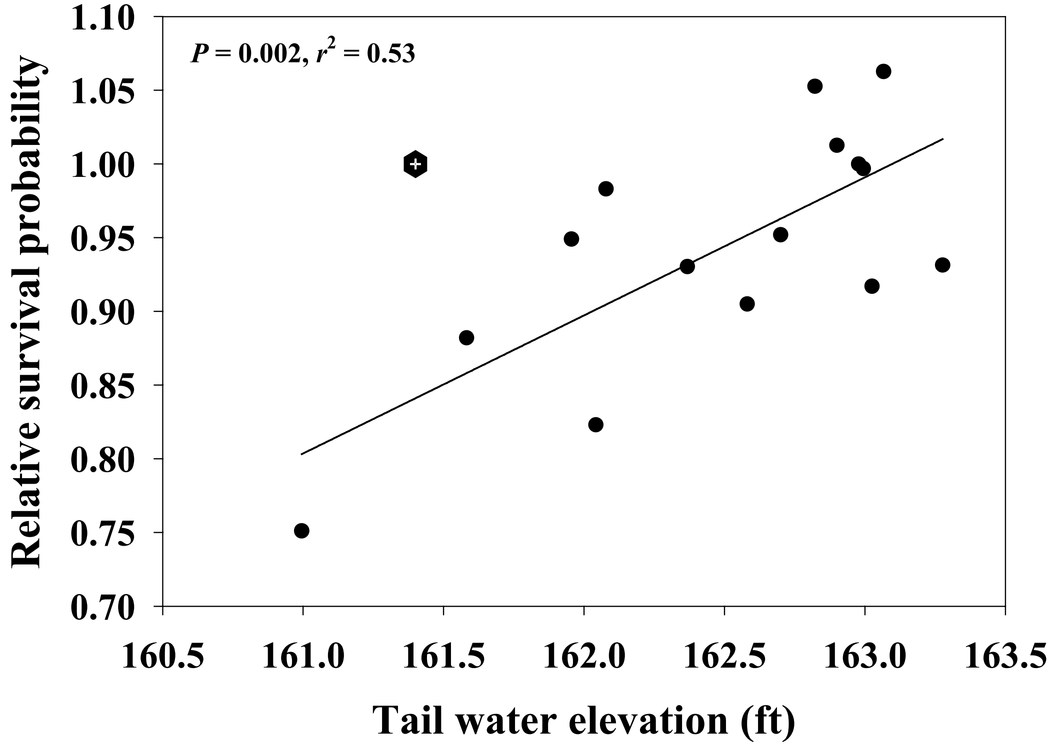


Figure 16. The relation of the tail water elevation in the tailrace of John Day Dam present during passage times of spillway passed steelhead trout during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 10 was designated as an outlier based on regression diagnostics and was deleted. The data for release 10 is represented as a hexagon on the plot.

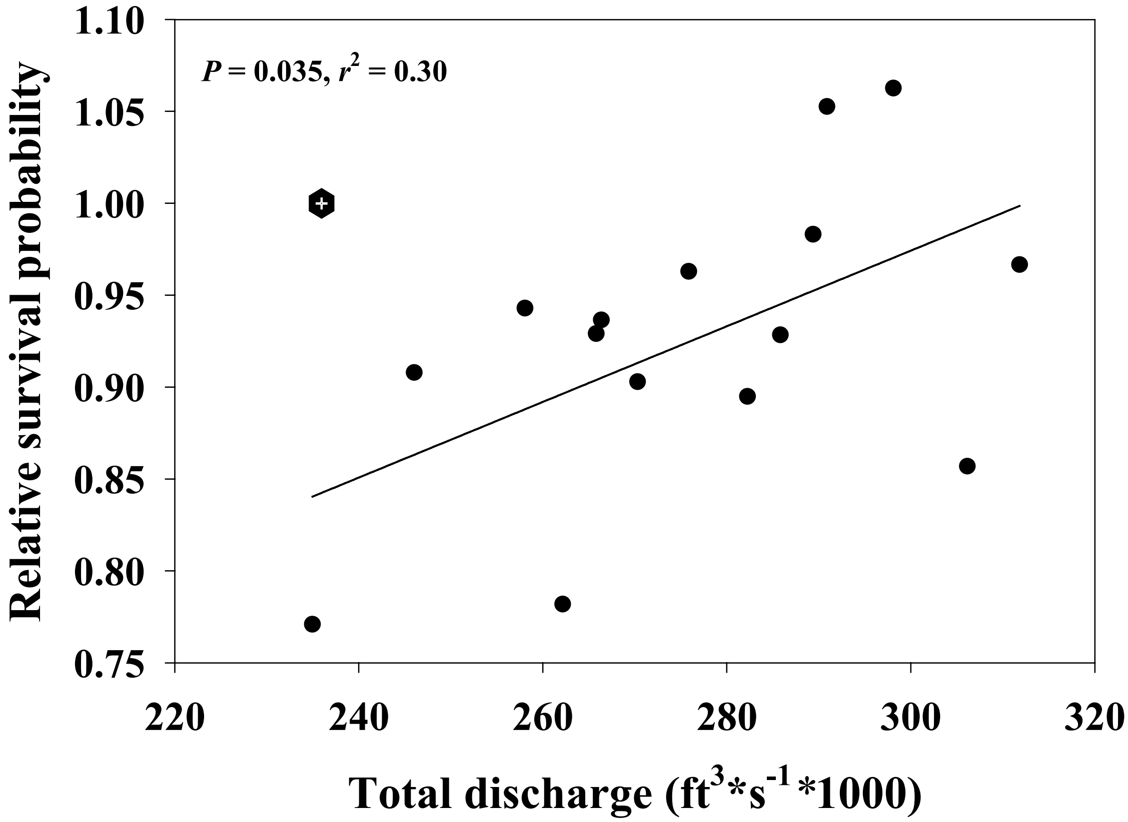


Figure 17. The relation of the total discharge ($ft^3 * s^{-1} * 1000$) through John Day Dam present during passage times of steelhead trout passing via all routes at John Day Dam during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 10 was designated as an outlier based on regression diagnostics and was deleted. The data for release 10 is represented as a hexagon on the plot.

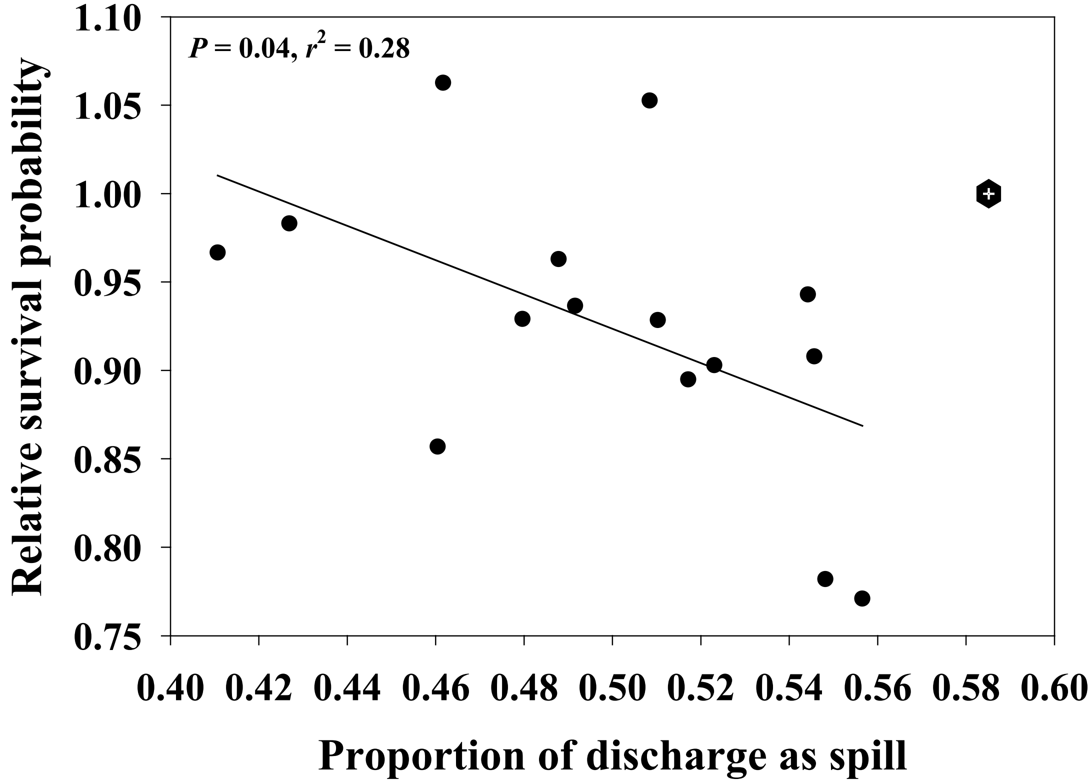


Figure 18. The relation of the proportion of the total discharge as spill through John Day Dam present during passage times of steelhead trout passing via all routes at John Day Dam during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 10 was designated as an outlier based on regression diagnostics and was deleted. The data for release 10 is represented as a hexagon on the plot.

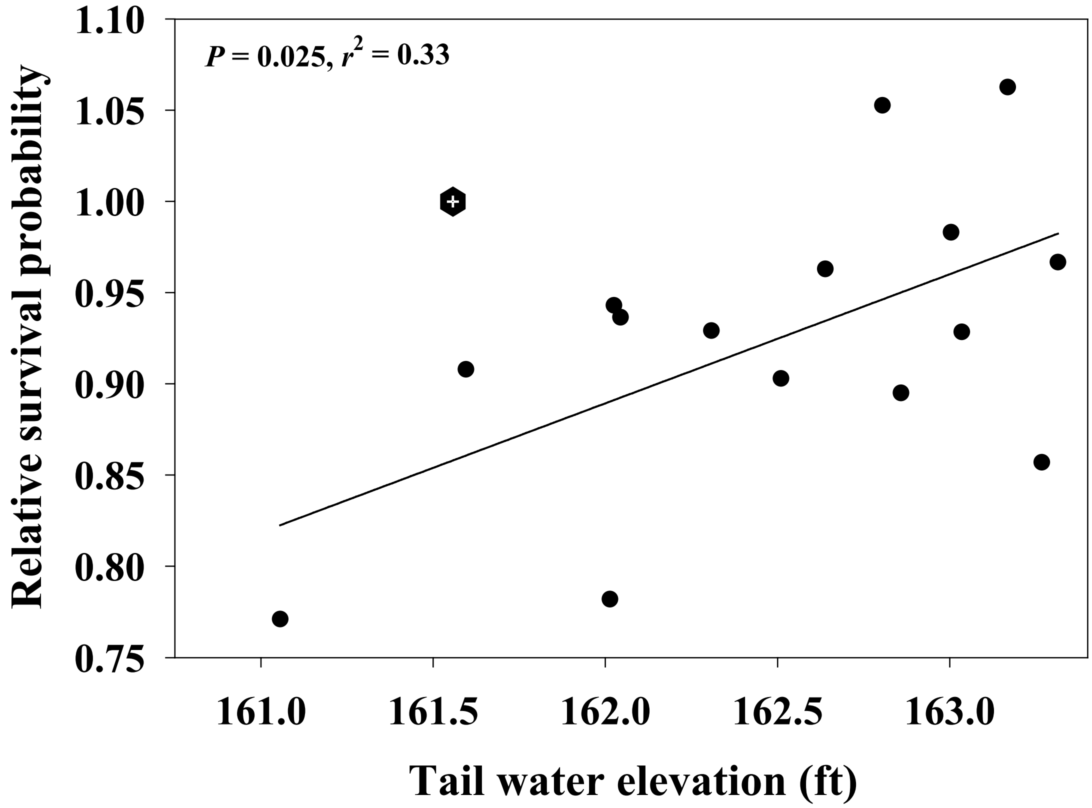


Figure 19. The relation of the tail water elevation in the tailrace of John Day Dam present during passage times steelhead trout passing via all routes at John Day Dam during each of 15 paired releases and the relative survival probabilities for each release during 2000. Release 10 was designated as an outlier based on regression diagnostics and was deleted. Release 10 is represented as a hexagon on the plot. Results of the linear regression are listed on the plot.

Table 46. Summary of the average total discharge ($ft^3*s^{-1}*1000$), proportion of discharge as spill, and tail water elevation (ft) present during the passage time of spillway passed yearling chinook salmon and steelhead trout and yearling chinook and steelhead passing all routes at John Day Dam during 0% day/53% night and 30% day/53% night spill conditions. Standard errors are in parentheses.

		Yearling chinook		Steelhead	
Variable	Test condition	Spillway	Total project	Spillway	Total project
Total discharge	0/53	277.0 (2.98)	276.3 (2.46)	282.2 (3.06)	283.2 (2.60)
	30/53	273.4 (2.28)	273.8 (2.08)	266.4 (2.20)	265.3 (1.85)
Proportion of discharge as spill	0/53	0.44 (0.016)	0.39 (0.016)	0.50 (0.011)	0.48 (0.01)
	30/53	0.41 (0.009)	0.42 (0.008)	0.53 (0.007)	0.53 (0.006)
Tail water elevation	0/53	162.6 (0.08)	162.7 (0.07)	162.7 (0.08)	162.7 (0.07)
	30/53	162.5 (0.07)	162.5 (0.06)	162.2 (0.07)	162.2 (0.06)

2.81 $ft^3 \cdot s^{-1} \cdot 1000$) was intermediate between the two night spill conditions. The proportion of total discharge as spill was lower during the 0% day/53% night spill condition during the night spill (0 = 0.49, SE = 0.008) than during the 30% day/53% night spill condition during the night spill (0 = 0.54, SE = 0.006). The proportion of total discharge as spill was lowest for the 30% day/53% night spill condition during the day spill (0 = 0.30, SE = 0.007) was intermediate between the two night spill conditions. The tail water elevation was lowest during the 30% day/53% night spill condition during the night spill (0 = 162.2 ft, SE = 0.07 ft) and similar between the 0% day/53% night spill condition during the night spill (0 = 162.7 ft, SE = 0.08 ft) and the 30% day/53% night spill condition during the day spill (0 = 162.7 ft, SE = 0.07 ft).

When the hourly observations during the hours of nighttime spill (1900 to 0600 h) for the 0% day/53% night and 30% day/53% night spill condition were evaluated, the relations between total discharge and proportion of total discharge as spill were similar to those observed for the conditions experienced during passage of steelhead and yearling chinook during the spring survival evaluation (Figures 20 and 21). That is, there was strong negative correlation between total discharge and the proportion of discharge as spill. Conversely, the relation of total discharge and spill proportion for the day spill during the 30% day/53% night spill condition during the hours of 0700 to 1800 h did not exhibit the strong negative correlation or the variability in spill levels compared to the night spill conditions. However, the relation between total discharge and tail water elevation in the John Day Dam tailrace exhibited strong positive correlations between the two variables similar to that observed for the conditions experienced by the steelhead trout and yearling chinook salmon in the survival evaluation for all spill conditions (Figure 21).

Few of the relations between total discharge, proportion of total discharge as spill, tail water elevation and the survival of yearling chinook passing via all routes at John Day Dam, and to a lesser extent spill passed fish, were significant. Given that we had knowledge from other studies done during 2000 at John Day Dam that suggested there were behavioral differences between yearling chinook and steelhead with regards to their passage timing, we further explored the possibility that the relationships observed for steelhead were being obscured by these behavioral differences. For instance, Beeman et al (2001a) found that regardless of the spill treatment block or condition (e.g., 30% day spill), that few steelhead passed during the day. As such, the relationships developed for steelhead likely represent the relation between the variables examined and conditions present primarily during the night spill condition, whereas the survival estimates for yearling chinook included values that represented conditions present during day spill. We hypothesized that since few yearling chinook passed during the day during the 0% day spill condition , that the relationships observed for steelhead may be present for yearling chinook passing during the 0% day/53% night spill blocks. Thus, we regressed the survival estimates for yearling chinook passing via all routes at John Day Dam against total discharge and the proportion of discharge as spill for each spill treatment. As with the previous analyses regression diagnostics were used to identify potential outliers.

The relation of total discharge and the survival of yearling chinook passing via all routes during the 0% day/53% night condition, proved to be highly significant (P = 0.001, r^2 = 0.90). However the variables were negatively correlated, the opposite of what we observed for steelhead (Figure 22). Conversely, the relation of the survival of chinook passing during the 30% day/53% night spill condition to total discharge was not found to be significant (Figure 22, P = 0.43, r^2 = 0.13). When we evaluated the relation of the survival of yearling chinook salmon and the proportion of discharge as spill, we found that the relation of the proportion of discharge as spill to survival for fish passed during the 0% day/53% spill condition was marginally insignificant (Figure 23, P = 0.12, r^2 = 0.42) but for fish passed during the 30% day/53% spill condition the relation was significant (Figure 23, P = 0.03, r^2 = 0.65). The relationships between survival and the proportion of discharge as spill showed conflicting trends, with the relation for the 0% day/53% night spill condition indicating a potential positive relationship but for the 30% day/53% spill condition the variables were negatively correlated.

Given the negative correlation with total discharge and the marginally insignificant result for the relation with the proportion of discharge as spill for fish passed during the 0% day/53% night spill condition, we then calculated the fish passage efficiency (FPE, proportion of fish passing via all non-turbine routes) for each release and evaluated its relation with survival to examine the hypothesis that more yearling chinook were being passed through the powerhouse resulting in lower survival during periods of lower spill percentages (since both spill percent and survival was negatively correlated with total discharge). The relation of the survival to fish passage efficiency (Figure 24) was found to be highly significant (P = 0.020, r^2 = 0.62) for fish passing during the 0% day/53% night spill condition and not significant for fish passing during the 30% day/53% night spill condition (P = 0.41, r^2 = 0.14). We further examined the relation between FPE for yearling chinook release groups to the proportion of discharge as spill during each of the spill treatments. We found that FPE was significantly related to the proportion of discharge as spill for the 0% day/53% night spill condition (Figure 25, P = 0.08, , r^2 = 0.50) but that the relationship was not significant for the 30% day/53% night spill condition (Figure 25, P = 0.47, r^2 = 0.11). We also evaluated the relation of FPE to the survival of steelhead trout passing via all routes at John Day Dam. We found that there was no significant relation between the FPE and survival for either spill condition (Figure 26, P > 0.10). We also found that FPE was not related to the proportion of discharge as spill for the 0% day/ 53% night spill condition (Figure 27, P = 0.46, r2 = 0.09) but was significantly related to the proportion of discharge as spill during the 30% day/53% night spill condition (Figure 27).

We also used the Cormack-Jolly-Seber model to evaluate the survival of yearling chinook (Table 47) and steelhead (Table 48) from near Rock Creek, WA to John Day Dam. The average survival of yearling chinook from their release point near Rock Creek, WA and John Day Dam was 0.975 (SE = 0.008) and for steelhead was 0.95 (SE = 0.013). We evaluated linear regressions to examine the relation of survival from Rock Creek to John Day Dam. Of primary interest were the potential effects of increased residence time

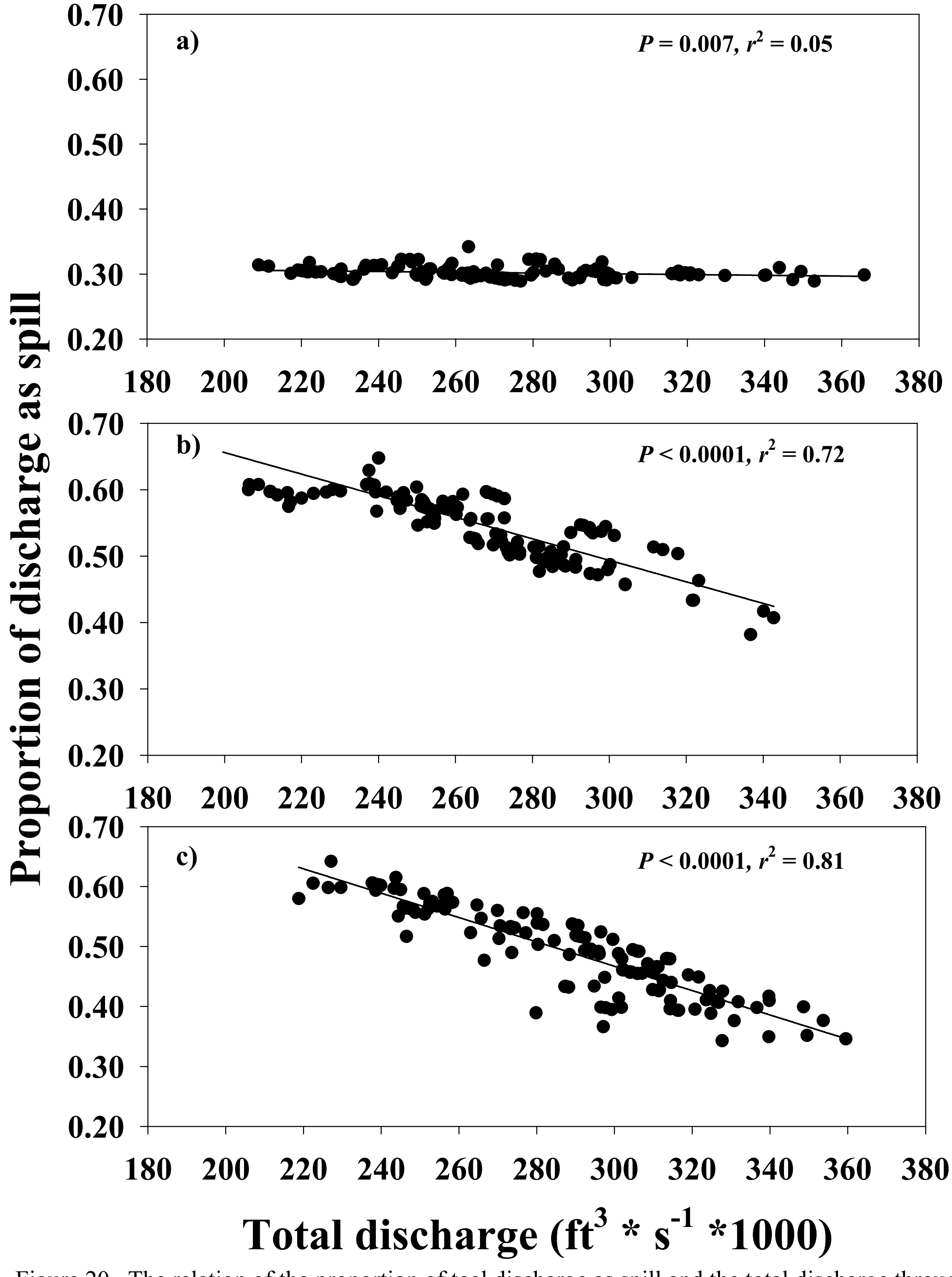


Figure 20. The relation of the proportion of toal discharge as spill and the total discharge through John Day Dam proportion of discharge as spill at John Day Dam for the a) 30% day/53% night spill condition during the hours of 0700 to 1800 h, b) 30%/53 % spill condition during the hours of 1900 to 0600 and c) 0%/53 % spill condition during the hours of 1900 to 0600 h.

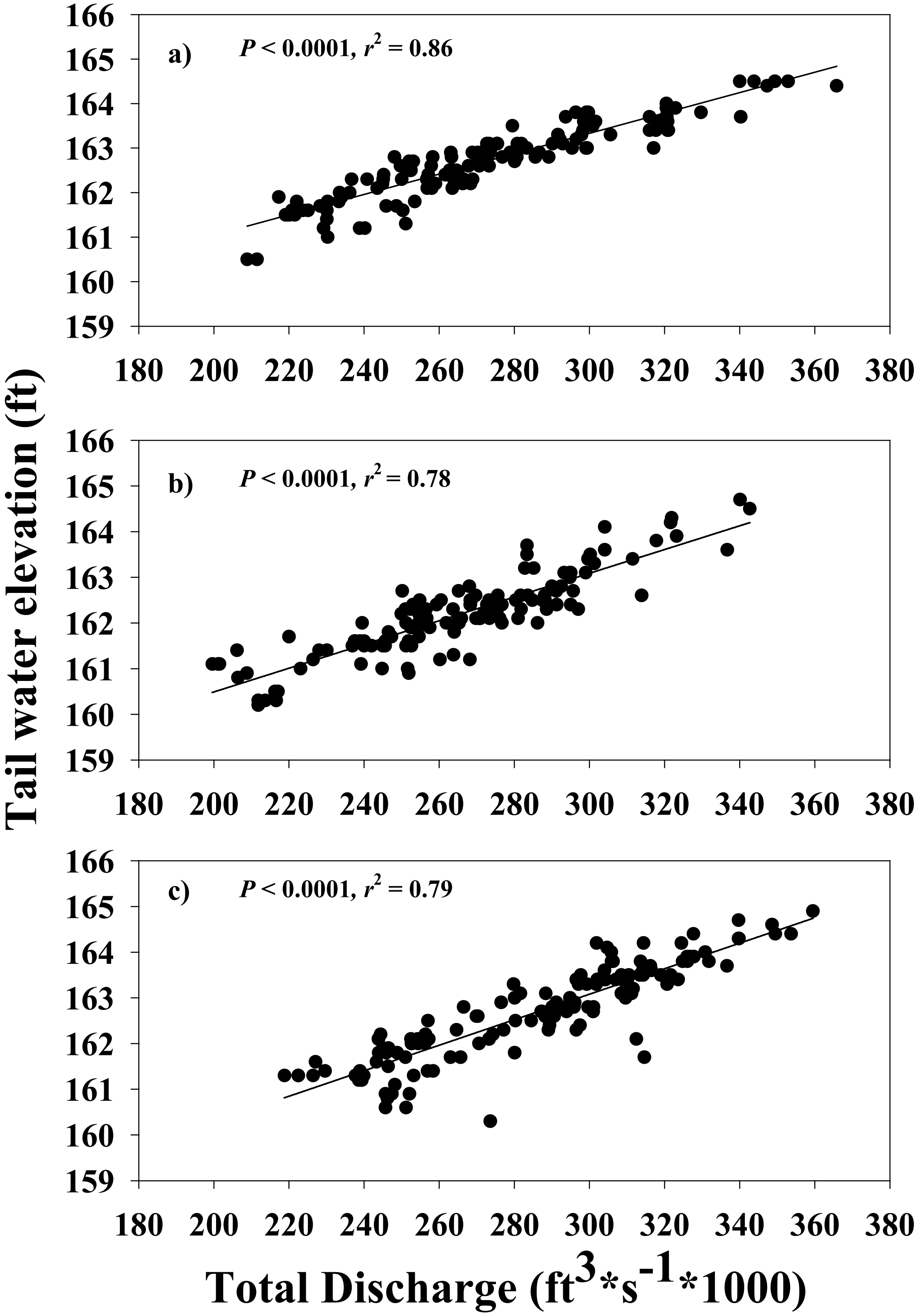
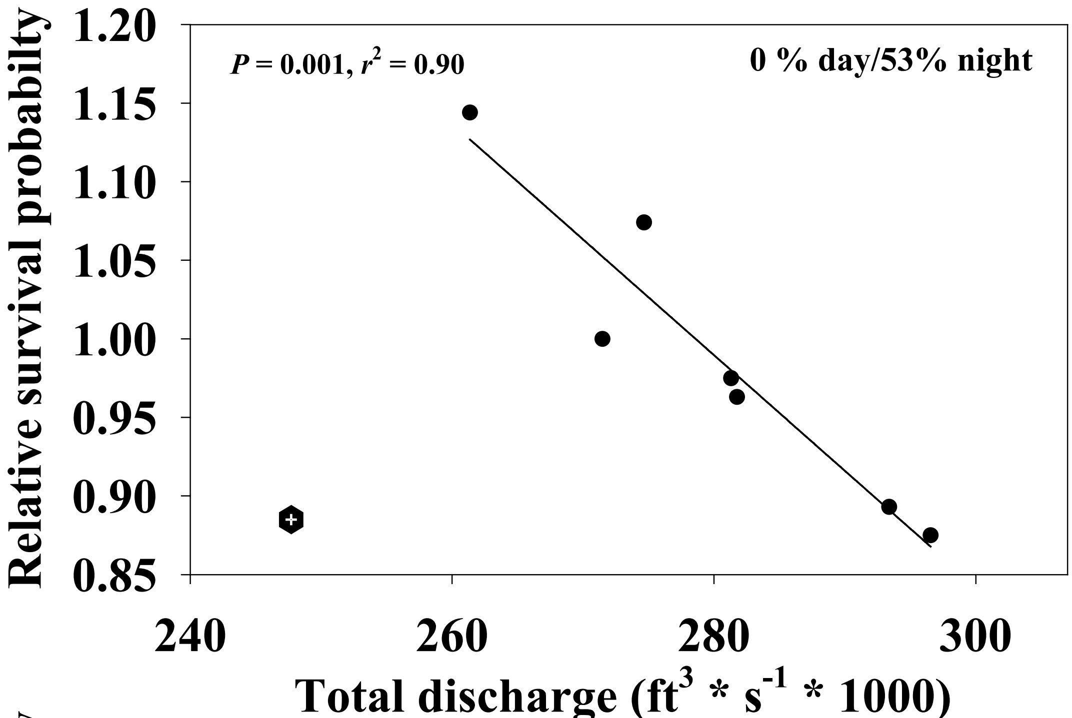


Figure 21. The relation of the tail water elevation in the John Day Dam tailrace and the total discharge at John Day Dam for all hourly observations for the a) 30% day/53% night spill condition during the hours of 0700 to 1800 h, b) 30%/53 % spill condition during the hours of 1900 to 0600 and c) 0%/53 % spill condition during the hours of 1900 to 0600 h during the 2000 spring survival evaluation at John Day Dam.



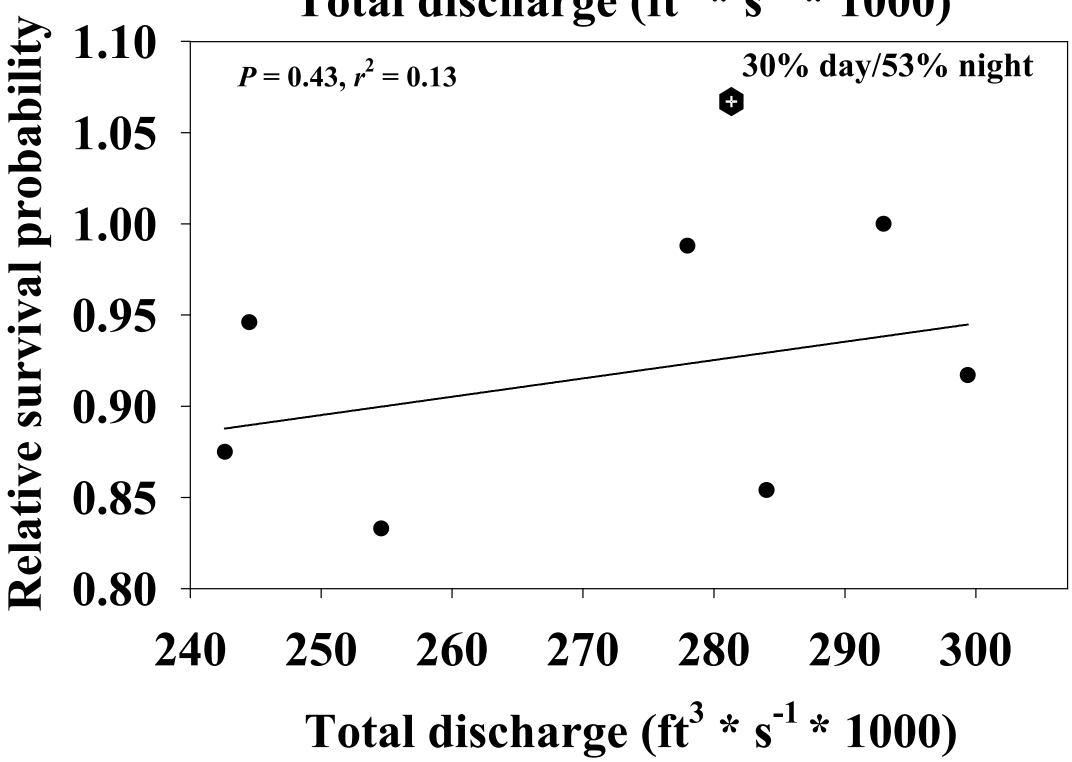


Figure 22. The relation of the relative survival of yearling chinook salmon passing via all routes at John Day Dam during each of 0% day/53% night and 30% day/53% night spill conditions and total discharge ($ft^3*s^{-1}*1000$). Release 10 was identified as an outlying observation during the 0/53 spill condition and release 4 was identified as an outlying observation for the 30/53 spill condition. These observations were not included in the analyses and are represented on the graphs as hexagons.

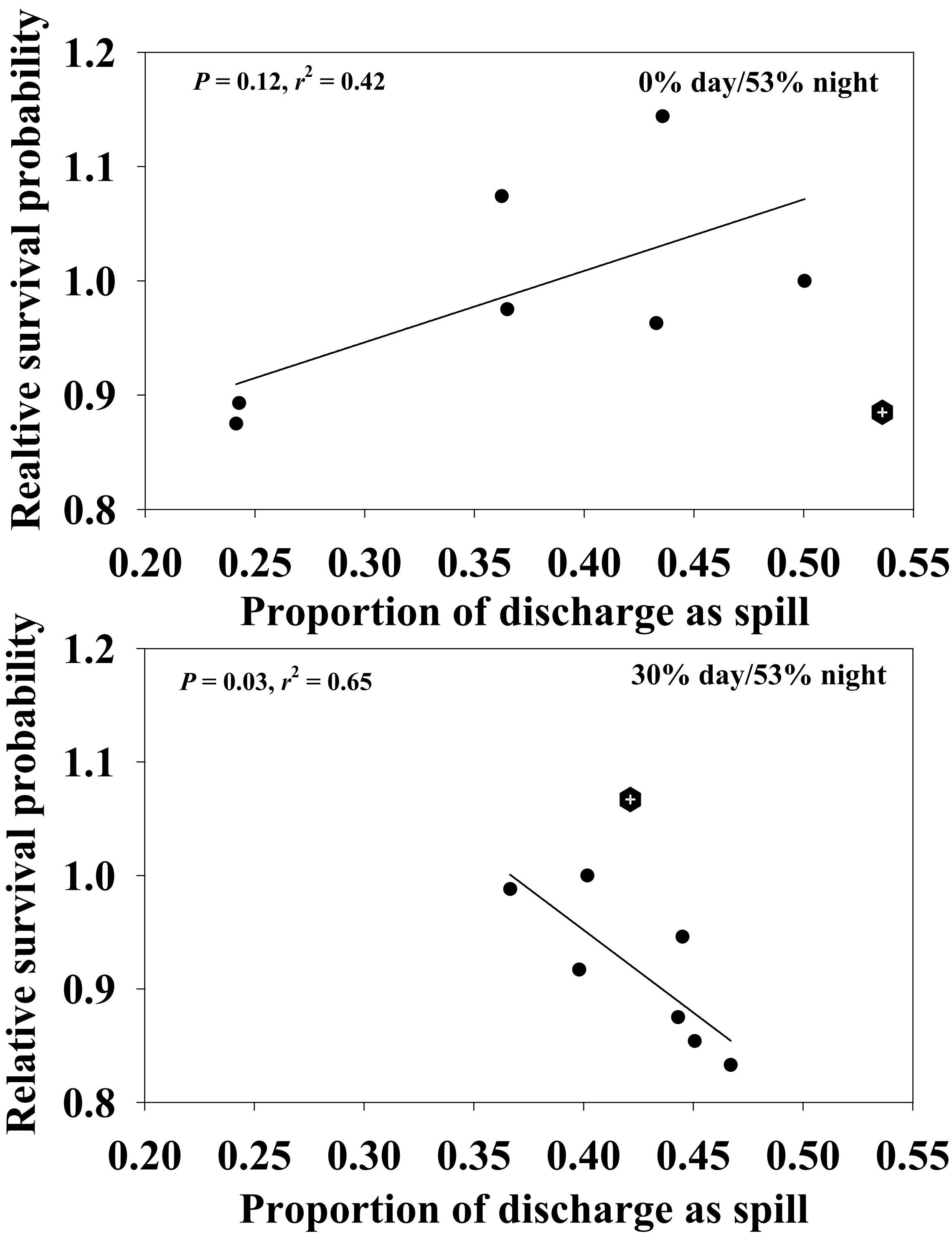


Figure 23. The relation of the relative survival of yearling chinook salmon passing all routes at John Day Dam during each of 0% day/53% night and 30% day/53% night spill conditions and the proportion of discharge as spill. Release 10 was identified as an outlying observation during the 0/53 spill condition and release 4 was identified as an outlying observation for the 30/53 spill condition. These observations were not included in the analyses and are represented on the graphs as hexagons.

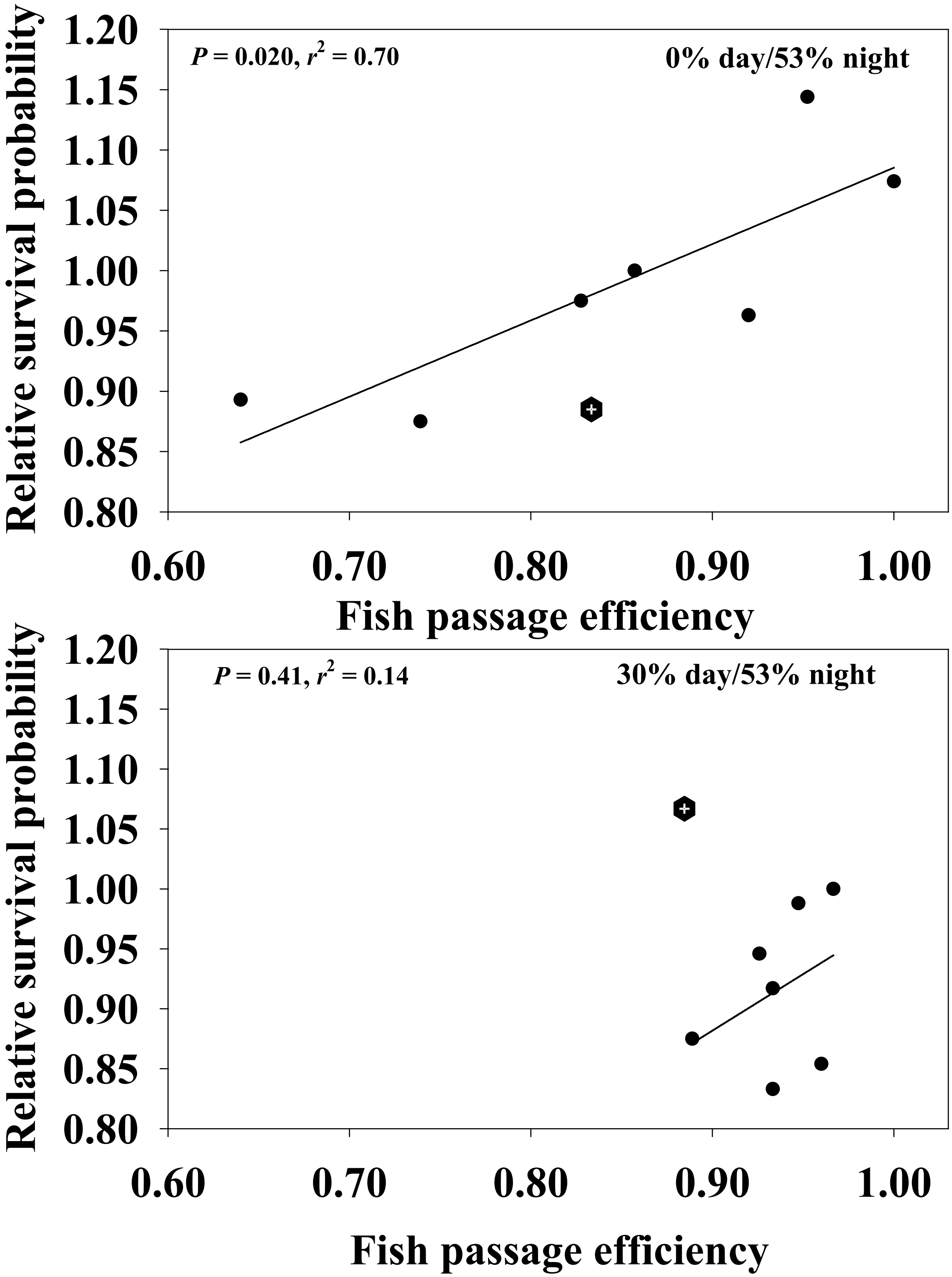


Figure 24. The relation of the relative survival of yearling chinook salmon passing via all routes at John Day Dam during each of 0% day/53% night and 30% day/53% night spill conditions and fish passage efficency. Release 10 and release 4 were not included in the analyses and are represented on the graphs as an hexagon.

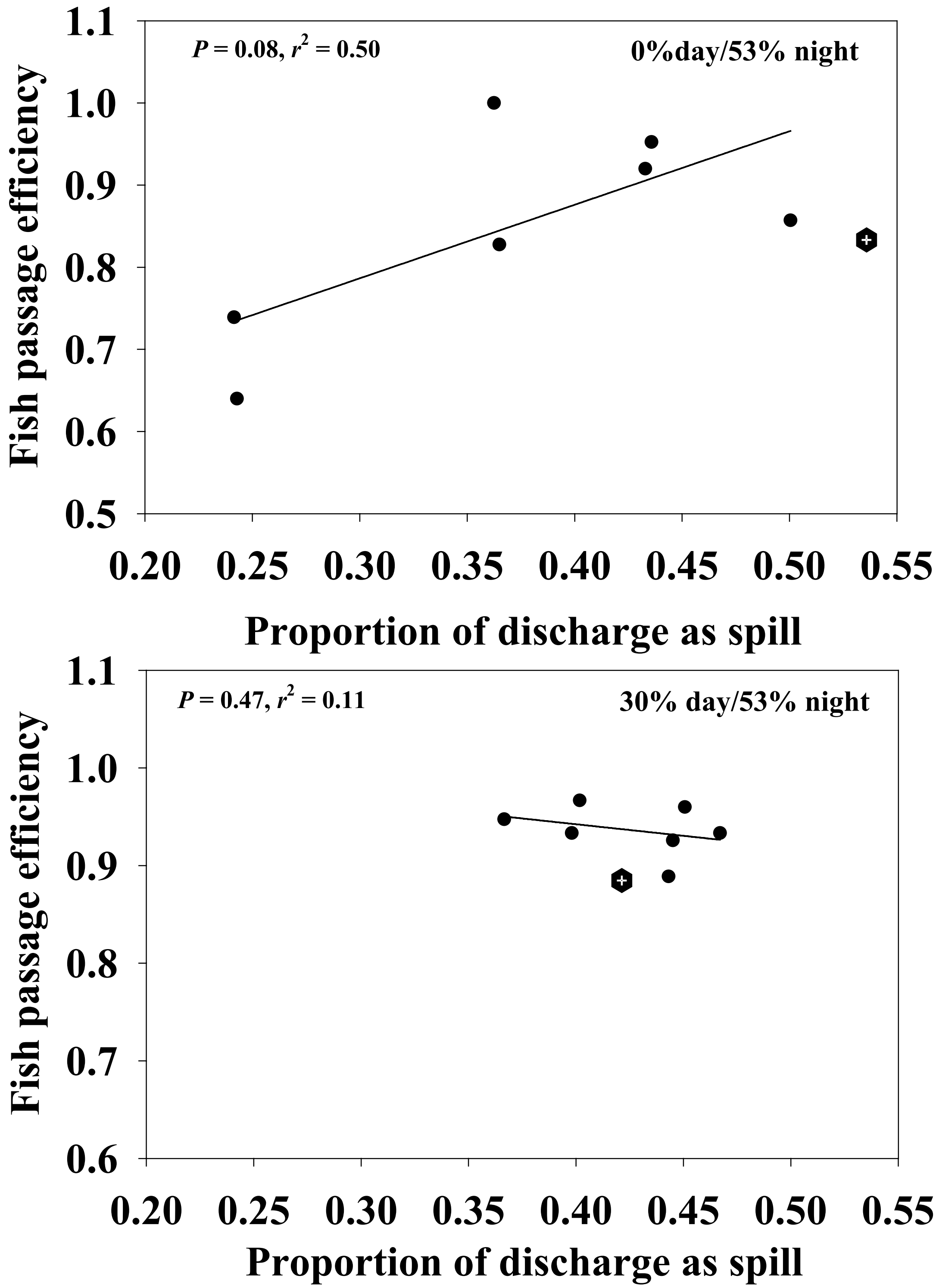


Figure 25. The relation of fish passage efficiency to the proportion of discharge as spill for conditions experienced by yearling chinook salmon passing via all routes at John Day Dam during each of 0% day/53% night and 30% day/53% night spill conditions and fish passage efficiency. Release 10 and release 4 were not included in the analyses and are represented on the graphs as hexagons.

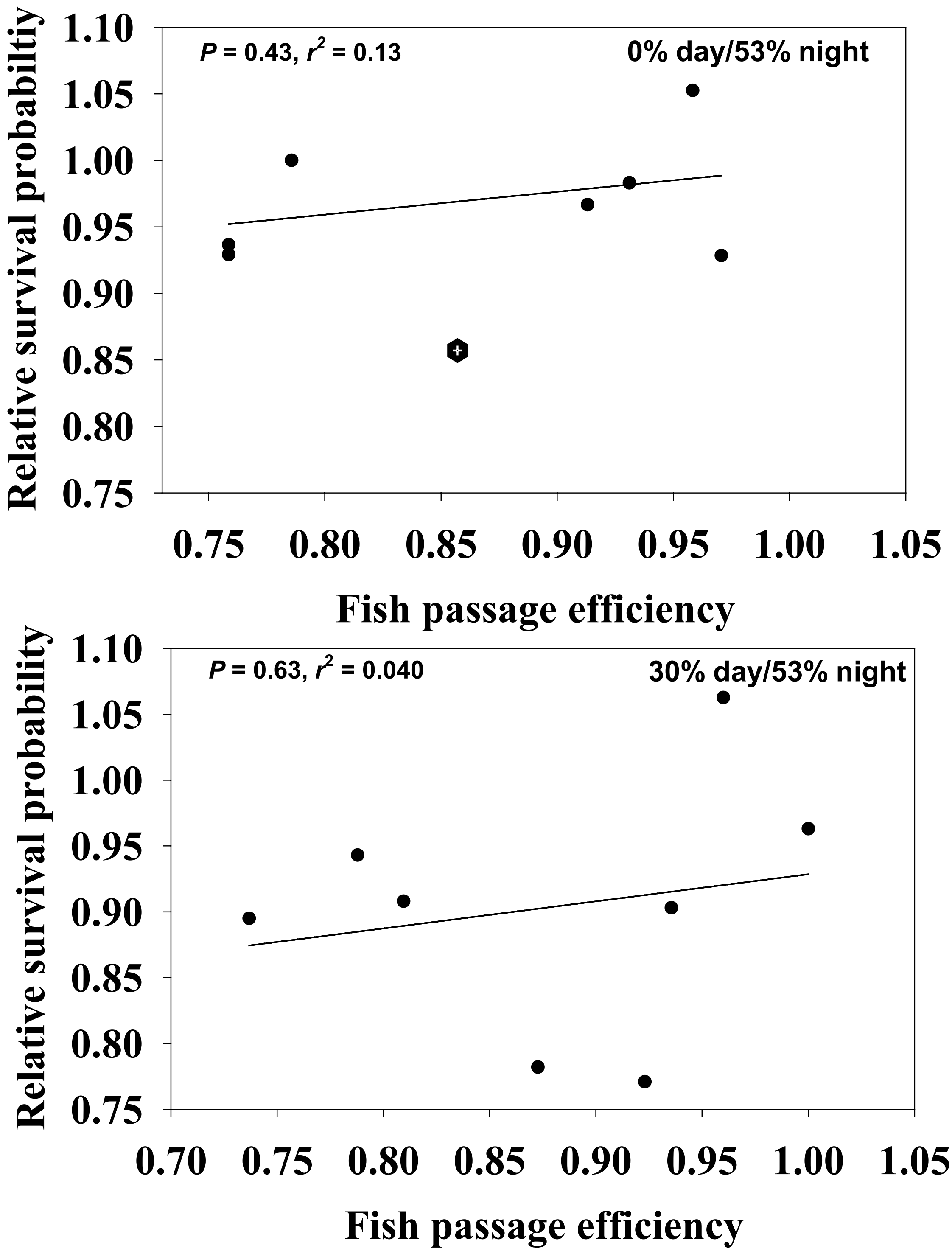


Figure 26. The relation of the relative survival of steelhead trout passing via all routes at John Day Dam to the fish passage efficiency (fish passing via all non-turbine routes) for each release. Release 2 was designated as an outlier for the 0% day/53% night spill condition and was not included in the analyses. This observation is shown as an hexagon on the graph.

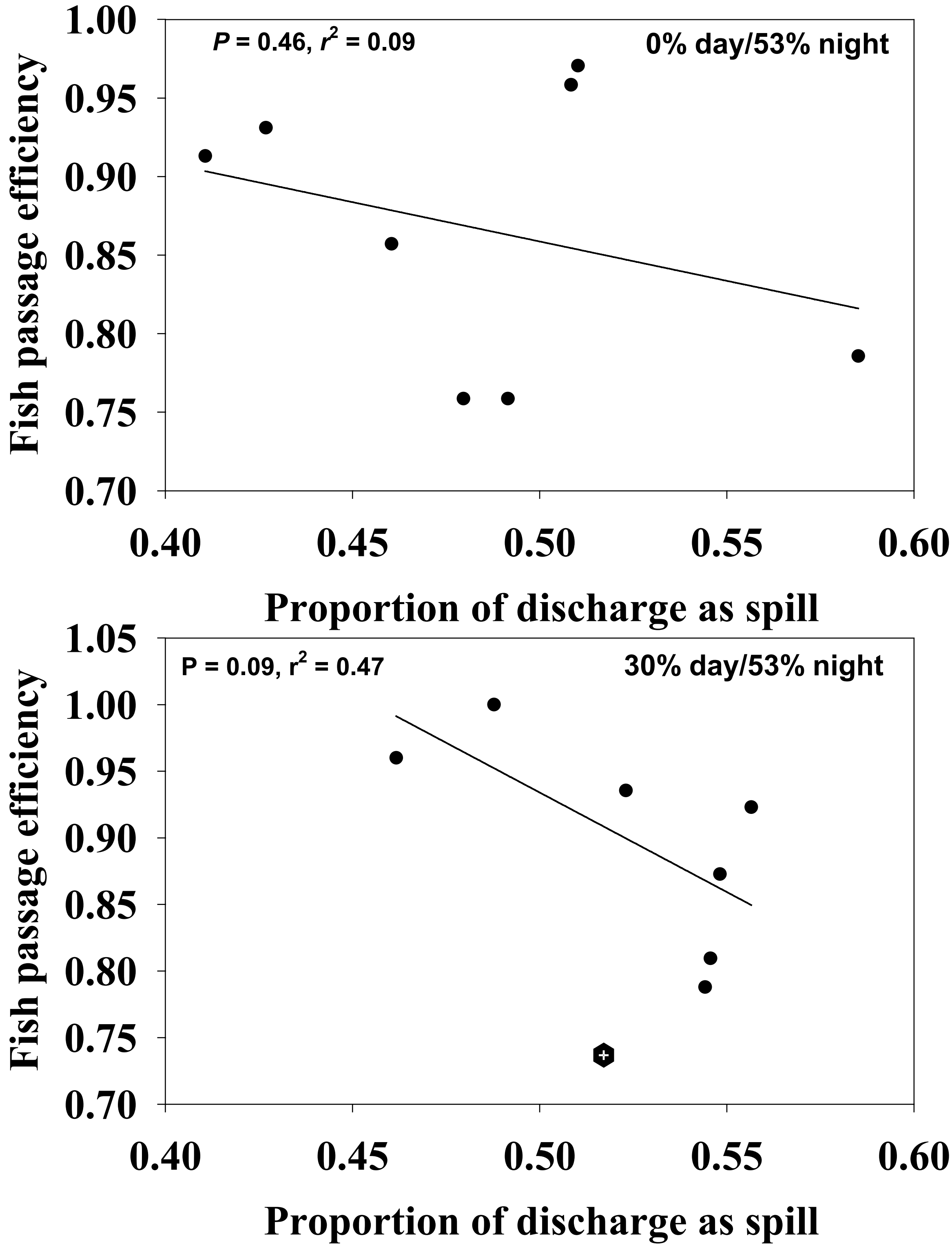


Figure 27. The relation of the fish passage efficiency of steelhead trout at John Day Dam to the proportion of discharge as spill. Release 15 was designated as an outlier for the 30% day/53% night spill condition and was not included in the analyses. This observation is shown as an hexagon on the graph.

Table 47. The survival of yearling chinook salmon released near Rock Creek, WA through various reaches from Rock Creek, WA to near Lyle, WA. Survival estimates are based on the Cormack-Jolly-Seber model (Cormack 1964, Jolly 1965, Seber 1965) and are not expressed relative to a control group.

	Survival (standard error) of yearling chinook through river reach			
Rock Creek Release Date	Rock Creek to John Day Dam [A]	John Day Dam to The Dalles Dam [A]	The Dalles Dam [A] to Bonneville Reservoir array	Overall survival from Rock Creek to Bonneville Reservoir array
05/01	0.929 (0.069)	0.923 (0.074)	0.844 (0.110)	0.723 (0.123)
05/02	1.048 (0.044)	0.750 (0.125)	1.060 (0.283)	0.833 (0.251)
05/03	1.000 (0.000)	0.833 (0.108)	0.667 (0.192)	0.556 (0.176)
05/03	1.040 (0.037)	0.833 (0.108)	0.923 (0.140)	0.800 (0.146)
05/04	0.933 (0.064)	0.929 (0.069)	1.000 (0.000)	0.867 (0.088)
05/05	1.000 (0.000)	0.964 (0.120)	0.605 (0.150)	0.583 (0.131)
05/06	0.933 (0.064)	1.000 (0.000)	0.804 (0.114)	0.750 (0.119)
05/06	1.000 (0.000)	1.000 (0.000)	0.867 (0.088)	0.867 (0.088)
05/07	0.857 (0.094)	0.917 (0.080)	1.038 (0.046)	0.816 (0.119)
05/08	0.938 (0.061)	1.000 (0.000)	0.867 (0.088)	0.813 (0.098)
05/09	0.923 (0.074)	1.000 (0.000)	0.917 (0.080)	0.846 (0.100)
05/09	1.000 (0.000)	0.900 (0.095)	1.066 (0.080)	0.960 (0.124)
05/10	0.975 (0.082)	0.615 (0.135)	1.000 (0.000)	0.600 (0.126)
05/11	1.010 (0.014)	0.923 (0.074)	0.857 (0.094)	0.800 (0.103)
05/12	1.016 (0.019)	0.765 (0.103)	0.964 (0.140)	0.750 (0.144)
05/12	1.000 (0.000)	0.929 (0.069)	1.006 (0.010)	0.935 (0.070)
05/13	0.882 (0.078)	1.000 (0.000)	0.953 (0.070)	0.841 (0.097)
05/14	0.948 (0.063)	0.943 (0.079)	0.923 (0.090)	0.825 (0.100)
05/15	1.000 (0.000)	0.824 (0.092)	0.929 (0.069)	0.765 (0.103)
05/15	0.938 (0.061)	0.867 (0.088)	0.923 (0.074)	0.750 (0.108)
05/16	0.875 (0.083)	0.643 (0.128)	0.889 (0.105)	0.500 (0.125)
05/17	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
05/18	1.014 (0.014)	0.882 (0.078)	0.963 (0.063)	0.861 (0.088)
05/18	1.000 (0.000)	0.750 (0.108)	0.917 (0.080)	0.688 (0.116)
05/19	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
05/20	1.012 (0.016)	0.853 (0.101)	0.909 (0.087)	0.786 (0.110)
05/21	1.000 (0.000)	0.880 (0.091)	0.842 (0.109)	0.741 (0.116)
05/21	1.000 (0.000)	1.000 (0.000)	0.933 (0.120)	0.933 (0.120)
05/22	1.000 (0.000)	1.000 (0.000)	0.933 (0.064)	0.933 (0.064)
05/23	0.933 (0.064)	1.000 (0.000)	1.000 (0.000)	0.933 (0.064)
05/24	1.000 (0.000)	1.000 (0.000)	1.022 (0.026)	1.022 (0.026)
05/24	1.000 (0.000)	0.875 (0.068)	0.879 (0.081)	0.769 (0.092)

[A]- Detections at dams are forebay detections

Table 48. The survival of steelhead trout released near Rock Creek, WA through various reaches from Rock Creek, WA to near Lyle, WA. Survival estimates are based on the Cormack-Jolly-Seber model (Cormack 1964, Jolly 1965, Seber 1965) and are not expressed relative to a control group.

	Survival (standard error) of yearling chinook through river reach			
Rock Creek Release Date	Rock Creek to John Day Dam [A]	John Day Dam to The Dalles Dam [A]	The Dalles Dam [A] to Bonneville Reservoir array	Overall survival from Rock Creek to Bonneville Reservoir array
05/01	0.909 (0.087)	1.000 (0.000)	0.900 (0.095)	0.818 (0.116)
05/02	1.000 (0.000)	0.769 (0.117)	0.933 (0.218)	0.718 (0.200)
05/03	0.989 (0.101)	0.778 (0.139)	0.800 (0.126)	0.615 (0.135)
05/03	1.006 (0.008)	0.923 (0.074)	1.054 (0.062)	0.980 (0.093)
05/04	0.923 (0.074)	1.000 (0.000)	1.110 (0.101)	1.026 (0.125)
05/05	1.000 (0.000)	1.000 (0.000)	1.028 (0.029)	1.028 (0.029)
05/06	0.873 (0.089)	0.917 (0.080)	0.833 (0.108)	0.667 (0.122)
05/06	1.000 (0.000)	1.000 (0.000)	1.016 (0.018)	1.016 (0.018)
05/07	1.004 (0.007)	0.929 (0.069)	0.943 (0.072)	0.880 (0.091)
05/08	1.000 (0.000)	0.933 (0.064)	1.020 (0.025)	0.953 (0.070)
05/09	1.014 (0.019)	0.833 (0.108)	1.038 (0.046)	0.879 (0.111)
05/09	0.933 (0.064)	0.929 (0.069)	1.000 (0.000)	0.867 (0.088)
05/10	1.000 (0.000)	0.857 (0.094)	1.000 (0.000)	0.857 (0.094)
05/11	0.951 (0.052)	0.941 (0.057)	1.018 (0.018)	0.911 (0.074)
05/12	1.000 (0.000)	0.880 (0.091)	0.833 (0.108)	0.733 (0.114)
05/12	0.900 (0.067)	1.002 (0.005)	0.966 (0.065)	0.873 (0.086)
05/13	0.929 (0.069)	1.000 (0.000)	0.846 (0.100)	0.786 (0.110)
05/14	0.923 (0.074)	1.000 (0.000)	1.000 (0.000)	0.923 (0.074)
05/15	1.000 (0.000)	1.000 (0.000)	0.935 (0.095)	0.935 (0.095)
05/15	0.800 (0.126)	1.000 (0.000)	1.000 (0.000)	0.800 (0.126)
05/16	0.850 (0.080)	0.706 (0.111)	0.917 (0.080)	0.550 (0.111)
05/17	1.010 (0.014)	0.929 (0.075)	0.947 (0.081)	0.889 (0.094)
05/18	1.000 (0.000)	0.886 (0.085)	0.873 (0.108)	0.773 (0.115)
05/18	1.012 (0.015)	0.789 (0.094)	0.993 (0.081)	0.794 (0.110)
05/19	1.000 (0.000)	0.900 (0.067)	0.727 (0.107)	0.655 (0.108)
05/20	1.008 (0.011)	0.842 (0.084)	1.000 (0.000)	0.850 (0.080)
05/21	0.700 (0.102)	0.857 (0.094)	1.000 (0.000)	0.600 (0.110)
05/21	0.938 (0.061)	0.867 (0.088)	0.879 (0.111)	0.714 (0.124)
05/22	0.857 (0.094)	0.667 (0.136)	1.000 (0.000)	0.571 (0.132)
05/23	0.929 (0.069)	0.923 (0.074)	0.917 (0.080)	0.786 (0.110)
05/24	1.068 (0.060)	0.643 (0.128)	1.052 (0.053)	0.723 (0.127)
05/24	1.018 (0.023)	0.818 (0.116)	1.000 (0.000)	0.833 (0.108)

[A]- Detections at dams are forebay detections

in the forebay of John Day Dam on the survival of yearling chinook and steelhead. Average residence times were calculated for each of the 32 groups of yearling chinook and steelhead released near Rock Creek, WA. We performed a natural log transformation on the residence times that normalized the distribution of this variable. No significant relation between the natural logarithm of residence times was detected for either yearling chinook (Figure 28, P = 0.69) or steelhead (Figure 28, P = 0.96). Overall survival probabilities of the yearling chinook release groups from near Rock Creek, WA to near Lyle, WA ranged from 0.5 to 1.0 and from 0.55 to 1.0 for steelhead.

The Dalles Dam

At The Dalles Dam, the USGS released radio-tagged yearling chinook in conjunction with releases of PIT-tagged yearling chinook and coho salmon made by the National Marine Fisheries Service. The National Marine Fisheries Service provided us with the survival probability estimates for the corresponding PIT-tag releases. We present the data they provided and the survival estimates for the radio-tag releases. Our objective was to provide comparisons between the estimates provided by the two different tagging techniques and the two estimation approaches (e.g., relative recovery methods based on relative detections of treatment and control groups at Bonneville Dam by the NMFS and the paired release-recapture models of Burnham et al., 1986 by the USGS). For a detailed description of the statistical methodology used to estimate survival using PIT-tags see Absalon et al. 2002).

The survival probabilities generated from releases of radio-tagged yearling chinook at The Dalles Dam indicated that survival was highest for yearling chinook passing via the ice and trash sluiceway, lowest for fish passing via the powerhouse, and intermediate for fish passing via the spillway (Table 49, Figure 29). Similar trends were observed for the estimates derived from releases of PIT-tagged yearling chinook and coho salmon with the survival highest for sluiceway passed fish, lowest for turbine passed fish, and intermediate for spillway passed fish. The average survival estimates generated from the two tagging and estimation techniques were similar for fish passing through the spillway (radio-tag = 92.7; PIT-tag = 91.1) and for fish passing via the powerhouse (radio-tag = 86.9; PIT-tag = 83.7), while the greatest difference observed was between the estimates for radio-tagged fish passing via the sluiceway (0 = 99.1) and PIT-tagged fish (0 = 93.0). In all cases the survival estimates generated from releases of radio-tagged fish were higher than for those generated for PIT-tag fish. However, estimates generated from releases of radio-tagged fish were on average contained within the 95% confidence intervals for the estimates generated from the PIT-tagged fish.

We used linear regression to examine the relation of the survival estimates generated from radio-tagged fish to spill and total discharge at The Dalles Dam. These analyses differ from those performed for John Day Dam in that all fish were released directly into the route of passage evaluated. Thus, all fish in a given release experienced essentially the same environmental conditions. Consequently, the dam operation conditions present at the time of release were used as opposed to averaging the conditions experienced by yearling chinook salmon as they passed the John Day Dam. No significant relation between the survival of radio-tagged yearling chinook released through The Dalles Dam spillway and spill (P = 0.97, r^2 <

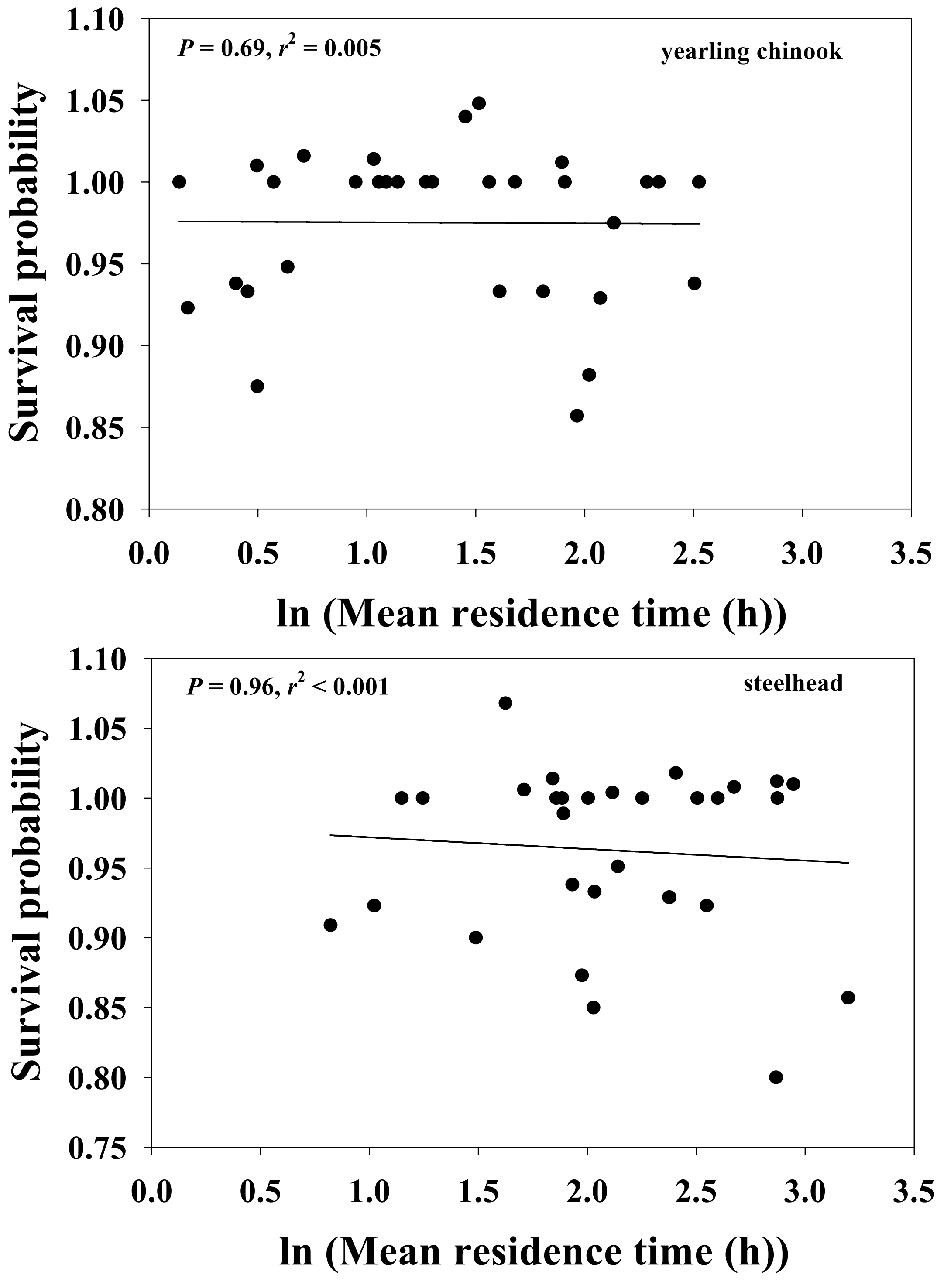


Figure 28. The relation of the survival of yearling chinook salmon and steelhead trout from Rock Creek to John Day Dam and residence time in the forebay of John Day Dam.

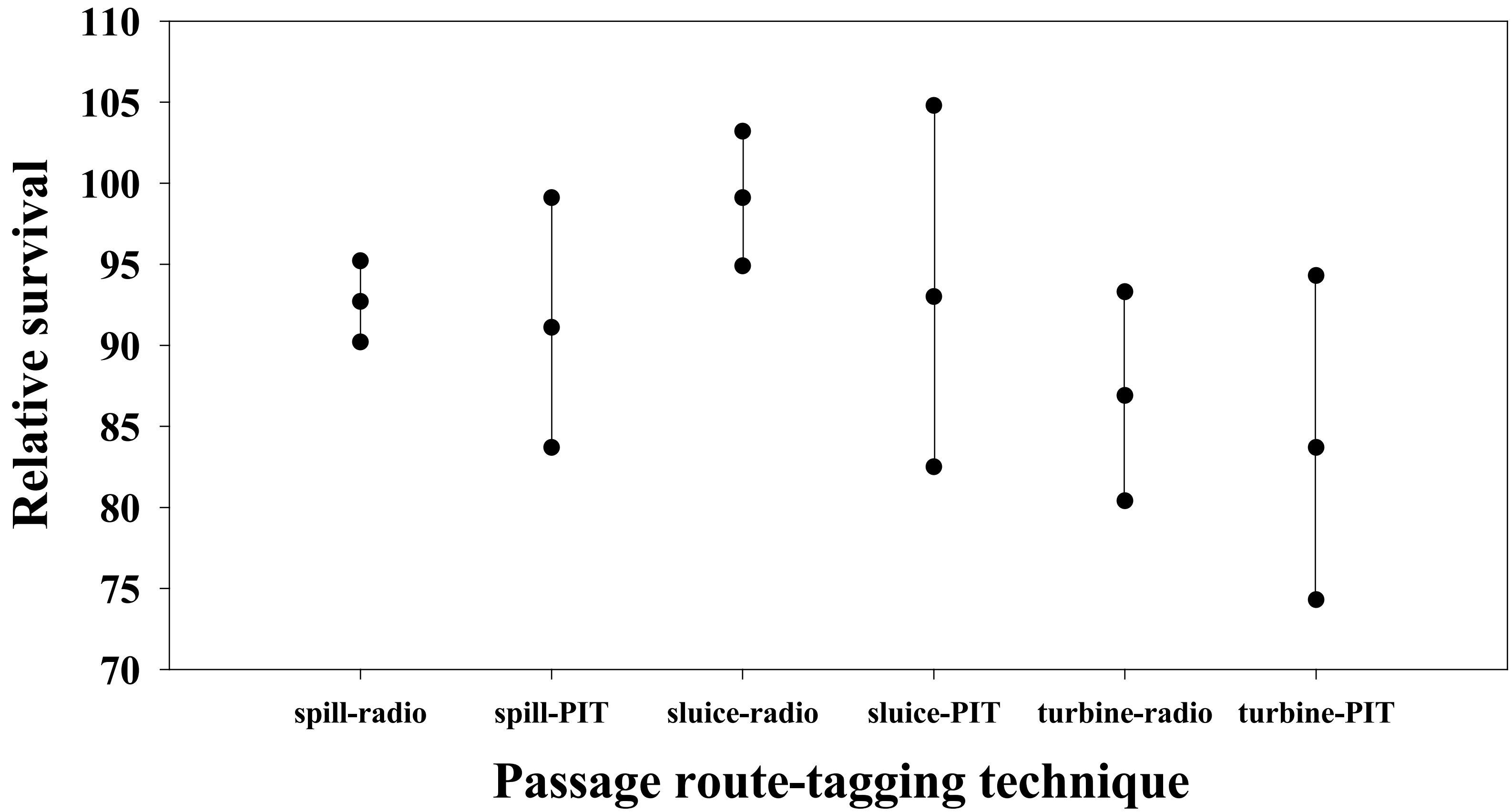


Figure 29. The relative survival estimates and approximate 95% confidence intervals produced from PIT-tagged yearling chinook and coho salmon based on relative recoveries at Bonneville Dam and from radio-tagged yearling chinook based on paired release-recapture models for fish released directly through the spillway (spill), ice and trash sluiceway (sluice), and through various turbine units at the powerhouse (turbine) at The Dalles Dam.

Table 49. The sample size (n), significance (P), and fit (r^2) of simple linear regression models relating survival probabilities estimated from paired releases of radio-tagged yearling and sub-yearling chinook salmon to various environmental parameters at The Dalles Dam during 2000. Estimates for the environmental parameters are those present during release times of treatment and control groups. Significant relationships at $\alpha = 0.10$ are denoted by ^{A}.

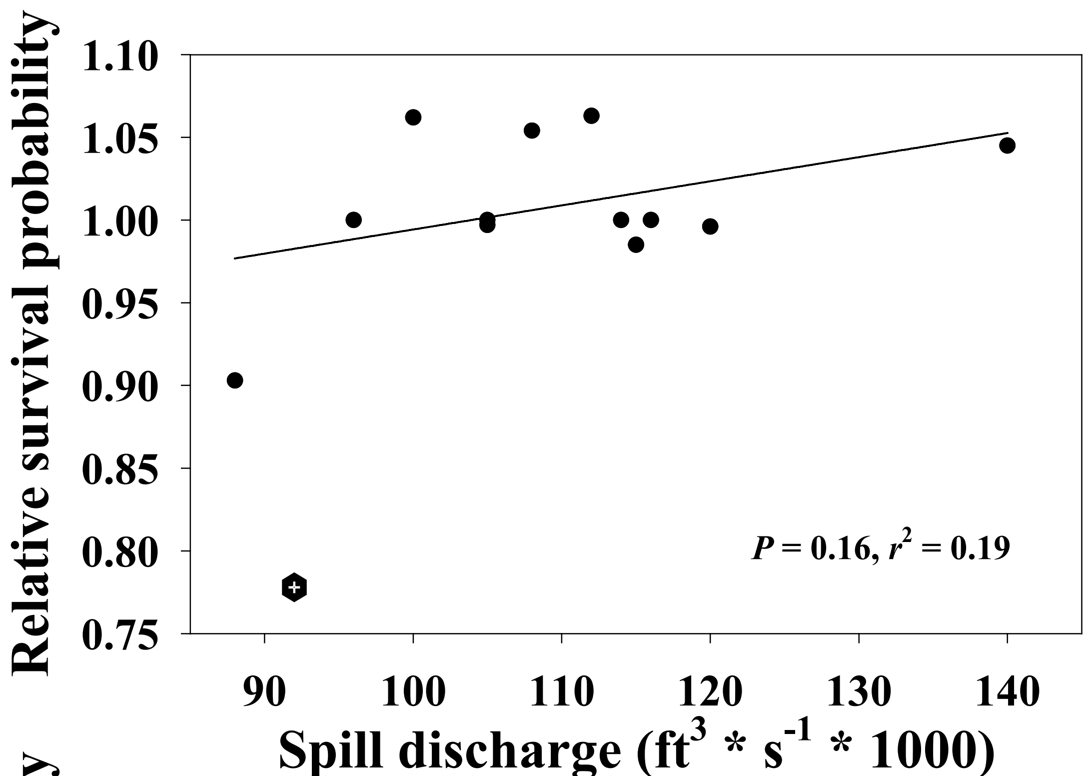
Independent variable in simple linear regression model (i.e., survival probability estimate = $\beta_o + \beta_1 \cdot$ (independent variable))	Species	Passage location	n	P	r^2
spill discharge	yearling chinook	spill	13	0.97	<0.01
total discharge	yearling chinook	spill	13	0.94	<0.01
spill discharge	yearling chinook	sluiceway	12	0.16	0.19
total discharge	yearling chinook	sluiceway	12	0.098^A	0.25
spill discharge	yearling chinook	turbine	13	0.76	<0.01
total discharge	yearling chinook	turbine	13	0.58	0.03
spill discharge	sub-yearling chinook	spill	9	0.60	0.04
total discharge	sub-yearling chinook	spill	9	0.50	0.07
spill discharge	sub-yearling chinook	sluiceway	9	0.83	0.08
total discharge	sub-yearling chinook	sluiceway	9	0.81	0.09
spill discharge	sub-yearling chinook	turbine	9	0.60	0.04
total discharge	sub-yearling chinook	turbine	9	0.61	0.04

0.001) and total discharge (*P* = 0.94, $r^2 < 0.001$) were detected (Table 49). Outlying observations were detected in both the relation of the survival and spill and total discharge. However, eliminating these observations from the data set did little to improve the fit or significance of these relationships. For yearling chinook salmon released through the ice and trash sluiceway (Figure 30), the relation between survival and spill discharge was marginally insignificant (*P* = 0.16, $r^2 = 0.19$) while the relation of survival and total discharge indicated a marginally significant relation (*P* = 0.098, $r^2 < 0.25$) when Release 8, that was identified as an outlying observation, was eliminated from the analysis. Similar to the yearling chinook released through the spillway, the survival of fish released through various turbine units at The Dalles Dam powerhouse was not significantly related to either spill (*P* = 0.76, $r^2 = 0.008$; Table 49) or total discharge (*P* = 0.58, $r^2 < 0.03$; Table 49). Similar to the relation of spill passed fish, outlying observations were identified but their elimination from the analyses did not significantly improve the fit or significance of the relationships.

Releases of sub-yearling chinook salmon were also made at The Dalles with the releases of radio-tagged fish being concurrent with releases of PIT-tagged fish by the NMFS. In general, there was not a similar pattern of agreement for the survival probabilities between the two different tagging and estimation techniques as was observed with the yearling chinook estimates (Table 50). The point estimates were lower for the radio-tagged sub-yearling chinook released through the spillway (0 = 82.6) than for PIT-tagged fish (0 = 89.7). For fish released through the sluiceway the estimates were similar for radio-tagged fish (0 = 90.2) and PIT-tagged fish (0 = 91.8) while estimates for radio-tagged fish released though the powerhouse (0 = 86.9) were higher than for PIT-tagged fish (0 = 77.4).

The patterns exhibited between the survival estimates for radio- and PIT-tagged fish released through the various routes of passage at The Dalles Dam were dissimilar. Estimates from radio-tagged sub-yearling chinook indicated that survival was highest for fish released through the sluiceway and lowest for fish released through the spillway; with releases of fish though the powerhouse at The Dalles Dam showing an intermediate survival value in relation to the two other routes (Table 50). Conversely, estimates generated with releases of PIT-tagged sub-yearling chinook indicating similar results as to those obtained for the yearling chinook releases with survival highest through the sluiceway, intermediate through the spillway, and lowest via the powerhouse (Table 50). While the point estimates of the survival generated from the two different tagging techniques showed disagreement in their magnitude and also in the trends in survival between the different routes of passage, the number of releases used in this evaluation was low (n = 9) and the estimates generated from the radio-tagged fish were contained within the 95% confidence intervals associated with the point estimates for the PIT-tagged sub-yearling chinook (Figure 31).

Survival of the treatment and control groups of radio-tagged sub-yearling chinook salmon from The Dalles Dam to the Bonneville reservoir array near Lyle, WA was lower than for yearling chinook released through the same routes of passage. Survival probabilities of the sub-yearling chinook released into the spillway averaged 0.56 (SE = 0.046) compared with 0.89 (SE = 0.16). For sub-yearling chinook released into the ice and trash sluiceway the survival probability was 0.63 (SE = 0.063) compared with 0.95 (SE = 0.019) for yearling chinook from The Dalles Dam to the Bonneville Reservoir array. For turbine released fish , the survival



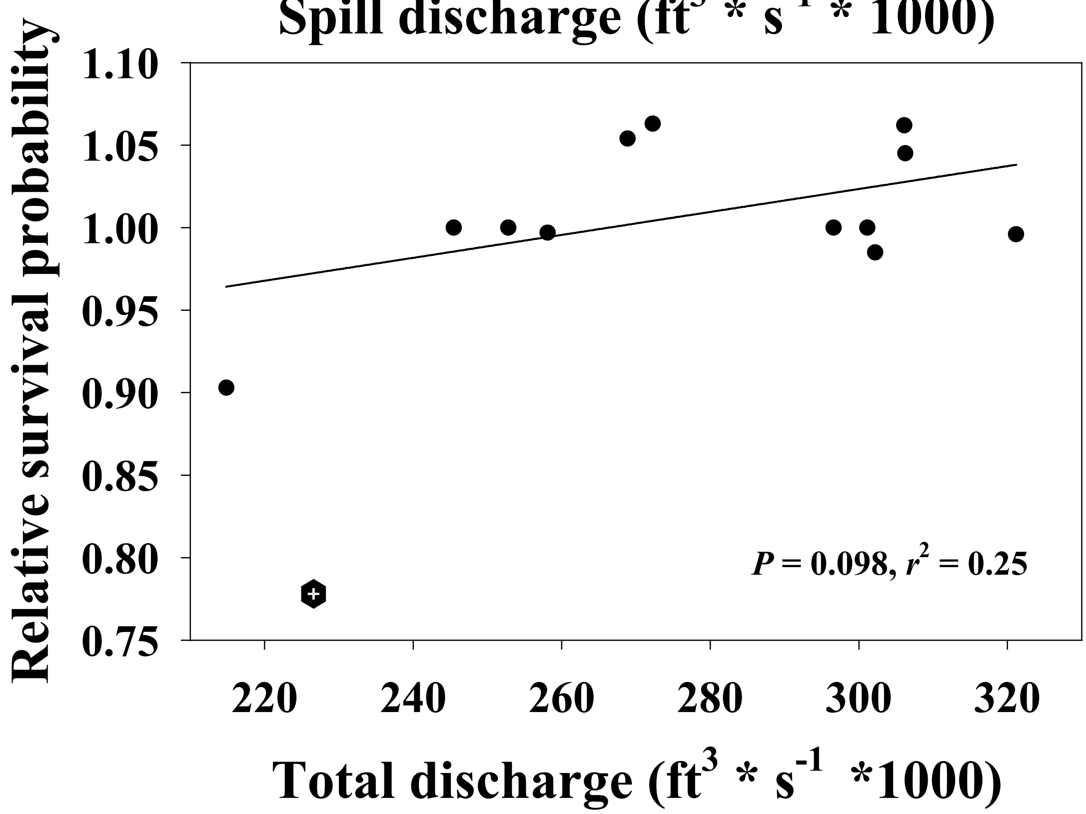


Figure 30. The relation of the relative survival of yearling chinook salmon released through the ice and trash sluiceway at The Dalles Dam and spill and total discharge ($ft^3 * s^{-1} * 1000$) at The Dalles Dam. Release 8 was identified as an outlying observation and was not included in the analysis but is represented on the plot as an hexagon.

Table 50. The survival probabilities expressed as a percent and their approximate 95% confidence intervals from 9 paired releases of radio-tagged and PIT-tagged sub-yearling chinook made through spillway, sluiceway, and through various turbine units at The Dalles Dam (treatment groups) and in the tailrace of The Dalles Dam (control groups).

		Survival (95% confidence interval) by tag-type	
Release location	N	Radio-tag	PIT-tag
Spillway	9	82.6 (64.8 – 100.4)	89.7 (78.4 – 102.7)
Sluiceway	9	90.2 (73.3 – 107.1)	91.8 (75.8 – 111.1)
Turbine	9	86.9 (71.8 – 102.0)	77.4 (63.9 – 93.8)

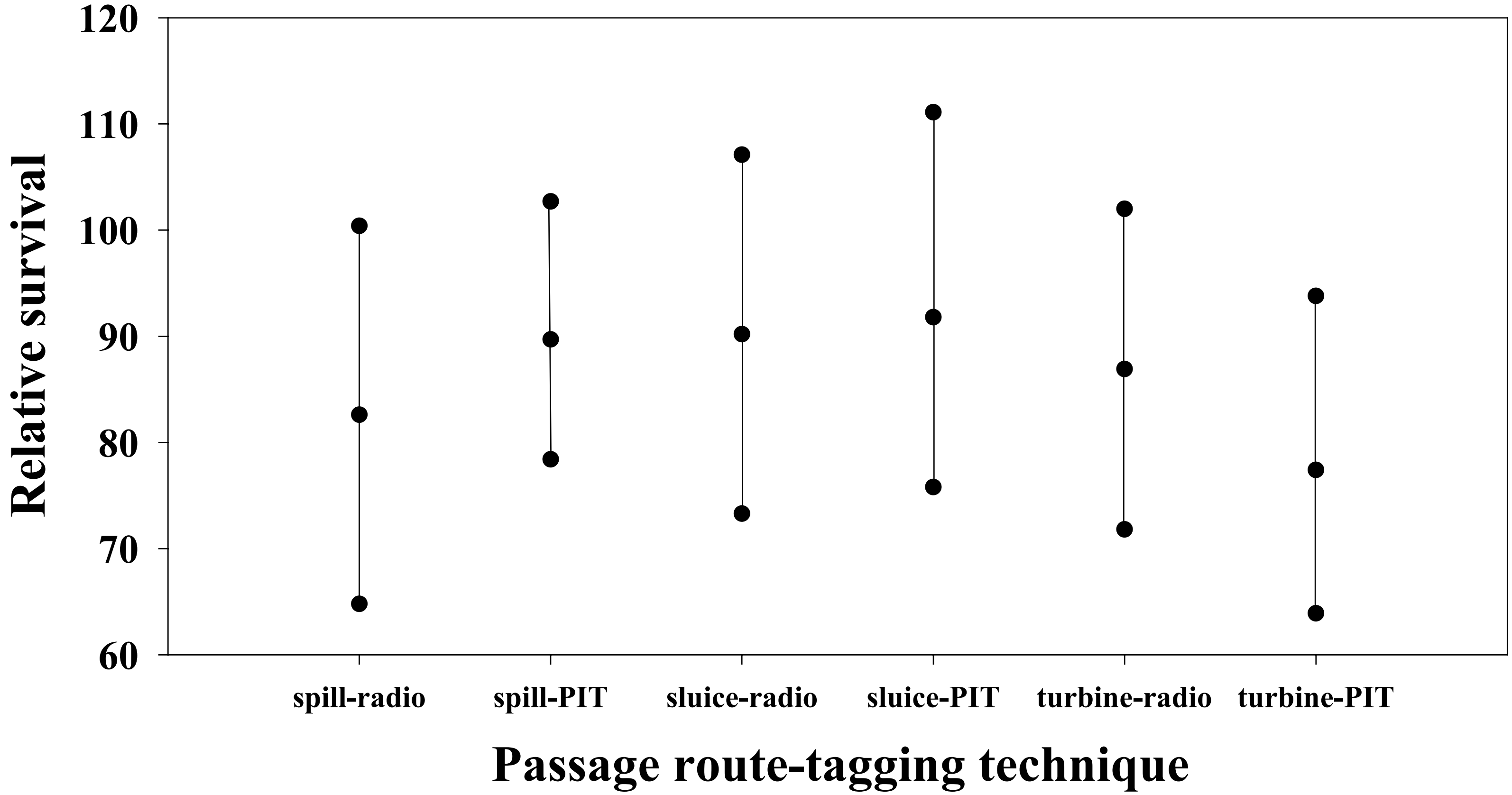


Figure 31. The relative survival estimates and approximate 95% confidence intervals produced from PIT-tagged sub-yearling chinook salmon based on relative recoveries at Bonneville Dam and from radio-tagged sub-yearling chinook based on paired release-recapture models.

probability of the sub-yearling chinook was 0.59 (SE = 0.03) while for yearling chinook the survival probability was 0.84 (SE = 0.03). Similar trends were observed between the control groups released as part of the paired releases (see Figure 3). The survival probability of the control group released in the tailrace of The Dalles Dam for the sub-yearling chinook evaluation was 0.71 (SE = 0.043) while for yearling chinook released in the tailrace was 0.96 (SE = 0.011).

As for the yearling chinook survival evaluation, we evaluated linear regressions to examine the relation of the survival of sub-yearling chinook to spill and total discharge at The Dalles Dam. No significant relationships between the survival of sub-yearling chinook and spill and total discharge were detected for fish released through the spillway, sluiceway, or the ice and trash sluiceway (Table 49) at The Dalles Dam. An evaluation of regression diagnostics indicated that there were observations that could be considered as outlying, however the elimination of these data points did not significantly improve either the fit or significance of the relationships.

Bonneville Dam

Yearling chinook salmon were released near Hood River, OR, through the new juvenile bypass at powerhouse 2, and in the tailrace of Bonneville Dam downstream of the confluence of the powerhouse 1, powerhouse 2, and spillway tailrace areas (see Figures 4 and 5). Releases made during 2000 were conducted to examine the feasibility of using releases of radio-tagged fish and radio-telemetry arrays below Bonneville Dam to estimate the survival of fish passing this project. The evaluation of the assumptions associated with the paired release-recapture survival estimation methodology constituted a major portion of this pilot study. The results of the evaluation are reported previously in the section presenting the results of tests designed to evaluate whether the assumptions associated with this study were met. Preliminary estimates of the survival of yearling chinook through Bonneville Dam are presented here. However, we caution the reader that one of the major assumptions associated with the models employed, namely that detections of fish downstream of their release point are alive. Releases of dead radio-tagged fish in the tailrace of Bonneville Dam indicated the possibility that dead steelhead trout may have drifted downstream of their release location and been detected at the downstream arrays. We present the results of the modeling exercise for planning purposes and would recommend that they be viewed in the context of the violated assumptions.

The survival and capture probabilities associated with releases of yearling chinook salmon detected at Bonneville Dam and known to have passed via the spillway and their associated tailrace releases are presented in Figure 32. As was true for the pilot study conducted during 1999 at John Day Dam, these results indicate that radio-telemetry systems are capable of providing high capture probabilities even in the un-impounded Columbia River below Bonneville Dam. The average survival estimate of the paired releases of yearling chinook salmon released near Hood River, OR and known to have passed via the spillway was 0.98 (N = 12, SE = 0.032). For fish released directly into the new juvenile bypass at powerhouse 2, the survival and capture probabilities are presented in Figure 33. Similar to the releases of yearling chinook released near Hood River, OR, releases of fish through the powerhouse 2 bypass also showed that detections of these fish by the telemetry arrays below Bonneville Dam resulted in

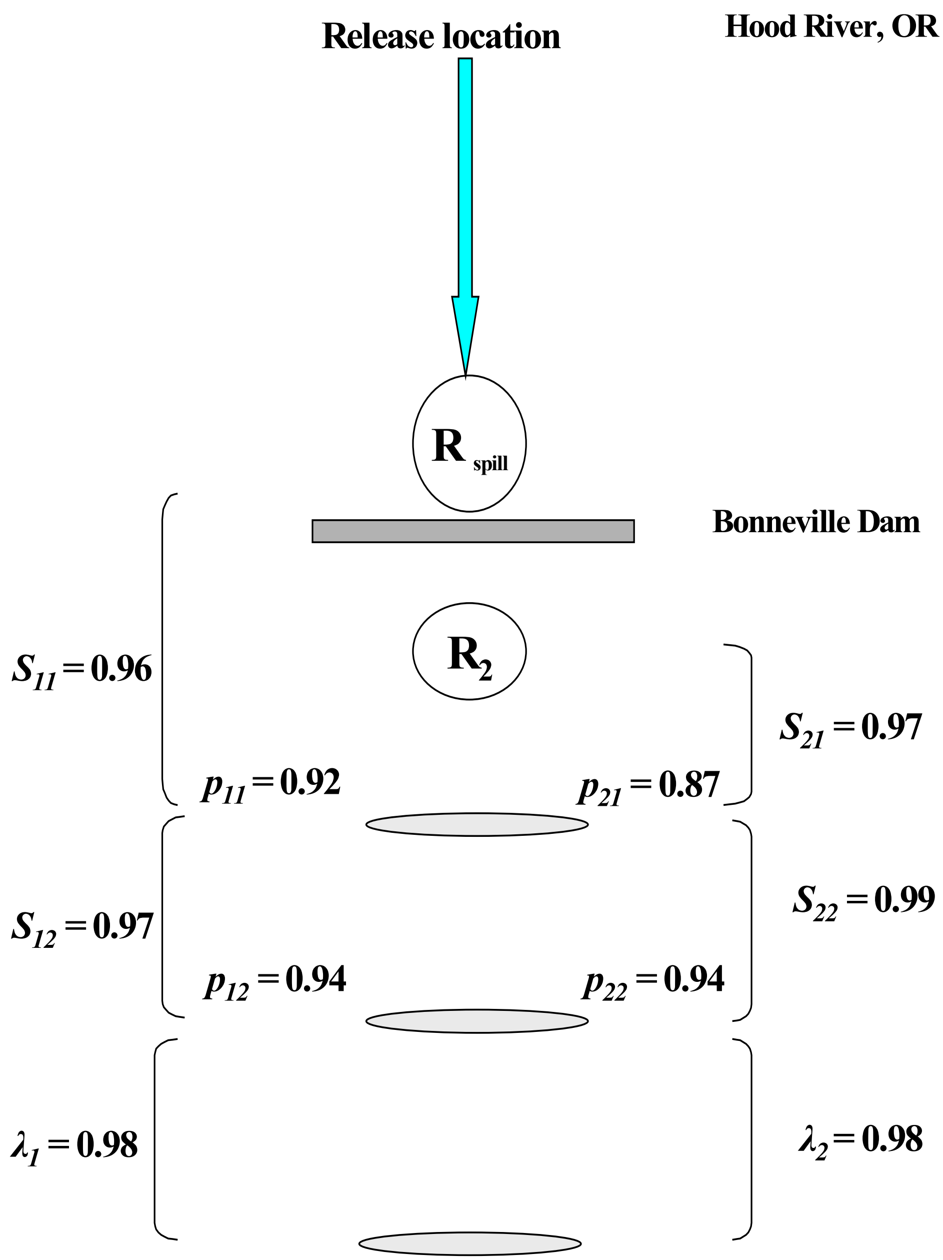


Figure 32. Schematic showing the capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from releases of yearling chinook salmon made near Hood River, OR, detected at Bonneville Dam and determined to have passed via the spillway and in the tailrace of Bonneville Dam. Dams are represented by rectangles and ovals represent detection arrays.

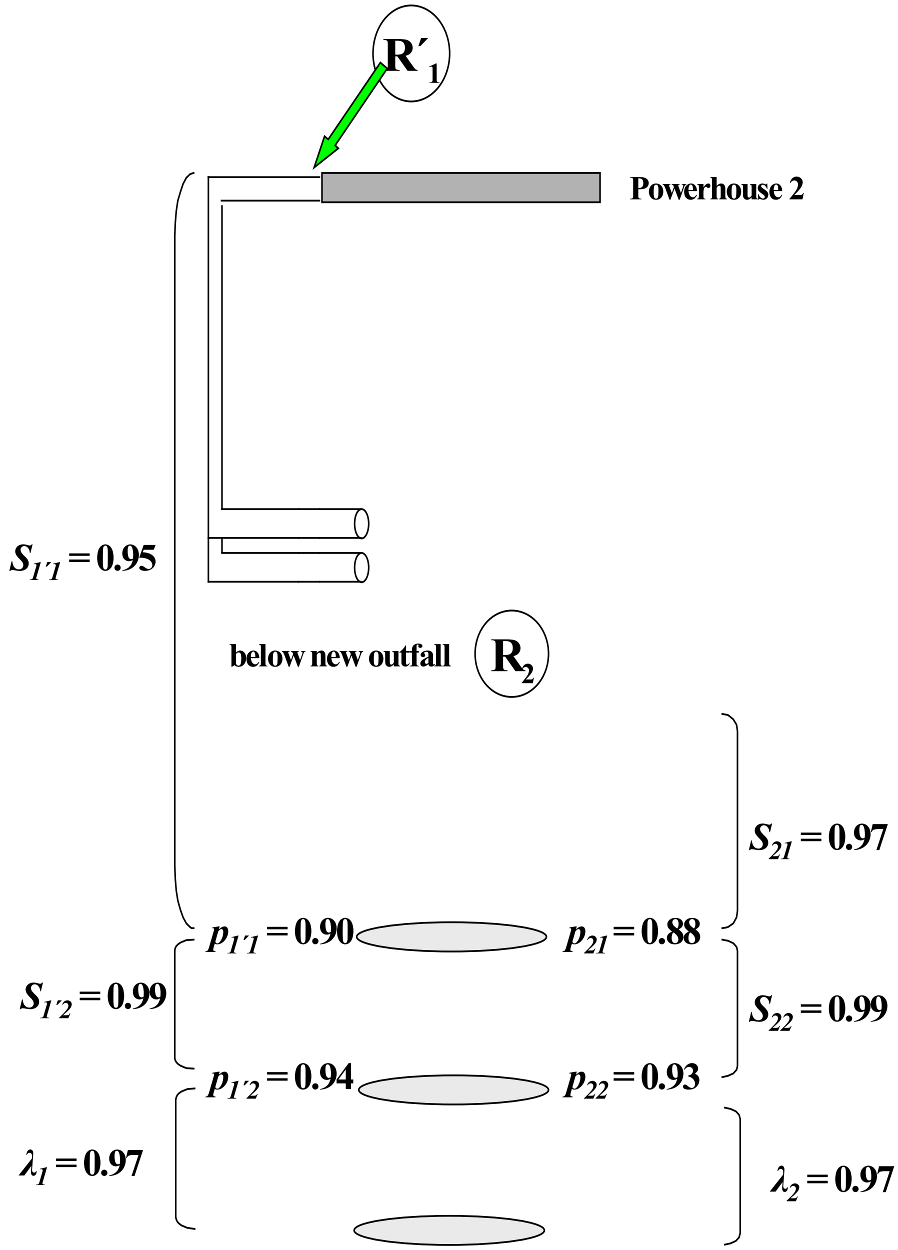


Figure 33. Capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) for releases of yearling chinook salmon through the juvenile bypass system at Bonneville Dam Powerhouse 2 and in the tailrace. Dams are represented by rectangles and ovals represent potential detection arrays.

high capture probabilities. The average survival of yearling chinook salmon released into the new juvenile bypass at Bonneville Dam was 0.98 (N = 12, SE = 0.025).

The survival of sub-yearling chinook salmon released near Hood River, OR (as part of an evaluation of the surface collector at powerhouse 1) was also evaluated to provide estimates of survival and capture probabilities that will aid the design of future studies. The survival of sub-yearling chinook from near Hood River, OR to the last telemetry array below Bonneville Dam, and including various stretches in between are presented in Table 51. Preliminary indications are that the telemetry systems used below Bonneville Dam also resulted in high capture probabilities for sub-yearling chinook salmon. The average capture probability of sub-yearling chinook salmon at Bonneville Dam was 0.87 and was 0.95 at the first two telemetry arrays below Bonneville Dam.

Discussion

Similar to releases made during 1999 (Counihan et al. 2001), the majority of the Burnham Tests 2 and 3 that test the assumption that upstream or downstream detections do not affect downstream survival and/or detection were incalculable for releases of yearling chinook salmon and steelhead trout at John Day, The Dalles, and Bonneville Dams and for releases of sub-yearling chinook salmon at The Dalles Dam. While we will continue to evaluate Burnham tests 2 and 3 in future years, the utility of these tests to discern whether assumptions A5 and A6 have been met is limited by the high capture probabilities now possible with the radio-telemetry detection arrays. Since we have constructed detection arrays that span the entire river channel, the possibility that this assumption could be violated if downstream detections were influenced by upstream passage routes is minimized (Skalski 1999a). Also, the lack of handling following initial release of radio-tagged fish also minimizes the risk that upstream detections affect survival (Skalski 1999a).

Alterations to the timing of releases of yearling chinook salmon and steelhead trout near Rock Creek, WA during 2000 improved past difficulties in matching up the passage time of the treatment groups with releases of control groups in the tailrace of John Day Dam so that the assumption of mixing of the treatment and control groups was met for most releases during 2000. However, while improvements were realized, significant differences still exist. For spill passed fish, 2 of 16 yearling chinook and 6 of 16 steelhead releases indicated that there were differences in the arrival times of the treatment and control groups at The Dalles Dam compared with 10 of 16 and 16 of 16 yearling chinook releases of yearling chinook and steelhead, respectively, made during 1999 (Counihan et al. 2001). Similar trends in the similarity of arrival times were observed at telemetry arrays downstream of The Dalles Dam. That significant differences in arrival times continued to persist during 2000 is likely due to the delay in passage (e.g., arriving during the day and then passing at night) exhibited by steelhead, and to a lesser extent, yearling chinook, at John Day Dam (Beeman et al. 2001a). Releases of control groups in the tailrace of John Day Dam were made during the day to aid the evaluation of passage behavior at the Dalles Dam and thus, may have arrival times at downstream arrays that differ from releases of steelhead trout at Rock Creek that arrive at John Day Dam during the day, but pass this project at night (Beeman et al. 2001a). Our evaluation of this assumption for yearling chinook salmon and steelhead trout passing via all routes exhibited similar trends. Further improvements in

Table 51. The survival of sub-yearling chinook salmon released near Hood River, OR through various reaches from Hood River, OR to survival gate 3, located at river kilometer 211, below Bonneville Dam. Survival gate 1 and survival gate 2 were located at river kilometer 226 and 217, respectively. Survival estimates are based on the Cormack-Jolly-Seber model (Cormack 1964, Jolly 1965, Seber 1965) and are not expressed relative to a control group.

Survival (standard error) of sub-yearling chinook through river reach				
Hood River Release Date and Time	Hood River to Bonneville Dam [A]	Bonneville Dam [A] to Survival Gate 1	Survival Gate 1 to Survival Gate 2	Overall survival from Hood River to Survival Gate 3
07/15/00 11:00	0.951 (0.032)	0.772 (0.056)	1.000 (0.000)	0.734 (0.055)
07/15/00 22:00	0.865 (0.045)	0.884 (0.046)	0.976 (0.024)	0.746 (0.053)
07/16/00 11:00	0.752 (0.091)	0.917 (0.080)	1.006 (0.007)	0.694 (0.087)
07/18/00 13:00	0.978 (0.035)	0.859 (0.069)	0.952 (0.046)	0.800 (0.073)
07/18/00 23:00	0.976 (0.035)	0.786 (0.078)	1.000 (0.000)	0.767 (0.077)
07/19/00 13:00	0.902 (0.046)	0.865 (0.056)	1.002 (0.003)	0.782 (0.065)
07/19/00 23:00	0.944 (0.045)	0.794 (0.069)	1.002 (0.003)	0.752 (0.069)
07/20/00 12:00	0.939 (0.042)	0.914 (0.051)	0.967 (0.033)	0.829 (0.059)
07/20/00 22:00	0.938 (0.041)	0.841 (0.061)	0.972 (0.035)	0.767 (0.066)
07/21/00 12:00	0.960 (0.046)	0.893 (0.061)	0.934 (0.046)	0.801 (0.057)
07/21/00 22:00	0.869 (0.047)	0.933 (0.037)	1.004 (0.004)	0.815 (0.054)

[A]- Detections at dams are forebay detections

eliminating or reducing the numbers of statistically significant differences could be realized by further altering the timing of the tailrace releases by incorporating the knowledge that both yearling chinook and steelhead tend to pass primarily at night at this project, regardless of dam operation conditions (Beeman et al 2001a). Another alternative is to make releases directly through the routes of interest at this project, thus eliminating the need to estimate the passage timing for fish released at Rock Creek. However, if releases were made directly into the routes of interest, more radio-tagged fish would be required to fulfill the joint needs of the survival and FPE components of the evaluations at John Day Dam. Further, having fish pass at times that reflect environmental conditions in proportion to those experienced by fish migrating down the river, as opposed to releasing groups of fish under the same dam operations, increases the types of environmental conditions experienced by the release groups and may increase our ability to determine relationships between survival and dam operation conditions. For instance, if all of the releases are made at a particular time everyday, as per typical releases made directly into a particular route of passage, and dam operations vary over time within a particular dam operation test (as they did for John Day Dam during 2000, see results and below), then we are characterizing only the survival of fish say, that pass through the spillway at 10:00 pm, when in actuality fish pass throughout the night and experience a range of hydraulic and dam operation conditions.

The differences in arrival times documented at John Day were not seen at either The Dalles Dam (releases made directly into the routes of interest) or at Bonneville Dam (releases made directly into routes of interest and also releases upstream of the project). For the releases made near Hood River, OR, there was not a pronounced diel pattern in passage times at Bonneville Dam (Evans et al. 2001) similar to that shown for yearling chinook and steelhead at John Day Dam (Beeman et al. 2001a). This result suggests that the lack of delay in passage for fish arriving at Bonneville Dam during the day may account for the reduced numbers of significant differences in arrival times between the treatment (released near Hood River, OR) and control groups (released in the tailrace of Bonneville Dam) when compared with John Day Dam. The assumption of mixing is satisfied if the paired releases mix as they migrate through the second river segment but can also be satisfied if the survival process is stable during passage by the two releases. Under similar flow and spill conditions, a stable survival process should be expected. The results of the sequential model selection process suggest that this may have been true for the majority of our releases at all of the projects and various routes evaluated despite any differences in arrival times. The results of the sequential model selection process suggest there is little evidence of a synergistic relationship between survival processes in the two river segments (i.e., fish released above the dam that survive the first river segment are no more or less susceptible to mortality in the second river segment than fish released below the dam; Assumption A8).

Releases of dead radio-tagged yearling chinook salmon and steelhead trout at John Day and The Dalles dams indicated that there was no evidence at these projects that dead radio-tagged fish drifted downstream and were detected and thus, assumed to be alive when in fact they were dead. However, dead radio-tagged steelhead trout, but no yearling chinook, were detected at arrays established below Bonneville Dam, indicating that there was the potential to violate the assumption that detections downstream of the release location are only of live fish.

The tailrace area of Bonneville Dam and also the Columbia River below the tailrace obviously differs from that of the impounded reaches of the Columbia River below John Day and The Dalles Dams. Parsley and Beckman (1994) in a survey of the hydraulic conditions in the Bonneville Dam tailrace concluded that the gradient, and thus, water velocities were greater below Bonneville Dam over a wide range of discharge conditions than in the tailrace areas below the John Day or The Dalles dams. The increased water velocities in the tailrace area and presumably, the un-impounded lower Columbia River, may account for the fact that dead steelhead released in the tailrace were detected at downstream arrays in this area and not downstream of John Day or The Dalles dams. That only steelhead but no yearling chinook were detected, may be due to the fact that juvenile steelhead are typically larger than yearling chinook, making them more susceptible to be carried in the drift. Other possible explanations include the possibility that the techniques used to kill the fish were insufficient and the potential for the tags used for steelhead were more likely to be detected than for those used to tag yearling chinook.

The detection of dead radio-tagged steelhead at downstream telemetry arrays may also be caused by consumption of these fish and subsequent downstream movements of predators. Petersen et al. (1994) demonstrated that dead juvenile salmonids in the tailrace of Bonneville Dam have a high probability of being consumed by northern pikeminnow. Although their studies were conducted in August and early-September, high rates of predation below Bonneville Dam also occur on yearling chinook and steelhead trout (Ward et al. 1995). During late-May and June, northern pikeminnow migrate upriver to spawn. However, the extent of their upriver movement is limited by the presence of dams on the mainstem (Gadomski et al. 2001). Following spawning, northern pikeminnow often move back down river to specific locations (Craig Barfoot and Jim Petersen, USGS, unpublished data). Post-spawned predators could have consumed the dead radio-tagged steelhead and carried the operating tag through the downriver arrays where they were detected. Future analyses will further explore this possibility.

Significant differences in the survival of juvenile steelhead passing during spill blocks with 0% day/53 % night and 30% day/ 53% night spill conditions were detected for steelhead passing via the John Day Dam spillway, with survival being lower during the 30% day/53% night spill condition. As stated previously, this result suggests that since the major difference between the spill blocks was the 30% day spill condition, this dam operation condition may have been the causal mechanism of the differences in survival. While the results for the yearling chinook spillway evaluation, and for the yearling chinook and steelhead passing via all routes evaluation were not found to be statistically different, the similarity in the trends exhibited for the survival estimates (higher survival during the 0% day/53% night spill condition) further suggested that the 30% day spill condition may have been affecting the survival of fish passing this project. However, further examination of this hypotheses did not indicate that survival was negatively related to the proportion of fish passing during the day or positively related to the number of fish passing during the night. In an evaluation of FPE and spill passage efficiency at John Day Dam that used the same fish evaluated during this study, Beeman et al. (2001a) found few steelhead trout passed during the day, regardless of the spill condition, which also suggests that differences in survival were not caused by decreased survival during the 30% day spill condition. The only significant relation we detected (Figure 11) suggested that the proportion of steelhead passing via all routes during the hours of 2100 and 0600 was negatively related to the survival probabilities of our release groups.

After examining the relation of the survival probabilities at John Day Dam to various behavioral, environmental, and dam operation conditions, we determined that the survival of steelhead passing via the spillway and via all routes was significantly related to total discharge (positively correlated), the proportion of discharge as spill (negatively correlated), and tail water elevation (positively correlated). Examination of the relation of these variables to one another indicated that they were strongly correlated. The proportion of discharge as spill was negatively related to total discharge and tail water elevation was positively related to total discharge and negatively related to the proportion of total discharge as spill. Thus it would appear, through the examination of these relationships, that the higher spill percentages were strongly associated with the lowest discharges during times of passage of the radio-tagged steelhead. Further, we would hypothesize from the relationships established, that steelhead trout passed during these episodes of higher spill percentages and low discharges survive at a lower level than steelhead passed at lower spill percentages and higher discharges. Lower discharges likely alter the hydraulic conditions present in the tailrace of John Day Dam, reducing water velocities and increasing the amount of juvenile salmonid predator habitat in this area, which may result in an increased risk of predation for fish passing during these conditions (Petersen et al. In review). Similarly, in a manuscript summarizing research conducted on the distribution of northern pikeminnow in the tailrace areas of The Dalles and John Day dams, Hansel et al. (In preparation) found significant correlations between the use of the tailrace area of John Day Dam by northern pikeminnow and decreased total discharge and increased spill discharge. Another potential mechanism for decreased survival rates during times of lower tail water elevation and higher spill percentages may be physical injury as fish pass over the spillway and are forced to contact the substrate below the spillway. Altered hydraulics in the tailrace area may also promote egress through areas with high predator densities during times of low discharge and increased spill. The dam operation and environmental conditions present during the two spill treatments further suggest that differences in these variables may have been the causative factor for the differences in survival between the two spill treatments. The summary of conditions experienced by radio-tagged steelhead during the two spill treatments indicate that on average, the total discharge was higher and the proportion of discharge as spill lower for fish passing during the 0% day/53% night spill condition than during the 30% day/53% night conditions.

Unlike steelhead trout, few significant relationships between the survival of yearling chinook survival and total discharge, proportion of total discharge as spill, and tail water elevation were detected when releases for both spill treatments were evaluated.

However, the relationships were stronger for spill passed fish than for fish passing via all routes, as opposed to the similarity in the trends shown between steelhead passed via the spillway and passing via all routes at John Day Dam. The differences between the relationships established for yearling chinook and steelhead passing via all routes at John Day Dam and the fact that the relationships between survival and total discharge, the proportion of total discharge as spill, and tail water elevation appeared stronger for spill passed yearling chinook than for fish passing via all routes may be partially explained by the behavioral differences observed between these species. For instance, Beeman et al. (2001a), found that yearling chinook were more apt to pass during periods of daytime spill when compared to steelhead. This result corroborates our findings that the average proportion of spill as discharge was lower (i.e., since more yearling chinook passed during the day and spill percentages were generally lower during the day than during the night) for yearling chinook than steelhead (Table 45). Further, no significant differences in spill passage efficiency (SPE) were detected between the two spill conditions for steelhead trout, but SPE was significantly higher for yearling chinook passing during the 30% day/53% night (Beeman et al. 2001a). Essentially, the evidence available to us suggests that the relationships between survival, total discharge, proportion of discharge as spill, and tail water elevation that were established for steelhead trout represent conditions primarily during the night spill condition whereas for yearling chinook, survival and the conditions experienced by yearling chinook also reflect conditions present during day spill.

When we examined the relationships between the survival of yearling chinook passing via all routes at John Day Dam and total discharge and the proportion of discharge as spill for each spill treatment, we detected a strong negative correlation between survival and total discharge and some indication that survival was positively related to the proportion of spill as discharge for fish passing during the 0% day/53% night spill condition but not for the 30% day/53% night condition. This result is the opposite of that observed for steelhead trout. Our hypothesis that survival of yearling chinook was related to FPE during the 0% day/53% night spill condition (which was related to the proportion of discharge as spill which in turn was related to total discharge) appears corroborated by our data. Given that fish passing through turbines generally survive at lower levels than fish passed via non-turbine routes, this result seems intuitive.

The significant negative relation between the survival and the proportion of discharge as spill for fish passing during the 30% day/53% night spill condition suggests that similar processes as that seen for steelhead may be occurring for yearling chinook that passed during this spill condition. This suggests that for yearling chinook passing during this spill block, survival was higher at lower spill percentages. Since spill percentages were consistently lower for the day spill condition (i.e., 30%) than for the night spill condition (i.e., 53%), the negative correlation between survival and the proportion of discharge as spill indicates that the survival of yearling chinook was not less for fish passing during the day. When this result is viewed in the context of the insignificant relation between survival and FPE for fish passing during this spill condition, the negative correlation between survival and the proportion of discharge as spill suggests that in the absence of the effects of reduced FPE, that the reduced discharge associated with higher spill percentages may be affecting the survival of yearling chinook in a similar fashion as that seen for steelhead. However, the insignificant relations between survival and FPE for yearling chinook passing during the 30% day/53% night condition may be a function of the range of values from which we assessed this relation (Figure 24). Similarly for steelhead trout, the fish passage efficiencies were generally high and may not have contained enough variation for a relation between survival and FPE to be detected. Releases 1 and 2, the paired releases that constituted the first the 0% day/53% night spill condition spill block in the experiment, obviously affect the nature of the relationship between survival and the proportion of spill and FPE, as they represent low values for each of these variables. Beeman et al. (2001a) similarly evaluated the effects of these two releases and conducted tests of FPE including and excluding these releases. When the releases for the first spill block were not included, there was no longer a significant difference in FPE between the two spill treatments for yearling chinook. For our evaluation, these releases provided a suitable range of values from which we were able to establish relationships between survival and these variables.

Our objective in evaluating survival at John Day Dam was to assess potential differences in survival given two different dam operation conditions. However, through an exploratory analysis of the conditions present during these two dam operations we found considerable variability in the conditions fish experienced as they passed this project within and between the two treatments. We demonstrated that the variability in total discharge, proportion of discharge as spill, and potentially tail water elevation may have affected the survival of fish and confounded the original intent of the experiment. The nature of our releases of treatment fish near Rock Creek, WA will preclude a direct assessment of survival during each particular spill condition (e.g., 30% day and 53% night) unless sufficient numbers of fish pass the project during each one of these conditions. Consequently we were not able to directly determine whether potential differences in survival could be attributed to decreased survival during the day. One alternative is to release predetermined numbers of fish directly through a given route and then assess survival through that route during a given dam operation as has been done at The Dalles Dam. This method has advantages in that survival during two or more different dam operations or two or more routes can be directly assessed. However, because our fish are released and pass through John Day Dam under a variety of conditions that affect not only the survival of fish through any given route of passage, but also affect the route taken, the nature of our releases also provides a realistic evaluation of the survival of juvenile salmonids as they pass through hydroelectric projects on the Columbia River. Dam operations that reduce discharges at night to store water for power generation (i.e., power peaking or load shaping) occur commonly throughout the basin. If releases are made at a particular time of the day throughout the experiment, the variability in the environmental conditions that occur during any particular treatment will not be fully represented. For instance, evaluating the survival of fish released at 2000 h during a 60% spill treatment may not adequately describe the survival of fish passing during this treatment throughout the night, if the environmental conditions vary considerably and predictably over this period (which they often do) to satisfy electric demand. Further, if two treatments are compared by releasing fish through a particular route and the particular release times chosen coincide so that the survival of fish is highest or lowest given the dam operations that typically occur during that time of day, differences between the two treatments could be exaggerated or diminished.

Survival estimates of yearling chinook salmon and steelhead trout generated from releases made near Rock Creek, WA, that were also used in the evaluation of the passage behavior of these species at John Day Dam (Beeman et al. 2001a) and the paired release-recapture evaluation of spillway and total project survival (this report), also allowed us to generate estimates of survival from Rock Creek, WA to John Day Dam, survival of the release groups through various stretches in between Rock Creek, WA a to near Lyle, WA, and also overall survival over this river reach. In general, survival from Rock Creek to John Day Dam was high for both yearling chinook salmon and steelhead. Our evaluation of the relation between forebay residence time and survival did not indicate that increased residence time resulted in lower survival from Rock Creek, WA to John Day Dam. Further, our attempts to relate forebay residence time to the survival of the paired release groups did not indicate any relation between forebay residence times and survival. However, the estimates generated are not measuring survival in the forebay of John Day Dam only, but survival over the reach from Rock Creek, WA to John Day Dam. Thus, the estimates will incorporate all potential sources of mortality over this distance and may obscure or overwhelm the mortality that occurs directly in the forebay.

The yearling chinook survival evaluation at The Dalles Dam suggested that the survival estimates generated using two different tags that can be used to uniquely identify individual fish (e.g., radio- and PIT-tags) and two different methods for assessing survival (e.g., relative recoveries and paired release-recapture) were similar. In general, the differences between the point estimates of survival from PIT- and radio-tagged yearling chinook were small. Trends shown by the estimates between the routes evaluated were similar with survival being highest for fish released into the ice and trash sluiceway and lowest for fish released through the various turbine units at the powerhouse. The 95% confidence intervals for the survival estimates generated from the radio-tag release were smaller than for the estimates generated from PIT-tag estimates, despite the fact that fewer radio-tagged fish than PIT-tagged fish were used in the evaluation. The smaller error estimates associated with the radio-tag releases, given the number of releases evaluated, are likely a result of the high detection probabilities possible with radio-telemetry systems when compared with detections of PIT-tagged fish at Bonneville Dam. In many instances, all fish released in the tailrace of The Dalles Dam (control group) were detected at the first array below this project. Similar to the results for PIT-tagged fish (Absalon et al. 2002), the survival of yearling chinook through the spillway and powerhouse were not significantly related to either spill or total discharge. One marginally significant result was detected suggesting that the survival of sluiceway passed fish was related to total discharge.

All of the average survival estimates generated from radio-tag releases were higher than for PIT-tagged yearling chinook salmon. One possible explanation for this result would be the hypothesis that larger fish are used in radio-tag evaluations because of the minimum size requirements associated with this tagging methodology. For this to be the cause of this result, PIT-tagged fish smaller than the minimum size required for radio-tag implantation would have to survive at levels less than that for larger radio-tagged fish. The survival of these smaller PIT-tagged fish would also have to be less than that for the same sized PIT-tagged fish released as controls, since the survival estimates represent the survival of treatment groups in relation to control groups released in the tailrace (e.g., if both the smaller sized Pit-tagged fish in the treatment and control groups had similar decreases in survival, than the ratio of treatment to control survival should be similar to that for radio-tagged fish because the decreases would cancel out). Since we are constrained by the size of fish that we can implant with radio-tags, we cannot assess the survival of fish smaller than that size and thus, have no way of testing that hypothesis using radio-tags.

One possible means for testing this hypothesis would be for the NMFS to eliminate all fish smaller than the minimum size required for radio-tagging and then rerun their estimates for the corresponding radio-tag releases. If the survival of the PIT-tagged fish smaller than the size required for radio-tagging is causing a decrease in the mean survival estimate, one would expect that the elimination of these fish would result in an increased estimate that will correspond with the point estimates of survival from the radio-tag releases. Another possible explanation would be the potential for differential survival between yearling chinook salmon and coho salmon. For our releases, only yearling chinook salmon were tagged whereas the NMFS also tagged and released coho salmon. To test whether this was the cause of the higher survival estimates for radio-tagged fish, the NMFS could eliminate all coho used in the releases made in conjunction with the USGS and then recalculate their estimates. Estimates generated from releases of PIT- and radio-tagged fish represent the mean of survival estimates from 13 releases made during 2000. As such, the estimates represent average values that have a corresponding error associated with them. The magnitude of the error estimates affect the range of values over which there is a certain probability that we can expect the estimates of the mean from repeated experiments to be. Thus, it is also possible that if the experiment were conducted again, the average estimate of survival generated from the two tagging techniques could be more or less similar and the trends shown between the two estimates for each of the three routes could be different, given the potential sampling variability associated with having different crews conduct the experiment on different samples of fish.

The estimates generated from radio- and PIT-tagged sub-yearling chinook were not as comparable as those generated for yearling chinook salmon. In general, the estimates generated from release of radio-tagged fish had large confidence intervals and did not exhibit the same trends as those shown for PIT-tagged fish. The number of releases we made was constrained by the availability of the small (nano-) coded radio-tags that were used to tag sub-yearling chinook. Consequently, we were only able to make 9 releases in conjunction with the NMFS. The small number of releases and the poor survival of our treatment and control groups compared to that of yearling chinook over the same distance, likely contributed to the variability in our survival estimates. However given the large confidence intervals associated with both the PIT- and radio-tag estimates, comparisons of the estimates generated from the two tagging methodologies seems questionable and of little value. However, the estimates generated during 2000 will be incorporated into the design of the work for 2001 and will provide a means to continue to improve our experiments in the future. No significant relations between the survival of sub-yearling chinook and total and spill discharge were detected.

We demonstrated that the release and detection schemes employed at John Day and The Dalles dams can be used to estimate survival through Bonneville Dam and in the lower Columbia River. Of particular interest were the high capture probabilities associated with radio-telemetry arrays in the un-impounded lower Columbia River, an area that we have had no prior experience working until 2000. Releases of yearling and sub-yearling chinook salmon have provided us with preliminary estimates of the survival and capture probabilities associated with conducting evaluations of the survival in this area of the lower Columbia River. As previously mentioned, dead radio-tagged steelhead were detected at array below Bonneville Dam indicating that the arrays used during 2000 will have to be moved further downstream to avoid the possibility of false positive detections in the future. During 2001,we will incorporate the information gathered during 2000 and continue our evaluation of survival through Bonneville Dam.

Acknowledgements

We thank Mike Langeslay, Rock Peters, and Blaine Ebberts and other personnel at the Army Corps of Engineers for their assistance in administering our contract and assisting with the logistics involved with coordinating this research at the John Day, The Dalles, and Bonneville dams. We also thank the countless staff at the Columbia River Research Laboratory who participated in the planning and collection and processing of the data associated with these studies. We also acknowledge the assistance of the administrative staff at the Columbia River Research Laboratory for their support in managing the contracts for this research.

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