U.S. Army Corps of Engineers
Portland District

Survival Estimates of migrant Juvenile Salmonids in the Columbia River through John Day Dam using Radio-Telemetry, 2003.

Final Report of Research
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Prepared by:

Timothy D. Counihan
Glen S. Holmberg
Christopher E. Walker
and
Jill M. Hardiman

United States Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
Cook, WA 98605

Prepared for:

U.S. Army Corps of Engineers
Portland District
Planning and Engineering Division
Environmental Resources Branch
Robert Duncan Plaza
333 S.W. 1st Avenue
Portland, Oregon 97204-3495

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Executive Summary

During 2003, the USGS Columbia River Research Laboratory continued evaluations of the survival yearling and subyearling Chinook salmon at John Day Dam. The objectives of these evaluations were to estimate and compare the survival probabilities of yearling and subyearling Chinook salmon through the juvenile bypass, spillway, and turbines at John Day Dam during different dam operations. For yearling Chinook salmon, survival was evaluated during 0% day/60% night and 0% day/45% night spill operations. For subyearling Chinook salmon, survival was evaluated during 0% day/60% night and 30% day/30% night spill operations. Releases of radio-tagged fish were comprised of site-specific releases through the juvenile bypass and turbine unit 4 at the powerhouse and releases of radio-tagged fish upstream of John Day Dam near Rock Creek, WA and in the John Day Dam tailrace. The radio-tagged fish were then interrogated using radio-telemetry systems at and below John Day Dam. The capture histories generated were then processed and analyzed using the paired release-recapture models of Burnham et al. (1987) for the site-specific releases and the Route Specific Survival Model for fish released above John Day Dam near Rock Creek, WA (Skalski et al. 2002).

Yearling Chinook salmon

Paired Release Recapture Model

Juvenile Bypass

We estimated that the survival of yearling Chinook salmon released through the John Day Dam juvenile bypass during 2003 ranged from 0.564 to 1.02. The average survival of yearling Chinook salmon released through the John Day Dam juvenile bypass during the 2003 migration season was 0.805 (± 0.040, 95% confidence interval). Survival of yearling Chinook through the juvenile bypass during the 60% night spill operations was estimated to be 0.764 (± 0.051, 95% confidence interval) and 0.848 (± 0.056, 95% confidence interval) during the 45% night spill operation. The estimated survival of yearling Chinook salmon during the 60% night spill operation was found to be significantly different than the estimated survival during the 45% spill operation (*t*-test, $P = 0.034$).

Turbine Unit 4

We estimated that the survival of yearling Chinook salmon released through turbine unit 4 at the John Day Dam powerhouse during both the 45% night and 0% day spill operations during 2003 ranged from 0.707 to 1.00. The average survival of yearling Chinook salmon released through turbine unit 4 during the 2003 migration season was 0.851 (± 0.040, 95% confidence interval). The survival probability of yearling Chinook released through turbine unit 4 during the 45% night spill operations was 0.807 (± 0.035, 95% confidence interval) and was 0.891 (± 0.062, 95% confidence interval) during the

0% day spill operations. The survival probabilities for yearling Chinook salmon released into turbine unit 4 during the 45% night and 0% day spill operations were found to be statistically different (variance weighted *t*-test, $P = 0.0353$). A variance-weighted *t*-test was used because unequal variances were indicated by all of Bartlett's, Brown-Forsythe, and Levene's tests for equal variance.

Route Specific Survival Model

During the 0% day/60% night spill operations, the survival of yearling Chinook salmon through the John Day Dam spillway was estimated to be 0.934 (SE = 0.0160; profile likelihood 95% confidence interval = [0.900, 0.963]). For yearling Chinook passing the juvenile bypass during the 0% day/60% night spill operations the estimated survival probability was 1.02 (SE = 0.009, profile likelihood 95% confidence interval [0.997, 1.036]) and for fish passing via the turbines the estimated survival was 0.820 (SE = 0.043, profile likelihood 95% confidence interval [0.729, 0.896]). The dam survival probability during the 0% day/60% night spill operations was estimated to be 0.940 (SE = 0.021).

During the 0% day/45% night spill operations, the survival of yearling Chinook salmon through the John Day Dam spillway was estimated to be 0.939 (SE = 0.016; profile likelihood 95% confidence interval = [0.903, 0.967]). For yearling Chinook passing the juvenile bypass during the 0% day/45% night spill operations the estimated survival probability was 0.988 (SE = 0.012, profile likelihood 95% confidence interval [0.959, 1.008]) and for fish passing via the turbines the estimated survival was 0.764 (SE = 0.046, profile likelihood 95% confidence interval [0.667, 0.847]). The dam survival probability during the 0% day/45% night spill operations was estimated to be 0.923 (SE = 0.024).

The estimated survival probabilities for yearling Chinook salmon passing via the spillway and turbines at John Day Dam were not found to be statistically different during the 0% day/60% night spill than for the 0% day/45% night spill operations (Table 10). However, the estimated survival probability for fish passing via the John Day Dam juvenile bypass during the 0% day/60% night spill operations was statistically different than during the 0% day/45% night spill operations (Z-test, $Z = 2.067$). The dam survival probability was not statistically different during the 0% day/60% night and 0% day/45% night spill operations (Table 10).

Subyearling Chinook salmon

Route Specific Survival Model

During the 0% day/60% night spill operations, the survival of subyearling Chinook salmon through the John Day Dam spillway was estimated to be 0.901 (SE = 0.012; profile likelihood 95% confidence interval = [0.877, 0.922]). For subyearling Chinook passing the juvenile bypass during the 0% day/60% night spill operations the estimated survival probability was 0.892 (SE = 0.018, profile likelihood 95% confidence

interval [0.855, 0.924]) and for fish passing via the turbines the estimated survival was 0.719 (SE = 0.024, profile likelihood 95% confidence interval [0.671, 0.764]). The dam survival probability during the 0% day/60% night spill operations was estimated to be 0.845 (SE = 0.016).

During the 30% day/30% night spill operations, the survival of subyearling Chinook salmon through the John Day Dam spillway was estimated to be 0.955 (SE = 0.008; profile likelihood 95% confidence interval = [0.938, 0.970]). For subyearling Chinook passing the juvenile bypass during the 30% day/30% night spill operations the estimated survival probability was 0.921 (SE = 0.020, profile likelihood 95% confidence interval [0.877, 0.955]) and for fish passing via the turbines the estimated survival was 0.722 (SE = 0.024, profile likelihood 95% confidence interval [0.673, 0.767]). The dam survival probability during the 30% day/30% night spill operations was estimated to be 0.886 (SE = 0.014).

The estimated survival probabilities for subyearling Chinook salmon passing via the spillway and turbines at John Day Dam were not found to be significantly different during the 0% day/60% night spill than for the 30% day/30% night spill operations (Table 13). However, both the spillway (Z-test; $Z = 3.86$) and dam (Z-test; $Z = 1.86$) survival probabilities were found to be significantly different. The estimated spillway and dam survival probability were higher during the 30% day/30% night spill operations.

Executive Summary Table

The survival probabilities generated from the evaluations of survival of yearling and subyearling Chinook salmon are presented in a summary table (see below). This table is provided as a reference as per discussions with and requests by the Study Review Workgroup.

Executive Summary Table. The estimated survival probabilities and 95% confidence intervals associated with radio-tagged yearling and subyearling Chinook salmon released directly into the juvenile bypass and turbine unit 4 at John Day Dam (paired release-recapture model) and above John Day Dam near Rock Creek, WA (route specific survival model) and in the tailrace of John Day Dam. See text of this report for details.

	Paired release-recapture model	
	Yearling Chinook	
	Juvenile bypass	
Treatment	S	95% CI
60% night spill	0.764	± 0.051
45% night spill	0.848	± 0.056
	Turbine	
	S	95% CI
45% night spill	0.807	± 0.035
0% day spill	0.891	± 0.062

	Route Specific Survival Model			
	Yearling Chinook		Subyearling Chinook	
	Spillway			
Treatment	S	95% CI [A]	S	95% CI [A]
0% day/60% night	0.934	0.900, 0.963	0.901	0.877, 0.922
0% day/45% night	0.939	0.903, 0.967	NA	NA
30% day/30% night	NA	NA	0.955	0.938, 0.970
	Powerhouse (unguided)			
	S	95% CI [A]	S	95% CI [A]
0% day/60% night	0.820	0.729, 0.896	0.719	0.671, 0.764
0% day/45% night	0.764	0.667, 0.847	NA	NA
30% day/30% night	NA	NA	0.722	0.673, 0.767
	Juvenile bypass (guided)			
	S	95% CI [A]	S	95% CI [A]
0% day/60% night	1.019	0.996, 1.036	0.892	0.855, 0.924
0% day/45% night	0.988	0.959, 1.008	NA	NA
30% day/30% night	NA	NA	0.921	0.877, 0.916
	Dam (all routes)			
	S	95% CI	S	95% CI
0% day/60% night	0.940	± 0.041	0.845	± 0.031
0% day/45% night	0.922	± 0.047	NA	NA
30% day/30% night	NA	NA	0.886	± 0.030

[A] – Profile likelihood 95% confidence interval

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) 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 increased 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. 1998, 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, however, precluded survival estimation in some specific reaches of the Columbia River and limited 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 2001, the USGS evaluated the survival of radio-tagged yearling and subyearling Chinook salmon and steelhead trout through the juvenile bypass at John Day Dam. Evaluations of survival through John Day Dam continued during 2002. We estimated the survival probabilities for fish passing via the juvenile bypass system, the spillway, and the turbines during 12 and 24 h spill operations. Site-specific releases were made directly into specific passage routes (e.g., the juvenile bypass and spillway). Releases of radio-tagged juvenile salmonids were also made upstream of John Day Dam near Rock Creek, WA and in the tailrace of John Day Dam. Both of these release scenarios were used to estimate survival probabilities at John Day Dam during 2002.

During 2003, the USGS Columbia River Research Laboratory continued evaluations of the survival of yearling and subyearling Chinook salmon at John Day Dam. The objectives of these evaluations were to estimate and compare the survival probabilities of yearling and subyearling Chinook salmon through the juvenile bypass, spillway, and turbines at John Day Dam during different dam operations. For yearling Chinook salmon, survival was evaluated during 0% day/60% night and 0% day/45% night spill operations. For subyearling Chinook salmon, survival was evaluated during 0% day/60% night and 30% day/30% night spill operations. During 2003, a combination of site-specific releases through the juvenile bypass and Turbine unit 4 at the powerhouse and releases of radio-tagged fish upstream of John Day Dam near Rock Creek, WA and in the John Day dam tailrace were used. The radio-tagged fish were then interrogated using radio-telemetry systems at and below John Day Dam. The capture histories generated were then processed and analyzed using the paired release-recapture models of Burnham et al. (1987) for the site-specific releases and the Route Specific Survival Model for fish released above John Day Dam near Rock Creek, WA (Skalski et al. 2002).

Methods

Study Area

The study area extended from the release location near Rock Creek downriver to the Hood River Bridge (Figure 1). During the 2003 spring juvenile salmonid migration, radio-tagged juvenile yearling Chinook salmon were released 23 km upriver of John Day Dam near Rock Creek, WA (river kilometer (RK) 367.7), directly into the John Day Dam juvenile bypass system, into turbine unit 4, and in the tailrace. During the summer migration season, subyearling Chinook salmon were released near Rock Creek and into the tailrace of John Day Dam. Antenna arrays within the study area were located on the John Day Dam (RK 346.9), the Biggs Bridge (RK 335.0), the Celilo Railroad Bridge (RK 323.7), The Dalles Dam (RK 308.1), near the town of Lyle, WA (RK 286.4), and on the Hood River Bridge (RK 273.2). All detection arrays spanned the breadth of the river channel. Arrays at dams were set up so that passage through various routes could be determined (Beeman et al. 2001a, Beeman et al. 2001b).

The John Day Dam consists of a powerhouse, a spillway, and a navigation lock (Figure 2). The powerhouse consists of 16 Kaplan turbine units, each with three intakes. Traveling screens in front of the turbine intakes divert migrating juvenile salmonids away from the turbines and into a juvenile bypass conveyance flume. The flume terminates over the tailrace on the south shore. At the north end of the powerhouse, four unused skeleton bays are reserved for future expansion. The spillway consists of 20 spillbays. Adult fish ladders are located on the Oregon (south) shore, and the Washington (north) side of the river between the spillway and the navigation lock.

System Antenna Configuration

Antenna arrays used to monitor movements and passage location of radio-tagged fish released at Rock Creek and John Day Dam consisted of 4-element Yagi aerial antennas placed on the forebay and tailrace sides of the dam and dipole underwater antennas on the forebay side, and stripped coaxial underwater antennas in the juvenile bypass system (Figure 3). We placed 10 aerial antennas on the forebay spillbays, and 12 aerial antennas on the forebay turbine bays, and 4 aerial antennas on the forebay navigational lock. Each aerial antenna covering the spillway and powerhouse was directed 45° away from the dam and provided coverage for two adjacent bays. Additionally, two barges were anchored in the forebay at the boat restricted zone boundary, with two aerial antennas on each barge. We placed 10 aerial antennas on the tailrace spillway, 10 on the powerhouse tailrace, and 10 on the juvenile bypass outfall. Detection range for aerial antennas was approximately 100 m but varies with the depth of the transmitter in the water column. See Beeman et al. (2004) for a comparison of underwater antennas. A total of 78 underwater antennas were attached to the spillway pier noses, and 88 underwater antennas monitored the powerhouse intakes and traveling screens. An additional 20 underwater antennas were mounted in the juvenile bypass conveyance flume. Underwater antennas were used to

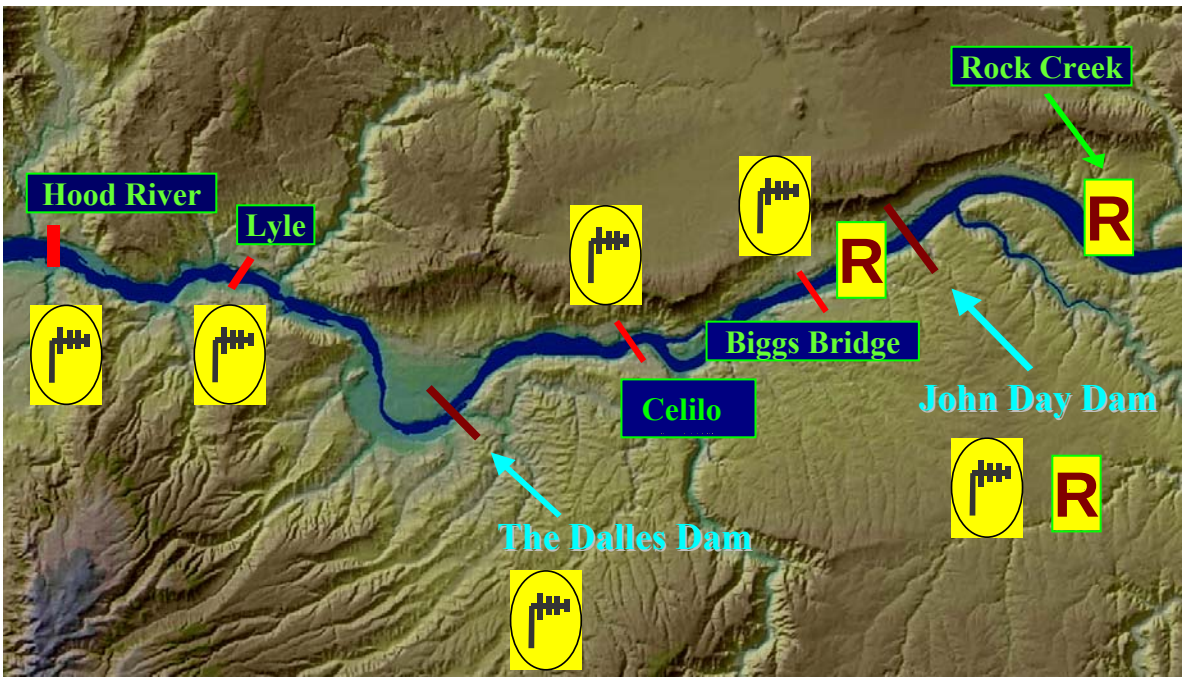

Figure 1. Release and detection locations for the John Day Dam survival evaluations, 2003. R = release locations and locations of radio-telemetry arrays are shown as yellow antenna symbols.

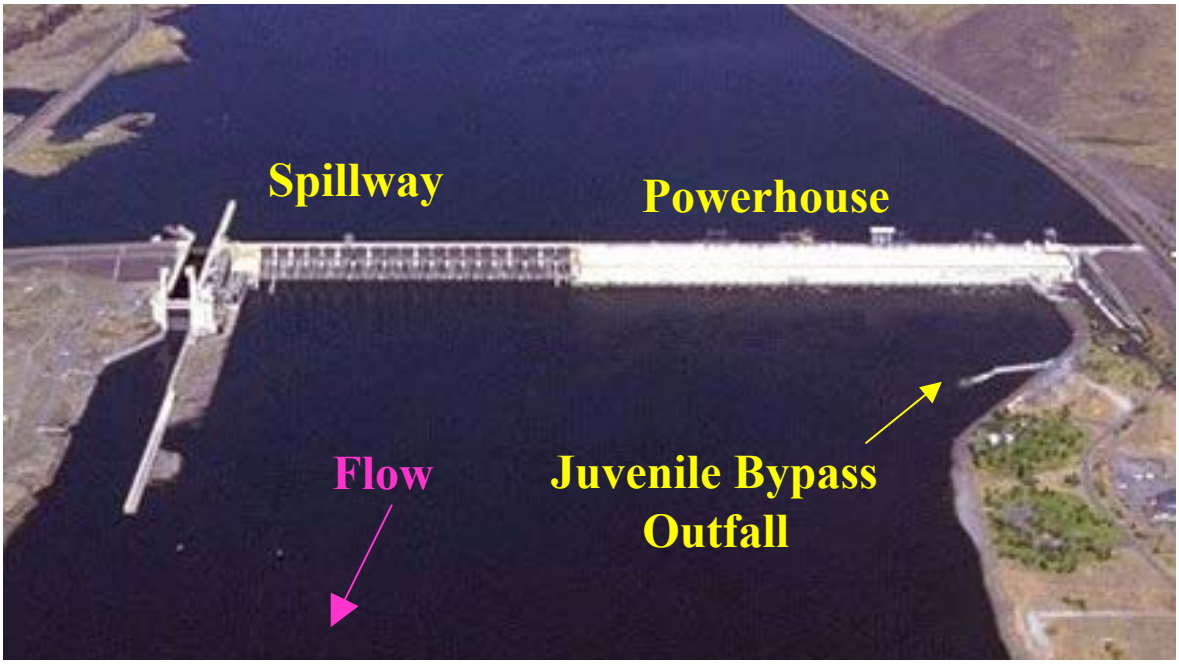

Figure 2. Aerial view of John Day Dam looking upriver (East).

Figure 3. Locations of radio-telemetry antennas at the John Day Dam during 2003. Black arrows show approximate locations of aerial antennas and red dots locations of underwater antennas.

interrogate and monitor radio-tagged fish (range ~ 10 m) of the turbine intakes, traveling screens, spillway tainter gates, and within the juvenile bypass system.

Antennas were connected to SRX-400 data logging telemetry receivers (Lotek Wireless, Newmarket, Ontario, Canada), Digital Spectrum processors (Lotek Wireless), or a Mutiprotocol Integrated Telemetry Acquisition System (MITAS; Grant Systems Engineering, King City, Ontario, Canada). Data logging devices stored detection histories for individual radio-tagged fish and were downloaded to a laptop computer every two to four days.

Test Conditions

To evaluate the efficacy of different water management strategies and spill discharge on the survival of juvenile salmonids passing John Day Dam, the Army Corps of Engineers planned to modify spill and project discharge during 22 4-day blocks, from 24 April to 22 July, 2003. These dam operations were to consist of two different spill conditions within each block, each lasting two days. The treatments were then randomized within the 4-day blocks. For both the spring and summer migrations seasons, the first prescribed treatment was to consist of no spill discharge from 0600 to 1800 h (day) and 60% discharge from 1800 to 0559 h (night) and is referred to as 0% day/ 60% night. During the spring migration, the second treatment was to consist of no spill discharge from 0600 to 1759 h (day) and 45% discharge from 1800 to 0559 h (night) and is referred to as 0% day/45% night. During the summer migration, the second

treatment was to consist of 30% spill discharge from 0600 to 1759 h (day) and 30% discharge from 1800 to 0559 h (night) and is referred to as 30% day/30% night. Releases of radio-tagged yearling Chinook salmon and subyearling Chinook salmon from near Rock Creek, WA were timed so that they arrived at John Day Dam during both spill conditions.

Radio Transmitters

We used pulse-coded transmitters (tags) manufactured by Lotek Wireless, Inc, (Newmarket, Ont.). Transmitters operated at frequencies between 150.320 and 150.760 MHz and used the Lotek Wireless "2000 code set", a pulse-coding scheme with 212 unique codes per frequency that allowed each individual fish to be recognized. A radio signal was emitted every 2 seconds. Two sizes of these transmitters were used to accommodate the different sizes of the spring and summer migrants. Transmitters implanted in yearling Chinook salmon were 7.3 mm in diameter x 18.0 mm in length and weighed 1.4 g in air (Lotek Wireless model 3KM) and those implanted in subyearling Chinook salmon were 6.3 mm x 4.5 mm x 14.5 mm long and weighed 0.85 g in air (Lotek Wireless model NTC-3-1). Expected battery life was 8 days for the KM tags and 8 days in the NTC tag.

Fish Tagging

Staff from the Pacific States Marine Fisheries Commission collected yearling and subyearling Chinook salmon to be implanted with radio transmitters at the juvenile collection and bypass facility at John Day Dam. Fish were typically held at the collection facility for 12 to 24 h prior to tagging. Fish were considered suitable for tagging if they were free of injuries, severe descaling, external signs of gas bubble trauma, or other abnormalities and met established length and weight criteria (Appendix 1). Transmitters were gastrically implanted using the methods of Martinelli et al. (1998). Following tagging, fish were held in 5 gal tanks, two fish per tank, at the juvenile bypass collection facility for 20 to 28 h. After the holding period, the tanks were checked for mortalities and fish were transported either to Rock Creek and released into the north river channel or were released at John Day Dam.

Releasing Radio-tagged Fish

Radio-tagged fish used to determine route specific survival at John Day Dam were released from a boat into the Columbia River at mid channel near Rock Creek, Washington. Radio-tagged fish used to determine site-specific survival at John Day Dam were released into the upstream end of the juvenile bypass system through a hose 10 cm in diameter placed in the air vent above turbine unit 15. Fish were also released directly into turbine unit 4. Refer to Beeman et al. (2001a) for specifics of the spillway release system. Control fish for route specific and site specific evaluations were released into the John Day Dam tailrace from a boat, 1 km downriver from the dam. The release site was positioned between the new north navigation buoy and the public boat ramp at a depth finder reading of 18.3 meters.

To release fish into turbine unit 4, fish were transported from the holding facility to a 200 gal release tank on the powerhouse forebay deck. Fish were released through a 10 cm diameter hose and delivered to the C slot of turbine unit four, two at a time, allowing 10 to 15 minutes between releases. Water was flushed through the hose after the last release.

Release Strategy

Releases at Rock Creek consisted of 40 groups of approximately 35 yearling Chinook salmon, and 56 groups of 70 subyearling Chinook salmon. Releases occurred at 0900 h and 2100 h (Tables 1 and 2).

Releases at John Day Dam consisted of yearling and subyearling Chinook salmon (Tables 3-6). Releases were also made in the tailrace of John Day Dam to form the paired release groups evaluated using the paired release recapture model. Yearling Chinook salmon were released into the bypass during 40 separate releases of approximately 40 fish per release at each location. Juvenile bypass releases occurred at 2300 h (Table 2). Yearling Chinook salmon were also released into turbine unit 4 during 21 separate releases of approximately 25 fish per release (Table 3). Tailrace releases were timed so that fish would enter the tailrace at the same time as fish released into the bypass or turbine. All bypass and turbine releases had corresponding tailrace releases. Additional tailrace releases were used as control groups for fish released at Rock Creek (Table 4). Subyearling Chinook salmon were released into the tailrace during 56 separate releases of approximately 50 fish per release at each location. Releases occurred at 2300 and 1100 h (Table 5).

Converting Radio Signals into Detection Histories

Aerial and underwater antennas attached to data logging equipment will record spurious radio signals or "noise" and designate them as such, or misinterpret other radio signals (e.g., from cars or trucks) and designate them with channel and code designations. After data collection, radio signals had to be interpreted and converted into detection histories. Data were processed using a combination of Statistical Analysis System (SAS) data processing programs and manual proofing. For instance, signals designated as noise were removed through the use of code in SAS and signals with time stamps recorded before the time of release were also discarded. Detection data were then merged with release data, records were proofed using SAS programs that assigned passage and location designators, and rejected records that did not meet minimum power thresholds, and/or travel time, geographic ranking, and residence time criteria established from previous years data. Records that did not meet the automatic proofing criteria were identified and then manually examined by a proofing staff member and designated with a passage location and time, and then reconciled by a second staff member if any disagreement in either the time of passage or passage location were noted.

Table 1. Release date, time, and number (N) of yearling Chinook salmon released into the Columbia River near Rock Creek, Washington, spring 2003.

Release	N	Date	Time
1	31	27 April	20:44
2	33	28 April	09:04
3	26	29 April	20:53
4	34	30 April	09:18
5	33	1 May	20:46
6	27	2 May	08:57
7	32	3 May	20:37
8	34	4 May	09:43
9	35	5 May	21:32
10	30	6 May	09:02
11	35	7 May	20:57
12	37	8 May	09:08
13	33	9 May	21:14
14	34	10 May	09:00
15	37	11 May	21:00
16	35	12 May	09:09
17	38	13 May	21:08
18	37	14 May	09:00
19	34	15 May	21:00
20	33	16 May	09:04
21	35	17 May	21:00
22	35	18 May	09:10
23	37	19 May	21:00
24	38	20 May	09:00
25	37	21 May	20:30
26	37	22 May	09:10
27	37	23 May	20:15
28	38	24 May	08:45
29	36	25 May	20:54
30	38	26 May	08:35
31	38	27 May	20:28
32	37	28 May	10:45
33	35	29 May	20:50
34	36	30 May	08:49
35	35	31 May	21:00
36	34	1 June	09:00
37	36	2 June	20:52
38	34	3 June	09:05
39	34	4 June	20:40
40	34	5 June	08:50
Overall:	1389		

Table 2. Release date, time, and number (N) of yearling Chinook salmon released into the John Day Dam juvenile bypass and tailrace, spring 2003.

Paired	Juvenile bypass			Tailrace		
Release	N	Date	Time	N	Date	Time
1	37	04/28/03	23:07	39	04/28/03	23:53
2	39	04/29/03	22:50	37	04/29/03	23:37
3	38	04/30/03	23:56	36	05/01/03	00:46
4	38	05/01/03	23:12	38	05/01/03	23:54
5	39	05/02/03	23:25	39	05/03/03	00:06
6	39	05/03/03	22:55	40	05/03/03	23:37
7	40	05/04/03	23:42	38	05/05/03	00:24
8	35	05/05/03	23:12	39	05/05/03	23:53[a]
9	40	05/06/03	23:14	38	05/06/03	23:52[a]
10	40	05/07/03	23:04	39	05/07/03	23:44
11	39	05/08/03	23:03	40	05/08/03	23:38
12	39	05/09/03	22:57[a]	40	05/09/03	23:31
13	39	05/10/03	23:32	40	05/11/03	00:09
14	39	05/11/03	23:02	40	05/11/03	23:41
15	40	05/12/03	23:19	40	05/13/03	00:02
16	40	05/13/03	22:57[a]	37	05/13/03	23:39
17	40	05/14/03	22:53	40	05/14/03	23:37
18	38	05/15/03	23:19	39	05/15/03	23:52
19	37	05/16/03	23:25	39	05/16/03	23:55
20	39	05/17/03	23:13	39	05/17/03	23:48
21	39	05/18/03	22:59[a]	40	05/18/03	23:37
22	38	05/19/03	23:01	40	05/19/03	23:39
23	38	05/20/03	23:40	37	05/21/03	00:23
24	40	05/21/03	23:06	40	05/21/03	23:39
25	39	05/22/03	23:10	38	05/22/03	23:47
26	40	05/23/03	23:03	40	05/23/03	23:42
27	39	05/24/03	23:33	39	05/25/03	00:08
28	40	05/25/03	23:04	40	05/25/03	23:39
29	40	05/26/03	23:36	40	05/27/03	00:13
30	38	05/27/03	23:17	40	05/27/03	23:58[a]
31	40	05/28/03	23:11	38	05/28/03	23:48
32	39	05/29/03	23:37	39	05/30/03	00:12
33	40	05/30/03	23:58[a]	40	05/31/03	00:42
34	40	05/31/03	22:59[a]	37	05/31/03	23:35
35	39	06/01/03	23:18	39	06/02/03	00:00
36	40	06/02/03	23:11	40	06/02/03	23:51
37	40	06/03/03	23:47	40	06/04/03	00:25
38	40	06/04/03	23:26	39	06/05/03	00:00
39	39	06/05/03	23:01	39	06/05/03	23:41
40	40	06/06/03	23:05	40	06/06/03	23:37
Overall:	1,563			1,562		

[a]- Release extends into the following day.

Table 3. Release date, time, and number (N) of yearling Chinook salmon released into turbine unit 4 and the tailrace at John Day Dam, spring 2003.

Paired	Turbine unit 4			Tailrace		
Release	N	Date	Time	N	Date	Time
1	24	04/30/03	23:27	36	04/30/03	11:46
2	25	05/01/03	11:01	25	05/01/03	11:45
3	25	05/04/03	23:08	38	05/04/03	00:24
4	23	05/05/03	11:03	25	05/05/03	12:03
5	23	05/06/03	22:50	38	05/06/03	23:53
6	25	05/07/03	10:45	26	05/07/03	11:37
7	25	05/10/03	22:59[a]	40	05/10/03	00:10
8	25	05/11/03	11:07	24	05/11/03	12:09
9	23	05/16/03	22:57	39	05/16/03	23:55
10	25	05/17/03	11:04	26	05/17/03	12:00
11	25	05/20/03	23:10	37	05/20/03	00:23
12	25	05/21/03	10:56	26	05/21/03	12:00
13	25	05/24/03	23:03	39	05/24/03	00:08
14	25	05/25/03	11:05	26	05/25/03	12:18
15	25	05/26/03	23:04	40	05/26/03	00:13
16	25	05/27/03	11:05	26	05/27/03	12:02
17	25	05/30/03	23:22	40	05/30/03	00:42
18	23	05/31/03	10:50	25	05/31/03	11:41
19	24	06/03/03	11:03	25	06/03/03	12:02
20	24	06/03/03	23:16	40	06/03/03	00:26
21	25	06/04/03	11:06	26	06/04/03	12:00
Overall:	514			667		

[a]: Release extends into the following day.

Table 4. Release date, time, and number (N) of yearling Chinook salmon released into the tailrace at John Day Dam, spring 2003. The releases in this table were additional releases made to compliment releases made near Rock Creek, WA.

Release	N	Date	Time
1	26	29 April	11:43
2	22	3 May	11:00
3	27	9 May	11:27
4	27	13 May	11:03
5	24	15 May	11:25
6	27	19 May	11:37
7	28	23 may	11:09
8	26	29 May	11:00
9	27	2 June	11:00
10	26	6 June	10:59
Overall:	260		

Table 5. Release date, time, and number (N) of subyearling Chinook salmon released into the Columbia River near Rock Creek, Washington, and into the tailrace at John Day Dam tailrace, summer 2003.

	Rock Creek			JDA Tailrace		
Release	N	Date	Time	N	Date	Time
1	59	22 June	09:31	51	23-Jun	11:18
2	71	22 June	21:30	45	23-Jun	23:12
3	65	23 June	09:00	49	24-Jun	11:28
4	66	23 June	21:36	55	24-Jun	23:18
5	75	24 June	09:10	50	25-Jun	11:24
6	67	24 June	21:15	49	25-Jun	23:59[a]
7	72	25 June	08:55	51	26-Jun	11:22
8	67	25 June	21:25	50	26-Jun	23:28
9	72	26 June	09:13	51	27-Jun	11:15
10	70	26 June	21:20	52	27-Jun	23:08
11	72	27 June	09:00	50	28-Jun	11:17
12	70	27 June	20:53	48	28-Jun	23:21[a]
13	73	28 June	08:50	51	29-Jun	11:10
14	70	28 June	20:35	49	29-Jun	23:15
15	75	29 June	09:07	47	30-Jun	11:19
16	72	29 June	21:08	50	30-Jun	23:09
17	69	30 June	08:47	50	1-Jul	11:19
18	69	30 June	20:52	55	1-Jul	23:22
19	68	01 July	09:04	52	2-Jul	11:06
20	70	01 July	21:00	54	2-Jul	23:14
21	73	02 July	08:41	29	3-Jul	11:13
22	67	02 July	21:00	49	3-Jul	23:14
23	62	03 July	09:05	48	4-Jul	11:09
24	71	03 July	20:30	50	4-Jul	23:14
25	72	04 July	09:20	57	5-Jul	11:14
26	76	04 July	20:15	51	5-Jul	23:19
27	75	05 July	09:20	51	6-Jul	11:12
28	73	05 July	20:30	47	6-Jul	23:16
29	74	06 July	09:00	49	7-Jul	11:17
30	76	06 July	20:45	49	7-Jul	23:12
31	73	07 July	08:40	49	8-Jul	11:04
32	76	07 July	21:10	49	8-Jul	23:16
33	75	08 July	09:00	51	9-Jul	11:12
34	74	08 July	21:00	46	9-Jul	23:19
35	75	09 July	08:36	51	10-Jul	11:21
36	76	09 July	20:30	49	10-Jul	23:25
37	74	10 July	08:46	50	11-Jul	11:17
38	69	10 July	21:00	51	11-Jul	23:08
39	72	11 July	09:22	50	12-Jul	11:08
40	75	11 July	20:44	58	12-Jul	23:06
41	76	12 July	09:08	58	13-Jul	11:13
42	76	12 July	20:55	56	13-Jul	23:21
43	75	13 July	08:55	56	14-Jul	11:17
44	75	13 July	20:45	52	14-Jul	23:18
45	76	14 July	09:05	47	15-Jul	11:10
46	75	14 July	21:00	49	15-Jul	23:15
47	76	15 July	08:40	46	16-Jul	11:19
48	76	15 July	20:55	47	16-Jul	23:11

[a] - Release extends into the following day.

Table 5 (continued). Release date, time, and number (N) of subyearling Chinook salmon released into the Columbia River near Rock Creek, Washington, and into the tailrace at John Day Dam tailrace, summer 2003.

	Rock Creek			JDA Tailrace		
Release	N	Date	Time	N	Date	Time
49	126	16 July	09:12	49	17-Jul	11:18
50	75	16 July	20:50	53	17-Jul	23:16
51	73	17 July	08:33	50	18-Jul	11:22
52	99	17 July	20:53	54	18-Jul	23:13
53	73	18 July	08:45	47	19-Jul	11:06
54	74	18 July	20:45	52	19-Jul	23:17
55	74	19 July	08:34	52	20-Jul	11:11
56	73	19 July	21:04	53	20-Jul	23:12
Overall:	4,122			2,814		

Statistical Methods

Paired-release Recapture Model

We used the paired-release recapture models of Burnham et al. (1987) to estimate the relative survival of juvenile yearling and subyearling Chinook salmon through the juvenile bypass at John Day Dam. The models of Cormack (1964), Jolly (1965), and Seber (1965) were also used to estimate the survival of yearling and subyearling Chinook salmon from John Day Dam to a radio-telemetry array in Bonneville Reservoir. 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 et al. 1998, 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.

Survival was estimated from paired releases by the expression:

$$\hat{S} = \frac{\hat{S}_{11}}{\hat{S}_{21}} \tag{1}$$

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

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

where $\hat{S}_{11} =$ survival estimates for fish released above the project of interest 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

$$\frac{S_{11}}{S_{21}} = \frac{S \cdot S_{21}}{S_{21}} = S \tag{3}$$

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:

		Release	
		R_1	R_2
Day of detections	1		
	2		
	3		
	⋮		
	D		

For each paired-release (R_1 and R_2), a chi-square test of homogeneity was performed at $\alpha = 0.10$. 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 $\alpha_{EW} = 0.10$ pertaining specifically to each paired-release recapture evaluation conducted at John Day Dam (Dunn-Sidak method, Sokal and Rohlf, 1995).

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.

We evaluated *t*-tests to compare the estimated survival of yearling Chinook salmon released through the John Day Dam juvenile bypass. The specific hypotheses tested were:

<u>Yearling Chinook</u>

$$H_0 : S_{JUVENILE\ BYPASS\ 60\%} = S_{JUVENILE\ BYPASS\ 45\%}$$

$$H_A : S_{JUVENILE\ BYPASS\ 60\%} \neq S_{JUVENILE\ BYPASS\ 45\%}$$

Bartlett's, Brown-Forsythe, and Levene's tests for equal variance were evaluated for each comparison and where suggested by the results of these tests, variance weighted *t*-tests were evaluated. The hypotheses were formulated to address the assumption that the spill levels outlined in the NMFS Biological Opinion would result in higher survival of juvenile salmonids passing John Day Dam (Mike Langeslay, Portland District, Army Corps of Engineers, personal communication).

We also evaluated t-tests to compare the estimated survival of yearling Chinook salmon released through turbine unit 4 at the John Day Dam powerhouse during both the 45% night and 0% day spill operations. The specific hypotheses tested were:

<u>Yearling Chinook</u>

$$H_0 : S_{TURBINE\,UNIT\,4\ \ 45\%\ NIGHT} = S_{TURBINE\,UNIT\,4\ \ 0\%\ DAY}$$

$$H_A : S_{TURBINE\,UNIT\,4\ \ 45\%\ NIGHT} \neq S_{TURBINE\,UNIT\,4\ \ 0\%\ DAY}$$

Bartlett's, Brown-Forsythe, and Levene's tests for equal variance were evaluated for each comparison and where suggested by the results of these tests, variance weighted t-tests were evaluated.

Estimable Parameters

The release and detection schemes used during 2003 allowed us to generate the survival and capture probabilities shown in Figure 4. The survival and capture probabilities shown in this schematic were generated for all of the site-specific releases at John Day Dam during 2003.

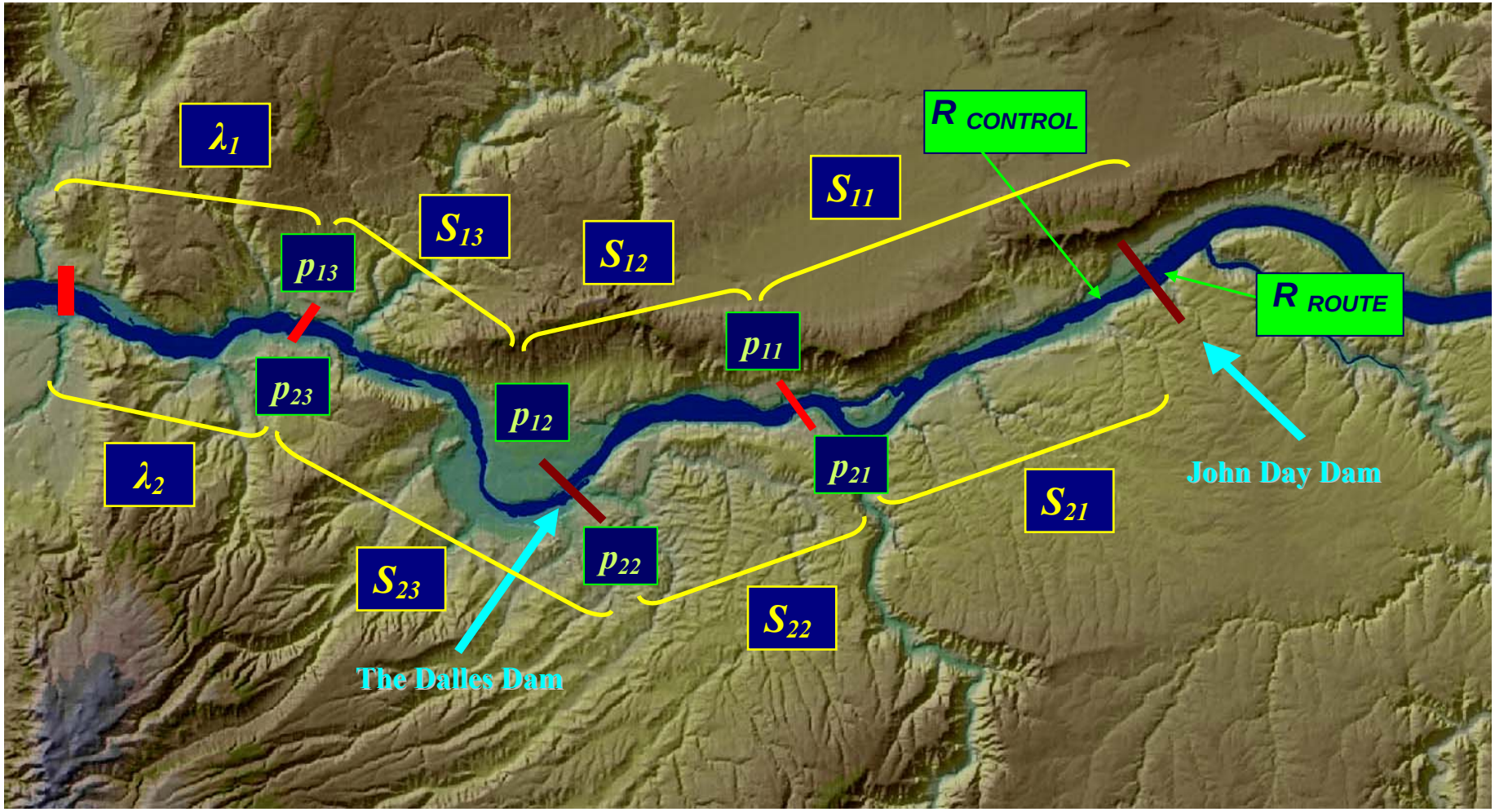

Figure 4. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from site-specific releases (R_{ROUTE}) at John Day Dam and in the John Day Dam tailrace.

Route Specific Survival Model

Model Assumptions

The assumptions associated with the Route Specific Survival Model (RSSM) are described in detail in Skalski et al. (2002) and are similar to those for the paired–release recapture model of Burnham et al. (1987).

Assumptions of the RSSM are:

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 tagged 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.

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

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

A9. Both the upstream and downstream release groups within a paired release experience the same survival probability in the segment of the river that they travel together.

Skalski et al.(2002) identified two additional assumptions associated with the RSSM:

A10. Routes taken by the radio-tagged fish are known without error.

A11. Detections in the primary and secondary antenna arrays within a passage route are independent.

Skalski et al. (2002) suggest that assumption A10 can be qualitatively assessed by examining radio telemetry detection histories to determine whether inconsistencies in individual fish detection histories exist. Skalski et al. (2002) use an example of a situation where a radio-tagged fish is detected in the upstream array of a route and then in the downstream array of another route, resulting in uncertainty in the route taken. That is, they used aerial antennas that monitored the tailrace area to help determine passage. Similar to the radio-telemetry system used in Skalski et al (2002), the double array we employed at John Day Dam consisted of aerial and underwater telemetry systems that interrogated fish in the immediate forebay area of each particular route, with the exception of the juvenile bypass system where underwater antennas were placed at two locations within the bypass structure. However, while we did have a radio-telemetry system monitoring the tailrace area of each route, we did not consider detections in the tailrace when determining passage routes.

Skalski et al. (2002) determined that while assumption A11 is necessary for valid estimation of in-route detection probabilities, the assumption cannot be empirically assessed with the data collected with this type of study. Rather, they suggest that the detection fields of the primary and secondary arrays should be located in a way that fish detected in one array does not have a higher or lower probability of being detected in the secondary array than the primary array. Further, they suggest that this is best accomplished by having independent receivers for each antenna array and by having the detection field of at least one array encompass the entire passage route. The arrays we deployed at the juvenile bypass, spillway and powerhouse conform to these requirements.

Parameter Estimation

The double radio-telemetry array systems that we deployed at John Day Dam allowed us to estimate route specific detection probabilities. In turn, these route specific detection probabilities can be incorporated into a statistical analysis that will extract route specific passage and survival (Skalski et al. 2002). The following parameters were defined for the construction of the RSSM used at John Day Dam: S_{POOL}, survival from the release location near Rock Creek, WA; G, conditional probability of guidance into the juvenile bypass, given that fish were going to the powerhouse; P_{PH}, powerhouse primary array detection probability; ($q_{PH} = 1 - P_{PH}$); P'_{PH}, powerhouse secondary array detection probability; ($q'_{PH} = 1-P'_{PH}$); P_{SPILL}, spillway primary array detection probability; ($q_{SPILL} = 1 - P_{SPILL}$); P'_{SPILL}, spillway secondary array detection probability; ($q'_{SPILL} = 1 - P'_{SPILL}$); P_{JBS}, juvenile bypass primary array detection probability; ($q_{JBS} = 1 - P_{JBS}$); P'_{JBS}, juvenile bypass secondary array detection probability; ($q'_{JBS} = 1 - P'_{JBS}$); S_{PH} , powerhouse survival probability; S_{SPILL}, spillway survival probability, S_{JBS}, juvenile bypass survival probability, λ, joint probability of surviving and being detected at the arrays below John Day Dam. The releases made near Rock Creek, WA (R_1) and the releases in the John Day Dam tailrace (R_2) were interrogated at five arrays below John Day Dam, the furthest downriver being an array deployed on the Hood River Bridge (Figure 3). A branching process was used to model the migration and survival of releases R_1 and R_2 (Figure 5). Additional details regarding the methodology used in the

formulation of the RSSM and the estimation of the associated parameters can be found in Skalski et al. (2002). For the RSSM survival probabilities, both standard errors and profile likelihood 95% confidence intervals are reported (Sklaski et al. 2002).

The route specific survival and passage probabilities can be combined using maximum likelihood estimation to estimate survival through the dam. The survival through John Day dam was estimated from the expression

$$\widehat{S}_{DAM} = (1-\widehat{E})(1-\widehat{G})\ \widehat{S}_{PH} + (1-\widehat{E})\,\widehat{G}\,\widehat{S}_{JBS} + \widehat{E}\,\widehat{S}_{SPILL}$$

The variance for the dam survival estimate was estimated using the delta method (Seber 1982, pp 7-9). All of the route specific survival and passage probabilities were estimated using the program USER (User Specified Estimation Routine) developed at the University of Washington (Lady et al. 2003; see: http://www.cqs.washington.edu/paramEst/USER/).

Comparisons of RSSM estimates between treatments

Z-tests were evaluated to assess the differences of route-specific survival estimates for yearling and subyearling Chinook salmon between treatments (i.e., spill operations) for each passage route (John Skalski and Jim Lady, University of Washington, personal communication). The hypotheses tested for yearling Chinook salmon passing via the juvenile bypass, spillway, turbines, and through all routes were:

$$H_0 : S_{0\%DAY/60\%\,NIGHT} = S_{0\%DAY/45\%\,NIGHT}$$
$$H_A : S_{0\%DAY/60\%\,NIGHT} \neq S_{0\%DAY/45\%\,NIGHT}$$

For subyearling Chinook salmon the hypotheses tested were:

$$H_0 : S_{0\%DAY/60\%\,NIGHT} = S_{30\%DAY/30\%\,NIGHT}$$
$$H_A : S_{0\%DAY/60\%\,NIGHT} \neq S_{30\%DAY/30\%\,NIGHT}$$

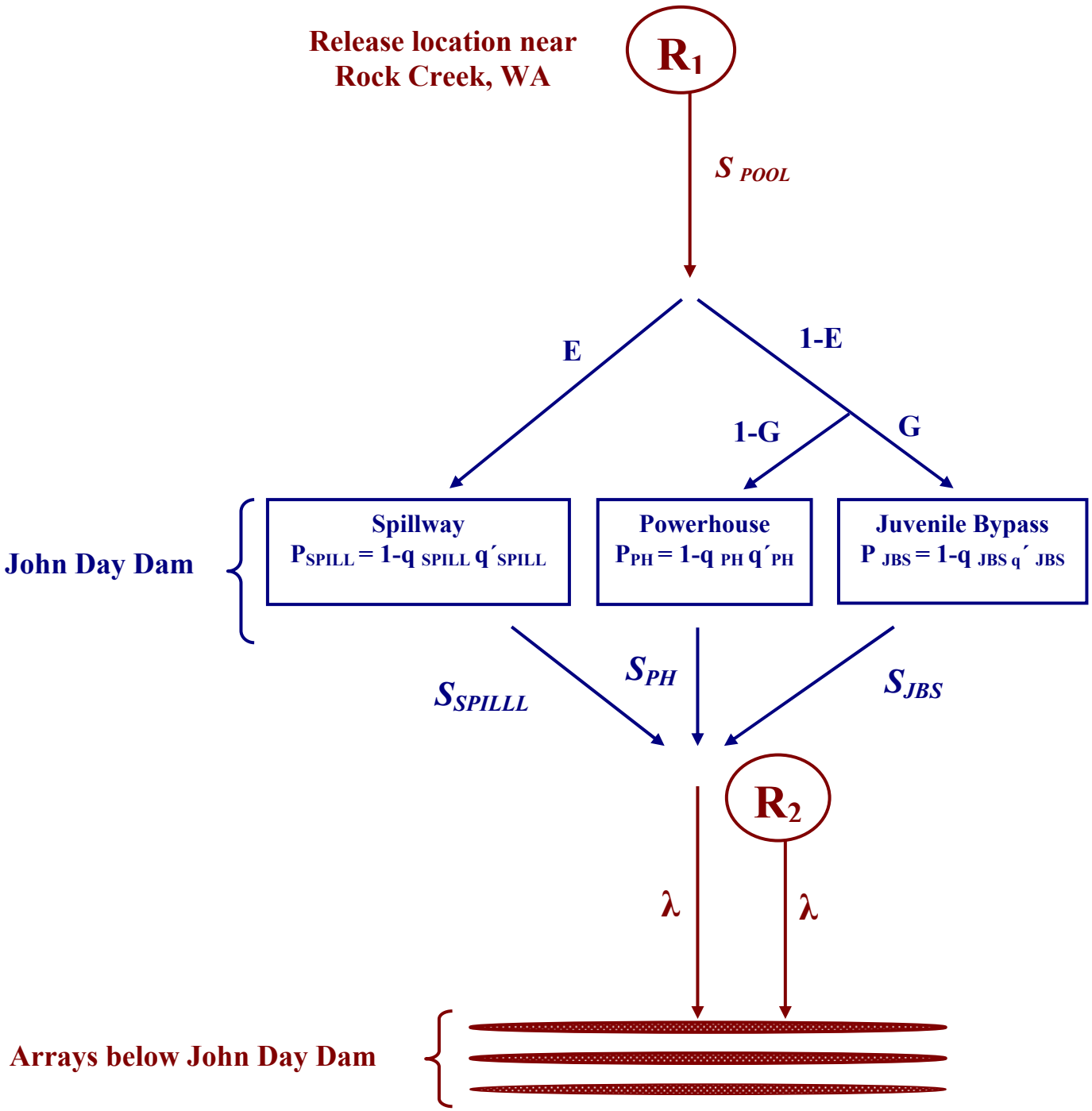

Figure 5. Schematic of route-specific passage and survival probabilities through John Day Dam for releases made near Rock Creek, WA (RK 367.7, John Day Reservoir) and in the tailrace of John Day Dam.

Results

Yearling Chinook salmon

Paired-release Recapture Model

Juvenile Bypass

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the yearling Chinook released into the juvenile bypass at John Day Dam and their corresponding tailrace releases were inconclusive. The results of these tests can be found in Appendix Table A2.1.

Tests of the Assumption of Mixing of the Treatment and Control Groups

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of yearling Chinook salmon indicated that there were no significant differences in arrival times between the two release groups at the downstream radio-telemetry arrays (Appendix Tables A3.1 and A3.2).

Releases of Dead Radio-tagged Fish

No dead radio-tagged fish were detected at any of the radio-telemetry arrays downstream of John Day Dam.

Survival Estimation

We estimated that the survival of yearling Chinook salmon released through the John Day Dam juvenile bypass during 2003 ranged from 0.564 to 1.02 (Table 6). The average survival of yearling Chinook salmon released through the John Day Dam juvenile bypass during the 2003 migration season was 0.805 (± 0.040, 95% confidence interval). Survival of yearling Chinook through the juvenile bypass during the 60% night spill operations was estimated to be 0.764 (± 0.051, 95% confidence interval) and 0.848 (± 0.056, 95% confidence interval) during the 45% night spill operation. The estimated survival of yearling Chinook salmon during the 60% night spill operation was found to be significantly different than the estimated survival during the 45% spill operation (*t*-test, $P = 0.034$).

Table 6. The estimated survival and standard error (SE) of yearling Chinook salmon released into the John Day Dam juvenile bypass during 2003. Releases were made directly into the juvenile bypass and in the tailrace of John Day Dam. The survival estimates presented are the estimated survival of the release group into the juvenile bypass to the release location of the tailrace release group. All releases were made during night spill operations. The specific dates and times of the releases can be referenced in Table 2.

Release	Spill Treatment (%)	Survival estimate	SE
1	60	0.88	0.08
2	60	0.95	0.06
3	45	0.82	0.07
4	A	A	A
5	60	0.71	0.08
6	60	0.76	0.07
7	45	0.95	0.05
8	45	0.79	0.08
9	45	1.00	0.06
10	45	0.86	0.07
11	60	0.84	0.07
12	60	0.56	0.08
13	45	0.90	0.06
14	45	0.84	0.07
15	60	0.72	0.08
16	60	0.65	0.08
17	60	0.69	0.09
18	60	0.68	0.08
19	45	0.75	0.08
20	45	0.89	0.07
21	60	0.67	0.08
22	60	0.70	0.09
23	45	0.63	0.09
24	45	0.80	0.07
25	60	0.59	0.08
26	60	0.76	0.09
27	45	0.58	0.08
28	45	0.90	0.06
29	45	0.83	0.07
30	45	1.02	0.05
31	60	0.7	0.08
32	60	0.90	0.05
33	45	0.98	0.05
34	45	0.95	0.05
35	60	0.95	0.06
36	60	0.9	0.06
37	45	0.68	0.08
38	45	0.95	0.06
39	60	0.76	0.07
40	60	0.90	0.06

A- Because of an equipment malfunction, this release was not included in the analyses.

Turbine Unit 4

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the yearling Chinook released into the juvenile bypass at John Day Dam and their corresponding tailrace releases were inconclusive. The results of these tests can be found in Appendix Table A2.1.

Tests of the Assumption of Mixing of the Treatment and Control Groups

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of yearling Chinook salmon indicated that there were no significant differences in arrival times between the two release groups at the downstream radio-telemetry arrays (Appendix Tables A3.1 and A3.2).

Releases of Dead Radio-tagged Fish

No dead radio-tagged fish were detected at any of the radio-telemetry arrays downstream of John Day Dam.

Survival Estimation

We estimated that the survival of yearling Chinook salmon released through turbine unit 4 at the John Day Dam powerhouse ranged from 0.707 to 1.00 (Table 7). The average survival of yearling Chinook salmon released through turbine unit 4 during the 2003 migration season was 0.851 (± 0.040, 95% confidence interval). The survival probability of yearling Chinook released through turbine unit 4 during the 45% night spill operations was 0.807 (± 0.035, 95% confidence interval) and was 0.891 (± 0.062, 95% confidence interval) during the 0% day spill operations. The survival probabilities for yearling Chinook salmon released into turbine unit 4 during the 45% night and 0% day spill operations were found to be statistically different (variance weighted *t*-test, $P = 0.0353$). A variance-weighted *t*-test was used because unequal variances were indicated by all of Bartlett's, Brown-Forsythe, and Levene's tests for equal variance.

Table 7. The estimated survival and standard error (SE) of yearling Chinook salmon released into the John Day Dam turbine unit 4 during 2003. Releases were made directly into turbine unit 4 and the tailrace of John Day Dam. The survival estimates presented are the estimated survival of the release group into turbine unit 4 to the release location of the tailrace release group. All releases were made during 0% day and 45% night spill operations. The specific dates and times of the releases can be referenced in Table 3.

Release	Spill Treatment (%)	Survival estimate	SE
1	45% night	0.92	0.07
2	0% day	1.00	0.06
3	45% night	0.78	0.08
4	0% day	0.99	0.09
5	45 % night	0.83	0.08
6	0% day	0.92	0.08
7	45% night	0.76	0.09
8	0% day	0.88	0.09
9	45% night	0.85	0.08
10	0% day	0.88	0.09
11	45% night	0.72	0.10
12	0% day	0.71	0.09
13	45% night	0.82	0.08
14	0% day	0.88	0.09
15	45% night	0.76	0.09
16	0% day	1.00	0.04
17	45% night	0.84	0.08
18	0% day	0.74	0.10
19	0% day	1.00	0.06
20	45% night	0.79	0.09
21	0% day	0.80	0.10

Route Specific Survival Model

Using capture histories generated from the detections of radio-tagged yearling Chinook salmon (Tables 8 and 9), we generated maximum likelihood estimates of the route-specific passage and survival probabilities for fish passing during the prescribed spill operation treatments (0% day/60% night, 0% day/45% night) along with associated standard errors and profile likelihood 95% confidence intervals.

0% day/60% Night Spill Operations

During the 0% day/60% night spill operations, the survival of yearling Chinook salmon through the John Day Dam spillway was estimated to be 0.934 (SE = 0.0160; profile likelihood 95% confidence interval = [0.900, 0.963]) (Figure 6, Table 10). For yearling Chinook passing the juvenile bypass during the 0% day/60% night spill operations the estimated survival probability was 1.02 (SE = 0.009, profile likelihood 95% confidence interval [0.997, 1.036]) and for fish passing via the turbines the estimated survival was 0.820 (SE = 0.043, profile likelihood 95% confidence interval [0.729, 0.896]) (Figure 6, Table 10). The dam survival probability during the 0% day/60% night spill operations was estimated to be 0.943 (SE = 0.021).

0% day/45% Night Spill Operations

During the 0% day/45% night spill operations, the survival of yearling Chinook salmon through the John Day Dam spillway was estimated to be 0.939 (SE = 0.016; profile likelihood 95% confidence interval = [0.903, 0.967]) (Figure 7, Table 10). For yearling Chinook passing the juvenile bypass during the 0% day/45% night spill operations the estimated survival probability was 0.988 (SE = 0.012, profile likelihood 95% confidence interval [0.959, 1.008]) and for fish passing via the turbines the estimated survival was 0.764 (SE = 0.046, profile likelihood 95% confidence interval [0.667, 0.847]) (Figure 7, Table 10). The dam survival probability (see p. 21, this report) during the 0% day/45% night spill operations was estimated to be 0.922 (SE = 0.024).

Comparisons of Estimators Generated During the 0% day/60% Night and 0% day/45% Night Spill Operations

The estimated survival probabilities for yearling Chinook salmon passing via the spillway and turbines at John Day Dam were not found to be statistically different during the 0% day/60% night spill than for the 0% day/45% night spill operations (Table 10). However, the estimated survival probability for fish passing via the John Day Dam juvenile bypass during the 0% day/60% night spill operations was statistically different than during the 0% day/45% night spill operations (Z-test, $Z = 2.067$). The dam survival probability was not statistically different during the 0% day/60% night and the 0% day/45% night spill operations (Table 10).

Table 8. Counts of radio-tagged yearling Chinook salmon for the releases from near Rock Creek, WA (R_1) and in the tailrace of John Day Dam (R_2) during the 0% day /60% night spill operations used in the route-specific survival model.

				Within-route histories at John Day Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 740$	100		36			
	101		15			
	110	Spillway	36	306	20	63
	111		353			
	110	Powerhouse	19	28	53	16
	111		78			
	110	Juvenile bypass	2	173	1	29
	111		201			
$R_2 = 978$	010		28			
	011		950			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 9. Counts of radio-tagged yearling Chinook salmon for the releases from near Rock Creek, WA (R_1) and in the tailrace of John Day Dam (R_2) during the 0% day /45% night spill operations used in the route-specific survival model.

				Within-route histories at John Day Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
$R_1 = 649$	100		31			
	101		21			
	110	Spillway	22	232	25	32
	111		267			
	110	Powerhouse	22	20	53	20
	111		71			
	110	Juvenile bypass	6	190	1	24
	111		209			
$R_2 = 1058$	010		17			
	011		1041			

[A] - Detection history recorded as: 1, detected; 0, not detected

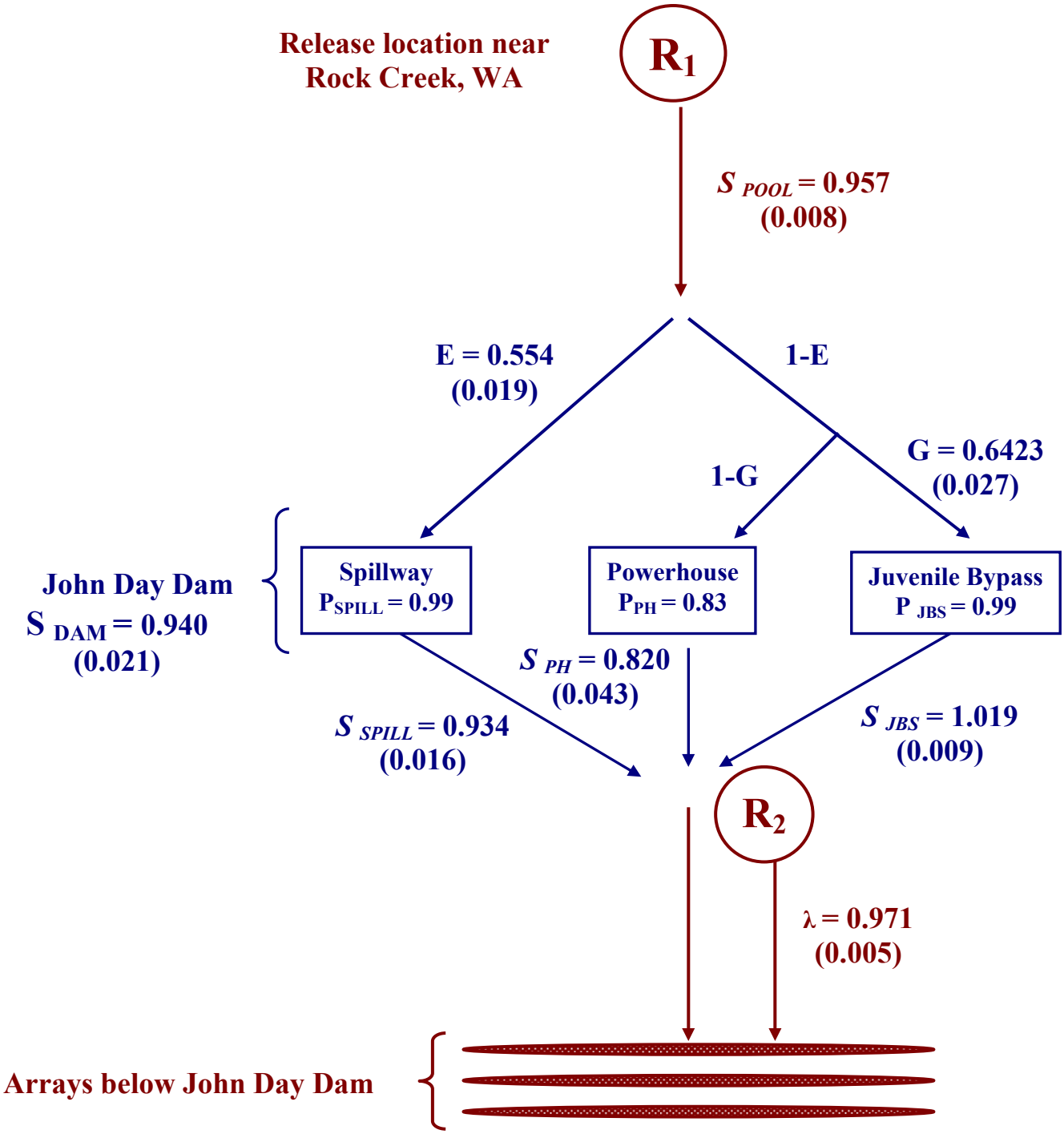

Figure 6. Schematic of estimated route-specific passage and survival probabilities for yearling Chinook salmon through John Day Dam during 0% day/60% night spill operations during 2003. Estimated standard errors are in parentheses.

Table 10. Summary table of estimated route specific survival probabilities and the maximum likelihood estimate of yearling Chinook salmon survival through John Day Dam (Dam survival) generated from the Route Specific Survival Model of John Day Dam during 2003. *Z*-tests were structured to assess whether the estimated survival probabilities during the 0% day/60% night spill operations were different than for the estimated survival probabilities during the 0% day/ 45% night spill operations. Significant results are indicated where $Z \geq 1.64$

	0 % day/ 60% night		0% day/45% night		
Passage route	S	SE	S	SE	*Z*
Powerhouse	0.820	0.043	0.764	0.046	0.889
Spillway	0.934	0.016	0.939	0.016	0.221
Juvenile bypass	1.019	0.009	0.988	0.012	2.067
Dam Survival	0.940	0.021	0.922	0.024	0.660

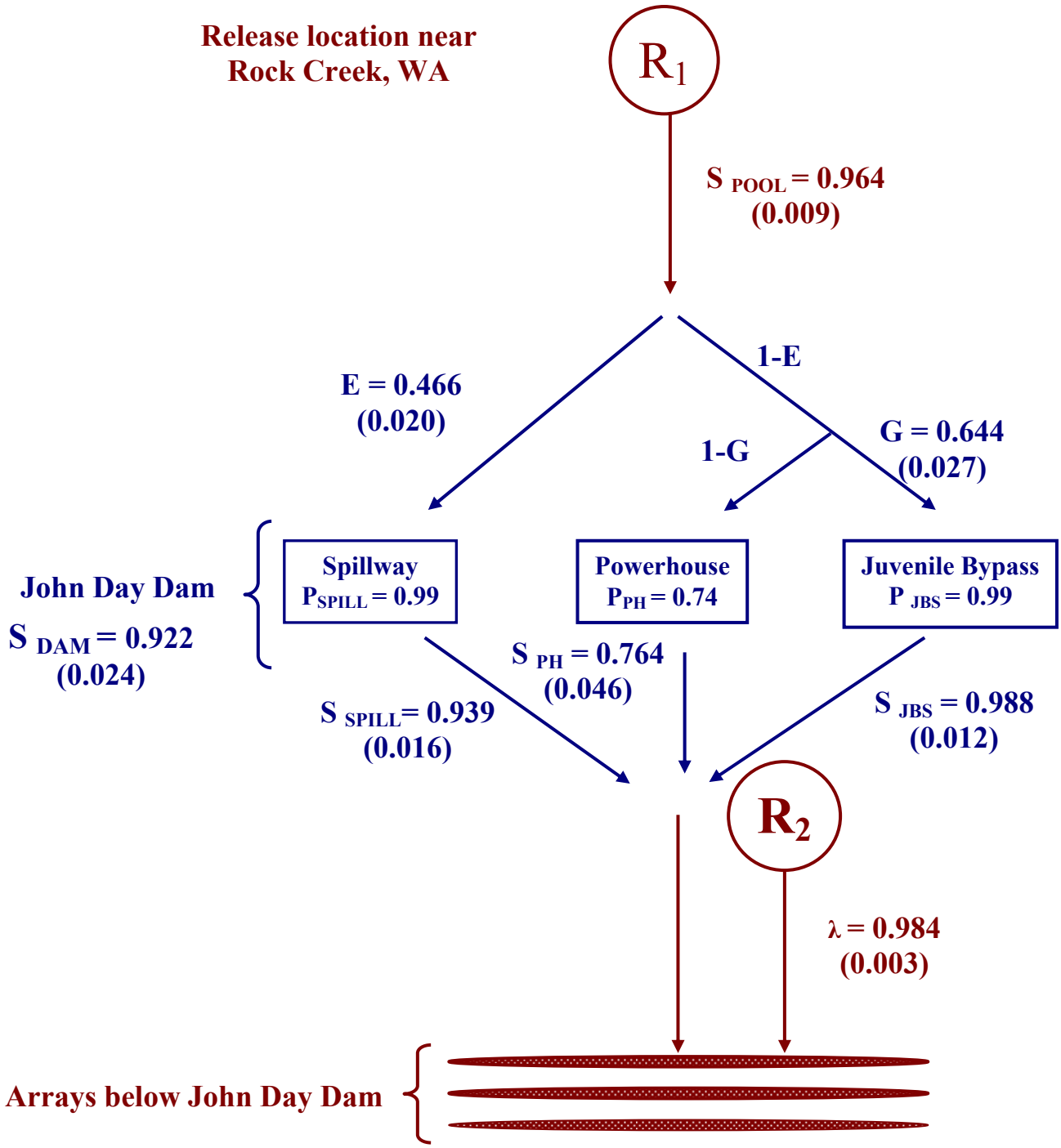

Figure 7. Schematic of estimated route-specific passage and survival probabilities for yearling Chinook salmon through John Day Dam during 0% day/45% night spill operations during 2003. Estimated standard errors are in parentheses.

Subyearling Chinook salmon

Route Specific Survival Model

Using capture histories generated from the detections of radio-tagged subyearling Chinook salmon (Tables 11 and 12), we generated maximum likelihood estimates of the route-specific passage and survival probabilities for fish passing during the prescribed spill operation treatments (0% day/60% night, 30% day/30% night) along with associated standard errors and profile likelihood 95% confidence intervals.

0% day/60% Night Spill Operations

During the 0% day/60% night spill operations, the survival of subyearling Chinook salmon through the John Day Dam spillway was estimated to be 0.901 (SE = 0.012; profile likelihood 95% confidence interval = [0.877, 0.922]) (Figure 8, Table 13). For subyearling Chinook passing the juvenile bypass during the 0% day/60% night spill operations the estimated survival probability was 0.892 (SE = 0.018, profile likelihood 95% confidence interval [0.855, 0.924]) and for fish passing via the turbines the estimated survival was 0.719 (SE = 0.024, profile likelihood 95% confidence interval [0.671, 0.764]) (Figure 8, Table 13). The dam survival probability during the 0% day/60% night spill operations was estimated to be 0.845 (SE = 0.016).

30% day/30% Night Spill Operations

During the 30% day/30% night spill operations, the survival of subyearling Chinook salmon through the John Day Dam spillway was estimated to be 0.955 (SE = 0.008; profile likelihood 95% confidence interval = [0.938, 0.970]) (Figure 9, Table 13). For subyearling Chinook passing the juvenile bypass during the 30% day/30% night spill operations the estimated survival probability was 0.921 (SE = 0.020, profile likelihood 95% confidence interval [0.877, 0.955]) and for fish passing via the turbines the estimated survival was 0.722 (SE = 0.024, profile likelihood 95% confidence interval [0.673, 0.767]) (Figure 9, Table 13). The dam survival probability during the 30% day/30% night spill operations was estimated to be 0.886 (SE = 0.015).

Comparisons of Estimators Generated During the 0% day/60% Night and 30% day/30% Night Spill Operations

The estimated survival probabilities for subyearling Chinook salmon passing via the spillway and turbines at John Day Dam were not found to be significantly different during the 0% day/60% night spill than for the 30% day/30% night spill operations (Table 13). However, both the spillway (Z-test; $Z = 3.86$) and dam (Z-test; $Z = 1.86$) survival probabilities were found to be significantly different. The estimated spillway and dam survival probabilities were higher during the 30% day/30% night spill operations.

Table 11. Counts of radio-tagged subyearling Chinook salmon for the releases from near Rock Creek, WA (R_1) and in the tailrace of John Day Dam (R_2) during the 0% day/60% night spill operations used in the route-specific survival model.

				Within-route histories at John Day Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
R_1 = 1923	100		319			
	101		83			
	110	Spillway	86	589	104	99
	111		706			
	110	Powerhouse	106	92	217	70
	111		273			
	110	Juvenile bypass	41	334	1	15
	111		309			
R_2 = 1411	010		15			
	011		1396			

[A] - Detection history recorded as: 1, detected; 0, not detected

Table 12. Counts of radio-tagged subyearling Chinook salmon for the releases from near Rock Creek, WA (R_1) and in the tailrace of John Day Dam (R_2) during the 30% day/30% night spill operations used in the route-specific survival model.

				Within-route histories at John Day Dam [A]		
Release	Detection History [A]	Route	Counts	11	01	10
R_1 = 2178	100		500			
	101		72			
	110	Spillway	58	859	99	54
	111		954			
	110	Powerhouse	103	85	214	75
	111		271			
	110	Juvenile bypass	20	215	1	4
	111		200			
R_2 = 1403	010		18			
	011		1385			

[A] - Detection history recorded as: 1, detected; 0, not detected

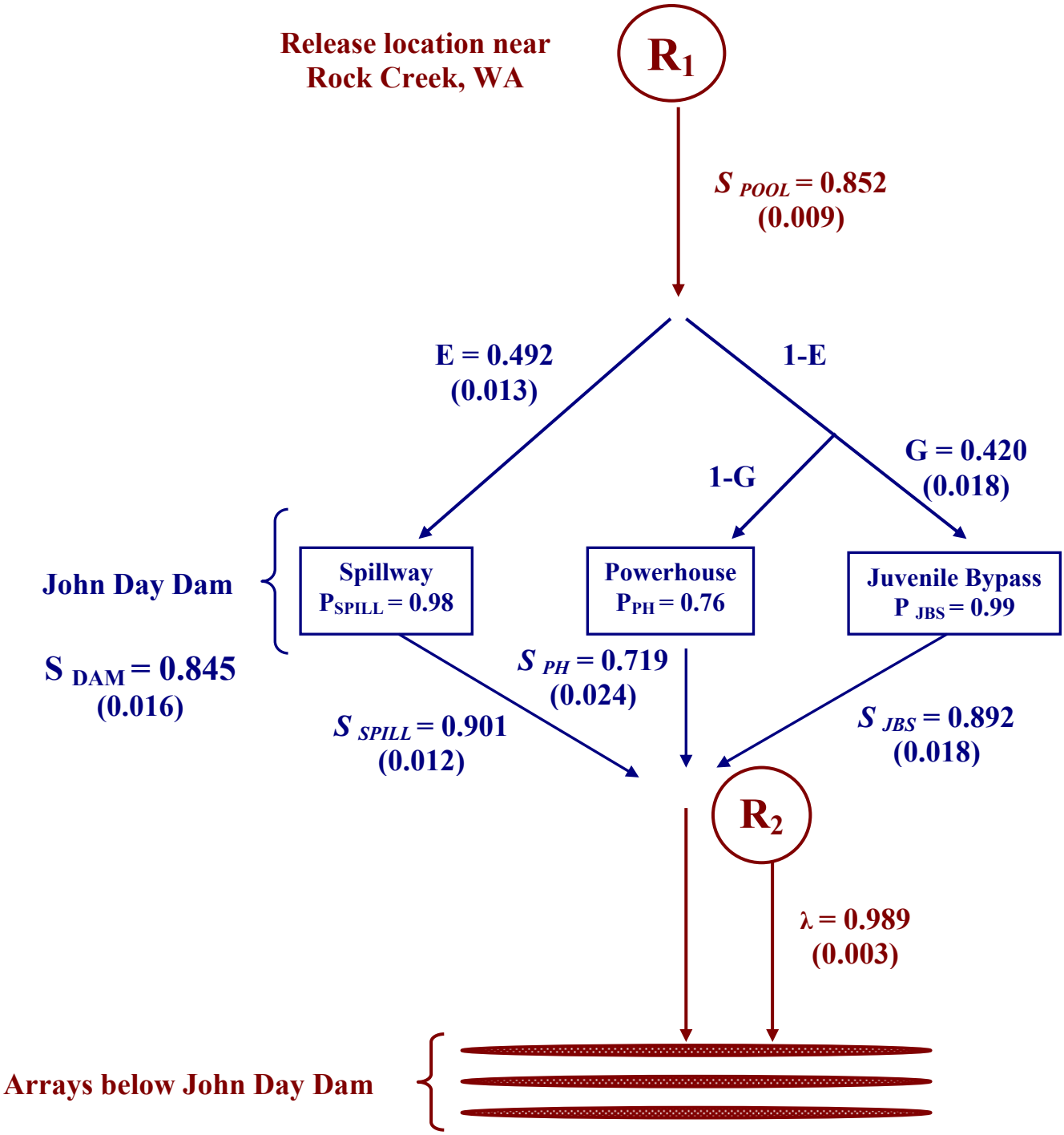

Figure 8. Schematic of estimated route-specific passage and survival probabilities for subyearling Chinook salmon through John Day Dam during 0% day/60% night spill operations during 2003. Estimated standard errors are in parentheses.

Table 13. Summary table of estimated route specific survival probabilities and the maximum likelihood estimate of subyearling Chinook salmon survival through John Day Dam (Dam survival) generated from the Route Specific Survival Model of John Day Dam during 2003. *Z*-tests were structured to assess whether the estimated survival probabilities during the 0% day/60% night spill operations were different than for the estimated survival probabilities during the 0% day/ 45% night spill operations. Significant results are indicated where $Z \geq 1.64$

	0 % day/ 60% night		30% day/30% night		
Passage route	S	SE	S	SE	*Z*
Powerhouse	0.719	0.024	0.722	0.024	0.09
Spillway	0.901	0.012	0.955	0.008	3.86
Juvenile bypass	0.892	0.018	0.921	0.020	1.10
Dam Survival	0.845	0.016	0.886	0.015	1.86

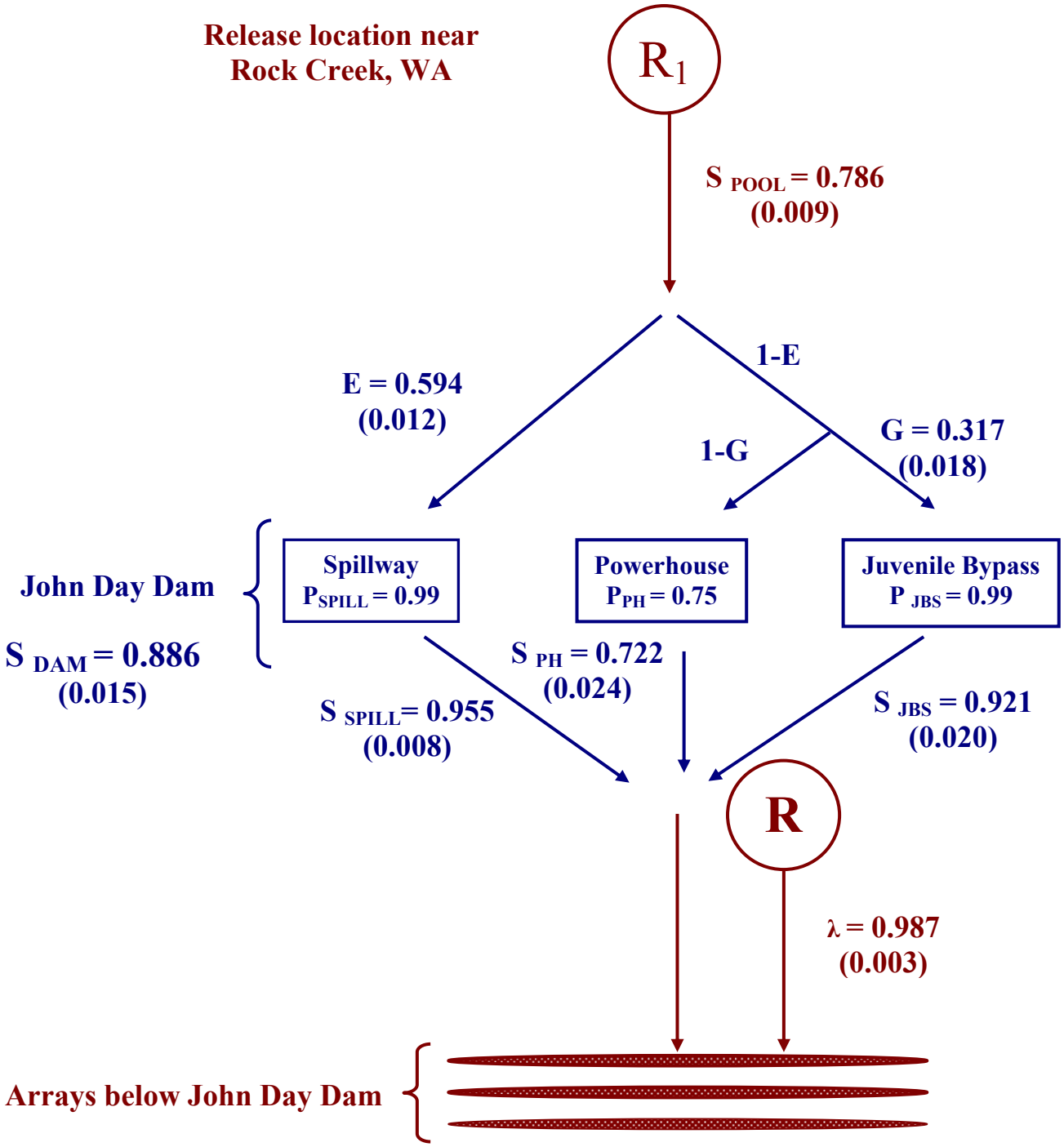

Figure 9. Schematic of estimated route-specific passage and survival probabilities for subyearling Chinook salmon through John Day Dam during 30% day/30% night spill operations during 2003. Estimated standard errors are in parentheses.

Discussion

The results of our evaluations of radio-tagged yearling Chinook salmon survival through John Day Dam during 2003 suggest that the estimated survival probabilities during the 60% night and the 0% day/ 60% night spill operations were not significantly different than during the 45% night or the 0% day/45% night spill operations, respectively, given the operation of John Day Dam during the spring and summer of 2003. The statistical comparisons of the estimated survival for yearling Chinook salmon released directly into the John Day Dam juvenile bypass did not support the hypothesis that survival during the 60% night spill operations was different than for a reduced night spill level (i.e., 45% night spill). Similarly, the estimated survival probabilities generated from releases of fish near Rock Creek, WA and the route specific survival model analyses through all routes collectively (i.e., dam survival), through the powerhouse (unguided), and through the spillway were not significantly different during the 0% day/60% night spill operations than for the 0% day/45% night spill operations. However, in contrast to the results of the 2002 evaluations (Counihan et al. 2006) of yearling Chinook salmon survival through the juvenile bypass that suggested that survival was lower during the 0% day/60% night than during the 30% day/30% night spill operations, the 2003 results suggest that the estimated survival probabilities during the 0% day/60% night spill operations were greater than for the reduced spill operations (i.e., 0% day/45% night).

The hydraulic conditions near the juvenile bypass outfall created by the dam operations at John Day Dam during 2002 was cited as a potential factor contributing to lower estimated survival probabilities during both the 60% night spill operations and the 0% day/ 60% night spill operations compared to the 30% night and 30% night/30% day spill operations (Counihan et al. 2006). A post-hoc analysis of the flow conditions present during the 2002 migration season was conducted at the Army Corps of Engineer's Energy Research and Development Center using a physical model of John Day Dam. Army Corps of Engineer staff along with staff from NOAA Fisheries and the USGS participated in this exercise. During model simulations of dam operations that resulted in delays of juvenile steelhead during 2002, it was discovered that discharge through the turbine units were not "bulked south" (i.e., discharge concentrated towards the south end of the powerhouse), as was stipulated in the Fish Passage Plan to promote good egress from the outfall of the JBS. The model simulation showed that during this type of dam operation (discharge not concentrated towards the south end of the powerhouse), velocities in front of the juvenile bypass outfall were approximately 2 to 3 $ft \cdot s^{-1}$. After evaluating simulations of other potential dam operations, the group determined that a minimum velocity of 4 $ft \cdot s^{-1}$ in front of the outfall should be set as the criteria for good JBS outfall egress conditions, and further, that these velocities could not be achieved without implementing the dam operation scenario suggested in the Fish Passage Plan. The implementation of the operations stipulated by the Fish Passage Plan during 2003 may have contributed to the improved survival through the juvenile bypass during the 60% night spill operations.

Despite the altered dam operations, the average estimated survival probability for yearling Chinook salmon released directly into the juvenile bypass was not significantly different during the 60% night spill than during the 45% night spill level. It does not appear that altering the dam operations during 2003 resulted in increases in the survival probabilities of fish passing via the juvenile bypass during the 60% night spill operations sufficient to indicate a survival benefit compared to the reduced spill levels. Further, the results showing increased survival for fish passing during the 0% day/60% night spill operations and not for fish passing only during the 60% night spill operation suggests that the survival of yearling Chinook passing via the juvenile bypass during spill operations other than the 60% night spill are driving the results seen during the 0% day/60% night spill operations. We examined the dam operation conditions experienced by yearling Chinook salmon during the 0%day/60% night and during the 60% night spill operations and found that the conditions during passage were different for these two groups (Figure 10, Table 14).

The estimated survival probabilities for yearling Chinook salmon released into turbine unit 4 were found to be significantly different and suggested that survival through this turbine unit was higher during the day releases (0% spill) than during the night releases (45% spill). Increased discharge through the John Day Dam powerhouse during periods of no spill may have resulted in improved egress through the tailrace or altered predator distributions, and thus resulted in increased survival of fish passing during the day. The average survival probability for all fish released directly through the turbine unit during the 0% day and 45% night site-specific releases (0.851, SE = 0.020) was higher than that estimated using the route specific survival model to evaluate survival of fish passing unguided through other turbine units at the powerhouse (0.764, SE = 0.046). The difference between these two values could suggest that survival through turbine unit 4 was higher than for fish passing other turbine units, that the estimated survival during the time of the site-specific releases is higher than for fish passing unguided through the powerhouse at other times, or that the differences are an artifact of the different release and detection schemes used for the route specific survival model versus the paired release recapture model. Some concerns have been expressed recently that the RSSM may be producing survival estimates that are biased high (John Skalski, University of Washington, personal communication). The rationale put forth is that treatment fish released some distance above the project may experience post-tagging mortality that would be expressed by the time they arrive at the project being evaluated. Conversely, control fish released in the tailrace of the project being evaluated would express this post-tagging mortality in the first river reach evaluated below the project. Consequently, since the survival of the control fish in the first river reach would be biased low, this bias could be incorporated into the survival estimates at the project, thus biasing them high. Until the potential for this to occur is examined in more detail, the absolute values of the estimates generated with this methodology should be viewed with caution.

Similar to our results for subyearling Chinook salmon during 2002 (Counihan et. al. 2006), the point estimated of survival for fish passing during the 0% day/60% night spill operations were lower than for fish passing during the 30% day/30% night spill

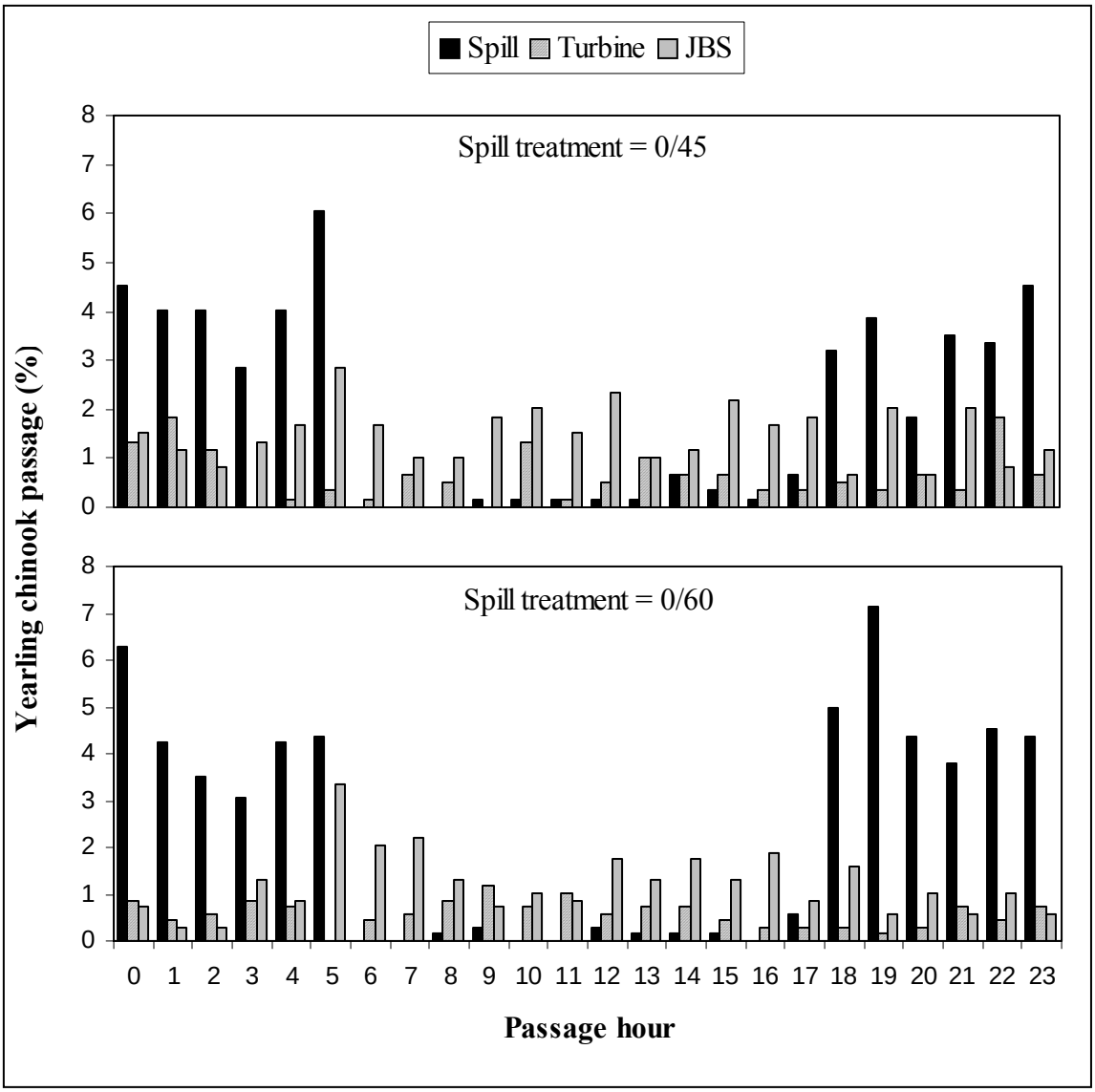

Figure 10. Percent of radio-tagged yearling Chinook salmon passage during two spill treatments at John Day Dam by hour during spring 2003. Yearling Chinook salmon were released daily from Rock Creek, WA at approximately 0900 and 2100 hours. Spill treatments were 0% day with 60% night spill (0/60) and 0% day with 45% night spill (0/45). Passage locations were through the spillway (Spill), powerhouse (Turbine) or juvenile bypass system (JBS).

Table 14. Dam operation conditions present during time of passage for yearling Chinook released near Rock Creek, WA, and passing via the juvenile bypass (RSSM JBS) during the 0% day/45% night (0%/45%) and 0% day/60% night (0%/60%) spill operations, or released directly into the juvenile bypass (JBS) during the 45% and 60% night spill operations at John Day Dam, 2003.

		45% night	0% /45%	60% night	0%/60%
		JBS n=742	RSSM JBS n=214	JBS n=783	RSSM JBS n=202
Spill (%)	Mean	45	21	60	22
	min	40	0	55	0
	max	47	59	67	68
Total discharge ($ft^3 \cdot s^{-1} \cdot 1000$)	Mean	247	262	231	258
	min	143	154	168	125
	max	361	416	289	352
Spill discharge ($ft^3 \cdot s^{-1} \cdot 1000$)	Mean	111	60	137	55
	min	67	0	101	0
	max	159	164	161	165

operations for all routes examined. These results suggest that the 0% day/60% night spill operations (12 h spill) did not result in a survival benefit for subyearling Chinook salmon when compared to the 30% day 30% night spill operations (24 h spill) at John Day Dam during 2002 and 2003.

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Appendix 1: Fork Lengths and Weights

Table A1.1.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weights (g) of yearling Chinook salmon released into Rock Creek above John Day Dam during spring 2003.

	Fork Lengths (mm)				Weights (g)			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	31	160	10.8	138-182	31	38.4	7.7	27.1-58.5
2	33	160	11.6	134-197	33	39.6	9.6	22.7-71.6
3	26	167	8.3	152-184	26	43.8	7.3	32.3-56.4
4	34	162	12.1	137-191	34	42.7	11.4	25.3-82.5
5	33	163	12.7	139-194	33	42.6	9.3	28.1-66.3
6	27	160	14.0	130-190	27	40.2	10.9	21.4-68.5
7	32	159	13.6	140-190	32	41.4	10.3	26.2-65.7
8	34	158	11.9	136-181	34	39.5	8.1	26.4-57.3
9	35	152	17.0	125-200	35	36.3	13.1	18.8-81.4
10	30	159	15.4	138-200	30	40.4	13.4	25.0-85.6
11	35	153	16.5	127-195	35	36.6	12.9	22.5-73.6
12	37	159	17.7	130-190	37	34.2	15.8	4.3-67.9
13	33	153	16.1	130-189	33	37.0	11.3	21.8-65.7
14	34	157	15.6	134-190	34	38.9	12.4	23.5-72.1
15	37	153	18.4	122-206	37	36.1	13.8	18.1-80.1
16	35	151	16.2	124-185	35	33.6	11.2	18.2-61.6
17	38	155	20.5	132-197	38	37.2	15.6	21.7-72.8
18	37	158	18.7	126-191	37	37.8	13.8	18.3-65.2
19	34	152	16.2	131-200	34	35.2	13.0	21.6-81.1
20	33	157	16.9	126-190	33	37.4	12.1	20.0-64.3
21	35	153	21.2	122-210	35	34.4	15.7	18.3-88.3
22	35	156	19.9	131-205	35	36.9	15.3	21.3-79.4
23	37	157	17.8	132-203	37	38.5	14.6	18.1-82.2
24	38	155	18.8	132-210	38	37.5	17.2	19.3-99.9
25	37	153	15.1	132-200	37	32.7	10.6	20.8-72.3
26	37	152	16.5	132-195	37	33.9	12.4	20.2-70.9
27	37	152	15.0	131-193	37	34.3	11.9	20.6-72.2
28	38	148	15.4	130-191	38	30.8	10.0	19.4-64.5
29	36	160	22.1	130-220	36	40.7	21.0	19.9-118
30	38	152	12.8	134-185	38	32.4	8.8	21.5-53.6
31	38	150	17.1	129-205	38	32.5	14.0	21.3-84.8
32	37	156	20.9	132-220	37	37.5	20.2	19.5-113.7
33	35	152	17.7	131-213	35	34.6	16.2	22.1-95.5
34	36	150	15.7	128-205	36	31.8	12.4	20.8-82.4
35	35	151	20.5	128-217	35	35.2	18.2	19.5-100.6
36	34	151	16.8	134-214	34	33.4	15.6	19.5-94.6
37	36	150	12.9	130-199	36	32.4	9.2	21.2-72.8
38	34	153	14.6	133-195	34	34.6	10.6	22.1-69.9
39	34	151	11.5	128-185	34	32.0	8.0	19.6-56.0
40	34	154	14.6	138-209	34	34.4	10.8	23.9-83.8
Overall:	1389	155	16.6	122-220	1389	36.3	13.4	4.3-118.0

Table A1.2.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weights (g) of subyearling Chinook salmon released into Rock Creek above John Day Dam during summer 2003.

	Fork Lengths (mm)				Weights (g)			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	59	114	3.0	110-124	59	15.2	1.5	13.1-20.0
2	71	114	4.1	110-127	71	15.5	2.2	11.8-23.0
3	65	115	4.8	110-141	65	15.8	2.8	13.3-31.5
4	66	115	5.1	110-134	66	15.6	2.5	12.9-24.0
5	75	115	3.3	110-124	75	15.0	1.4	12.1-21.0
6	67	115	3.8	110-127	67	15.2	1.9	13.0-21.4
7	72	115	3.6	110-128	72	15.6	1.8	13.1-22.4
8	67	114	2.7	111-122	67	14.3	1.2	13.0-17.9
9	72	115	3.3	111-126	72	15.3	1.8	12.6-21.1
10	70	115	4.0	110-132	70	15.5	1.8	13.0-23.8
11	72	115	3.1	110-126	72	15.6	1.4	13.2-19.9
12	70	114	2.5	110-122	70	14.7	1.2	12.9-19.1
13	73	115	3.2	110-125	73	15.4	1.7	13.0-21.7
14	70	115	3.9	110-137	70	14.6	2.1	13.0-27.0
15	75	114	2.6	110-122	75	15.0	1.4	13.0-18.2
16	72	115	4.1	110-132	72	15.7	2.2	13.2-25.2
17	69	115	4.1	110-129	69	14.7	2.0	13.0-24.8
18	69	114	2.9	110-122	69	15.5	1.6	12.9-20.2
19	68	115	3.6	110-128	68	15.1	2.0	13.0-22.4
20	70	115	4.0	110-130	70	16.3	2.4	13.1-25.0
21	73	115	3.8	110-127	73	15.6	2.6	13.0-25.9
22	67	115	4.3	110-135	67	15.0	2.3	13.0-26.1
23	62	115	5.3	110-131	62	16.2	3.1	13.1-25.8
24	71	117	4.9	110-139	71	16.1	2.9	13.1-30.8
25	72	115	4.5	109-130	72	16.5	2.3	13.3-24.5
26	76	117	4.5	110-133	76	15.7	2.1	13.2-24.4
27	75	115	4.6	110-127	75	16.5	2.4	13.2-22.8
28	73	115	4.0	110-129	73	15.8	1.9	13.1-23.3
29	74	116	4.9	110-139	74	15.4	2.3	13.0-24.8
30	76	117	5.1	110-138	76	16.8	2.7	13.1-27.4
31	73	117	5.2	110-140	73	16.1	2.6	13.1-26.8
32	76	116	5.4	110-133	76	16.6	2.7	13.2-25.2
33	75	117	4.5	110-132	75	15.8	2.1	13.1-21.7
34	74	114	4.9	110-134	74	16.6	2.6	13.3-26.6
35	75	117	5.0	110-134	75	17.1	2.7	13.7-25.1
36	76	114	4.5	110-137	76	16.2	2.3	13.1-27.5
37	74	116	4.9	110-133	74	16.8	2.7	13.4-26.2
38	69	116	6.5	110-145	69	17.1	3.3	13.3-34.1
39	72	115	4.6	110-129	72	16.4	2.3	13.1-22.2
40	75	116	6.1	110-142	75	16.0	2.7	13.2-24.8

Table A1.2.(continued)-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weights (g) of subyearling Chinook salmon released into Rock Creek above John Day Dam during summer 2003.

	Fork Lengths (mm)				Weights (g)			
Release	N	Mean	SD	Range	N	Mean	SD	Range
41	76	115	5.3	109-132	76	16.8	2.6	13.2-26.9
42	76	120	9.1	110-145	76	17.4	4.1	13.0-29.9
43	75	121	9.1	111-145	75	19.0	4.2	14.0-30.7
44	75	120	7.9	110-147	75	17.3	3.6	13.0-32.3
45	76	122	9.3	110-147	76	19.0	4.3	13.7-31.8
46	75	120	9.0	110-153	75	19.0	4.5	13.6-37.0
47	76	121	8.4	111-150	76	17.7	3.9	13.4-34.0
48	76	118	7.3	110-145	76	17.9	3.8	13.2-32.4
49	126	120	10.2	110-152	126	18.9	4.9	14.0-37.2
50	75	119	8.8	110-152	75	18.5	4.3	13.7-35.9
51	73	119	8.8	110-150	73	17.8	4.1	13.0-37.1
52	99	121	8.6	110-151	99	19.7	4.3	14.0-38.9
53	73	122	9.3	110-145	73	19.3	4.2	13.9-35.0
54	74	119	7.1	111-148	74	18.9	4.0	13.5-37.1
55	74	117	6.8	110-148	74	17.1	3.2	13.3-32.9
56	73	117	7.7	110-150	73	18.3	3.8	13.7-36.4
Overall:	4122	117	6.3	109-153	4122	16.6	3.2	11.8-38.9

Table A1.3.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of yearling Chinook salmon released into the top of the John Day Dam juvenile bypass system and tailrace during spring 2003.

Paired	Juvenile Bypass System				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	37	161	10.0	143-190	39	161	10.6	140-180
2	39	160	16.8	134-230	37	165	12.0	145-191
3	38	161	14.8	128-186	36	156	13.8	132-197
4	38	158	13.9	127-183	38	158	12.9	134-178
5	39	162	12.2	140-195	39	160	13.5	116-180
6	39	156	15.4	129-190	40	156	14.9	130-190
7	40	155	16.0	126-185	38	151	14.5	125-180
8	35	152	16.3	123-205	39	156	16.8	125-192
9	40	151	16.2	128-187	38	153	12.4	136-182
10	40	147	14.9	129-191	39	150	17.1	124-193
11	39	155	20.3	125-200	40	152	17.7	114-191
12	39	153	14.5	130-190	40	157	17.9	130-198
13	39	161	18.0	135-195	40	153	17.1	129-195
14	39	146	14.5	122-190	40	150	17.3	120-189
15	40	156	16.9	122-190	40	148	15.4	126-181
16	40	153	14.8	134-189	37	155	17.0	130-192
17	40	147	13.3	126-181	40	150	17.5	122-191
18	38	152	17.9	126-190	39	150	14.1	124-187
19	37	154	14.0	130-180	39	149	12.6	130-175
20	39	156	19.8	127-207	39	147	15.4	129-203
21	39	150	15.2	126-197	40	153	18.0	126-195
22	38	149	20.5	125-210	40	146	14.0	128-189
23	38	151	22.5	125-212	37	151	18.3	127-202
24	40	145	13.1	126-190	40	147	14.0	126-185
25	39	148	17.5	127-205	38	150	17.4	122-195
26	40	149	15.5	129-199	40	147	12.5	130-175
27	39	151	16.0	130-198	39	147	11.1	132-183
28	40	150	12.2	130-182	40	143	6.6	132-158
29	40	153	18.0	125-213	40	151	16.1	128-193
30	38	158	22.2	130-213	40	154	20.5	130-209
31	40	149	12.1	131-187	38	147	13.3	131-196
32	39	149	12.8	126-180	39	146	12.0	132-180
33	40	149	14.5	125-201	40	159	22.7	131-209
34	40	152	16.7	132-203	37	153	18.2	125-202
35	39	150	17.0	125-205	39	149	18.3	122-205
36	40	149	14.2	133-193	40	153	16.6	135-217
37	40	153	13.7	134-198	40	151	12.7	133-193
38	40	149	12.7	126-200	39	147	10.4	130-175
39	39	156	20.2	125-224	39	152	17.0	130-210
40	40	150	14.4	121-211	40	148	16.4	121-213
Overall:	1563	153	16.4	121-230	1562	152	16.0	114-217

Table A1.4.-The sample size (N), mean, standard deviation (SD), and range of weights (g) of yearling Chinook salmon released into the top of the John Day Dam juvenile bypass system and tailrace during spring 2003.

Paired	Juvenile Bypass System				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	37	40.0	7.6	27.5-63.2	39	38.7	8.5	20.3-59.0
2	39	41.4	17.2	24.2-130.3	37	44.1	10.3	30.7-71.6
3	38	41.2	11.0	20.1-62.3	36	38.0	10.9	23.6-71.3
4	38	39.0	10.1	20.1-60.3	38	39.4	9.3	23.4-61.4
5	39	45.4	11.3	28.8-82.0	39	43.1	8.1	28.2-63.4
6	39	39.1	12.6	22.7-80.0	40	39.7	11.4	22.7-65.8
7	40	38.5	11.5	19.9-61.5	38	35.2	10.4	18.0-57.1
8	35	35.7	13.2	18.0-89.2	39	37.9	12.6	19.2-70.0
9	40	34.3	12.3	2.3-67.2	38	36.7	9.1	24.8-61.6
10	40	31.6	10.2	20.7-69.1	39	34.0	12.5	18.0-68.3
11	39	38.5	15.0	20.1-78.0	40	36.4	12.2	23.7-72.0
12	39	36.1	10.5	20.7-60.4	40	38.8	13.9	22.2-76.0
13	39	41.5	14.0	22.9-72.7	40	35.1	12.5	21.2-77.5
14	39	31.6	10.3	19.3-67.1	40	34.2	11.9	18.1-65.8
15	40	38.4	12.9	18.9-74.4	40	32.5	10.6	20.0-57.8
16	40	34.2	11.3	20.9-60.4	37	35.3	12.7	19.5-72.5
17	40	30.2	8.9	18.8-57.0	40	33.4	13.1	18.9-68.7
18	38	35.4	11.9	19.8-62.8	39	33.7	9.4	18.4-62.5
19	37	35.0	9.3	21.3-55.1	39	32.7	8.4	18.4-49.3
20	39	37.5	16.0	18.9-96.9	39	30.9	11.4	19.0-80.9
21	39	33.5	11.5	20.1-80.6	40	36.3	14.6	18.9-79.9
22	38	33.4	18.4	18.0-102.2	40	29.4	9.9	19.7-67.0
23	38	34.3	20.3	18.1-113.9	37	33.2	13.8	18.2-75.5
24	40	29.9	11.1	19.4-76.4	40	30.8	9.0	21.0-60.8
25	39	32.6	15.0	19.0-91.7	38	34.1	14.8	3.4-82.1
26	40	30.3	11.2	19.5-70.3	40	28.4	8.9	3.0-48.3
27	39	32.5	11.6	19.3-71.1	39	30.0	8.0	20.8-60.0
28	40	32.0	9.0	18.7-57.2	40	27.0	4.1	20.3-36.5
29	40	34.6	15.2	19.4-97.0	40	33.4	11.8	20.3-65.5
30	38	37.8	18.8	19.8-91.2	40	33.3	17.2	4.0-80.8
31	40	30.0	8.0	18.1-58.9	38	29.6	10.5	19.9-73.9
32	39	30.5	10.0	2.5-56.8	39	29.2	7.6	20.3-52.8
33	40	32.0	11.8	19.4-82.4	40	39.7	18.7	19.2-82.8
34	40	34.4	13.4	22.3-84.7	37	36.0	14.0	19.0-79.2
35	39	33.8	14.2	18.3-84.8	39	32.9	13.7	18.2-82.7
36	40	31.8	10.4	22.0-72.8	40	35.6	14.9	23.2-103.8
37	40	32.2	10.2	21.6-69.3	40	32.1	9.4	20.9-64.6
38	40	32.2	10.2	21.1-80.5	39	31.2	6.2	23.7-49.3
39	39	39.6	18.4	19.8-120.4	39	35.9	14.9	21.3-94.2
40	40	33.6	11.5	18.6-90.7	40	32.0	12.7	18.2-93.6
Overall:	1563	35.1	13.2	2.3-130.3	1562	34.5	12.2	3.0-103.8

Table A1.5.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of yearling Chinook salmon released into the John Day Dam turbine unit 4 and tailrace during spring 2003.

Paired	Turbine Unit 4				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	24	158	15.5	121-180	36	156	13.8	132-197
2	25	156	11.2	128-178	25	161	11.4	143-194
3	25	154	16.7	125-200	38	151	14.5	125-180
4	23	159	16.1	126-196	25	153	12.7	129-180
5	23	155	15.8	132-185	38	153	12.4	136-182
6	25	153	14.6	134-185	26	154	16.4	132-193
7	25	156	15.0	132-200	40	153	17.1	129-195
8	25	157	19.1	130-190	24	156	17.2	130-200
9	23	151	11.7	137-190	39	149	12.6	130-175
10	25	150	14.8	132-187	26	156	15.9	130-190
11	25	145	11.1	126-167	37	151	18.3	127-202
12	25	147	14.7	127-190	26	148	14.8	133-190
13	25	149	16.7	130-210	39	147	11.1	132-183
14	25	147	12.0	134-188	26	148	14.3	127-188
15	25	148	15.3	122-196	40	151	16.1	128-193
16	25	149	20.8	125-214	26	148	14.4	129-195
17	25	154	18.6	130-196	40	159	22.7	131-209
18	23	155	22.8	131-220	25	164	23.1	133-212
19	24	150	17.5	128-198	25	149	15.6	133-193
20	24	159	22.5	129-213	40	151	12.7	133-193
21	25	149	8.3	130-165	26	154	15.4	135-198
Overall:	514	152	16.4	121-220	667	152	16.0	125-212

Table A1.6.-The sample size (N), mean, standard deviation (SD), and range of weight (g) of yearling Chinook salmon released into the John Day Dam turbine unit 4 and tailrace during spring 2003.

Paired	Turbine Unit 4				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	24	38.9	10.3	18.5-55.8	36	38.0	10.9	23.6-71.3
2	25	36.8	7.3	20.8-50.7	25	41.6	9.1	31.3-73.5
3	25	36.2	12.5	19.6-80.7	38	35.2	10.4	18.0-57.1
4	23	39.1	12.2	20.4-70.0	25	35.9	8.8	19.0-60.2
5	23	37.1	12.0	22.2-62.9	38	36.7	9.1	24.8-61.6
6	25	35.8	10.7	24.7-62.2	26	37.1	12.7	22.8-69.9
7	25	36.9	11.3	20.3-75.1	40	35.1	12.5	21.2-77.5
8	25	40.0	14.6	21.1-70.8	24	38.2	12.9	22.7-76.8
9	23	35.1	10.3	25.9-73.1	39	32.7	8.4	18.4-49.3
10	25	32.5	10.1	21.4-57.6	26	35.8	11.7	20.0-61.0
11	25	29.0	6.9	19.6-43.6	37	33.2	13.8	18.2-75.5
12	25	31.2	10.9	19.3-64.9	26	30.7	10.4	21.0-64.7
13	25	32.8	13.6	21.2-88.6	39	30.0	8.0	20.8-60.0
14	25	31.2	8.6	23.6-65.5	26	32.1	10.7	18.7-69.0
15	25	31.3	10.8	19.6-68.3	40	33.4	11.8	20.3-65.5
16	25	32.6	16.5	18.6-95.4	26	30.1	10.5	19.0-69.3
17	25	34.6	13.9	18.7-68.7	40	39.7	18.7	19.2-82.8
18	23	37.2	19.6	19.3-101.0	25	43.8	20.8	21.9-87.2
19	24	32.8	13.7	19.2-70.3	25	33.1	13.1	21.3-78.2
20	24	38.8	17.6	21.0-86.6	40	32.1	9.4	20.9-64.6
21	25	30.5	4.8	19.8-39.2	26	35.2	13.9	22.6-79.6
Overall:	514	34.7	12.4	18.5-101.0	667	35.1	12.4	18.0-87.2

Table A1.7.-The sample size (N), mean, standard deviation (SD), and range of weights (g) and fork lengths (mm) of yearling Chinook salmon released into the John Day Dam tailrace during spring 2003.

	Fork Lengths (mm)				Weights (g)			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	26	162	11.2	145-189	26	40.7	9.0	29.4-63.4
2	22	161	11.6	138-183	22	38.8	8.1	26.2-57.7
3	27	155	18.1	125-188	27	38.0	13.5	19.0-65.0
4	27	152	21.0	129-216	27	37.0	19.9	21.6-113.7
5	24	152	16.3	131-206	24	33.6	13.4	20.7-83.8
6	27	155	18.9	135-210	27	35.9	15.9	22.1-93.5
7	28	147	14.4	127-192	28	30.3	10.5	19.0-69.4
8	26	150	14.5	126-188	26	32.1	8.8	18.2-51.7
9	27	148	9.5	135-179	27	31.5	6.7	22.9-54.3
10	26	157	20.7	128-206	26	38.8	16.8	19.6-84.7
Overall:	260	154	16.5	125-216	260	35.6	13.2	18.2-113.7

Table A1.8.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weights (g) of subyearling Chinook salmon released into John Day Dam tailrace during summer 2003.

	Fork Lengths (mm)				Weights (g)			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	51	114	3.2	110-126	51	15.2	1.4	13.3-20.1
2	45	116	2.7	112-122	45	14.8	1.3	13.2-18.8
3	49	113	2.7	110-124	49	14.9	1.2	13.0-18.9
4	55	116	3.2	112-128	55	14.5	1.5	13.0-21.5
5	50	113	3.4	110-122	50	15.4	1.5	13.3-19.6
6	49	115	2.4	112-121	49	14.3	1.2	13.0-19.5
7	51	113	3.5	110-122	51	15.3	1.6	13.0-19.3
8	50	114	3.6	110-129	50	14.8	1.8	13.0-22.5
9	51	116	2.8	111-127	51	14.4	1.5	13.0-22.0
10	52	114	4.4	110-139	52	15.4	2.6	13.0-30.7
11	50	115	2.9	112-128	50	14.3	1.3	13.0-18.3
12	48	113	2.8	110-121	48	14.9	1.6	13.0-22.1
13	51	115	3.2	111-128	51	14.7	1.5	13.0-20.0
14	49	112	2.8	108-120	49	14.7	1.3	13.0-19.1
15	47	113	2.5	110-121	47	14.8	1.4	13.0-20.1
16	50	113	3.9	110-127	50	15.3	2.2	13.1-22.3
17	50	116	4.4	111-131	50	16.2	2.7	13.0-25.9
18	55	113	3.6	110-124	55	15.5	2.2	13.1-22.7
19	52	115	4.8	110-137	52	15.9	2.8	13.0-26.3
20	54	116	4.1	111-127	54	15.4	2.1	13.0-22.7
21	29	115	4.5	110-128	29	15.6	2.6	13.0-22.8
22	49	114	3.7	111-127	49	16.2	2.2	13.2-22.7
23	48	115	3.7	110-128	48	15.8	2.0	13.0-24.5
24	50	117	5.5	110-137	50	17.2	3.0	13.5-26.7
25	57	115	3.5	110-127	57	16.1	2.1	13.1-25.2
26	51	116	4.5	110-126	51	17.2	2.6	14.0-23.3
27	51	116	4.6	110-128	51	16.8	2.4	13.0-23.4
28	47	115	3.9	110-127	47	16.0	2.2	13.0-21.7
29	49	117	6.2	110-138	49	17.8	3.7	13.6-28.6
30	49	115	4.4	110-132	49	16.4	2.5	13.0-26.1
31	49	118	6.0	110-135	49	18.1	3.2	13.0-26.6
32	49	116	6.0	110-139	49	17.0	3.0	13.4-28.0
33	51	117	5.1	110-141	51	17.4	2.1	13.3-22.8
34	46	118	8.8	110-158	46	18.2	4.4	13.0-37.2
35	51	117	5.7	110-137	51	17.4	2.8	13.6-25.8
36	49	116	6.1	110-140	49	16.6	2.7	13.1-26.6
37	50	115	4.0	110-125	50	15.7	1.9	13.0-20.6
38	51	116	7.8	110-140	51	16.6	3.2	13.2-26.8
39	50	116	6.6	110-145	50	16.4	3.1	13.5-28.9
40	58	117	7.4	110-143	58	17.0	3.6	13.8-32.2

Table A1.8.(continued)-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weights (g) of subyearling Chinook salmon released into John Day Dam tailrace during summer 2003.

	Fork Lengths (mm)				Weights (g)			
Release	N	Mean	SD	Range	N	Mean	SD	Range
41	58	119	8.7	110-148	58	18.6	4.5	14.3-34.5
42	56	119	7.7	110-143	56	17.6	3.3	13.4-29.2
43	56	121	8.7	110-138	56	18.2	3.7	13.4-27.7
44	52	118	8.5	110-143	52	17.5	3.6	13.0-30.1
45	47	120	7.7	112-143	47	17.7	3.2	13.9-28.4
46	49	119	8.6	111-145	49	18.5	3.5	13.6-28.0
47	46	120	7.6	111-145	46	17.5	3.1	13.7-26.3
48	47	118	8.4	110-142	47	17.2	3.7	13.8-30.0
49	49	119	8.0	110-141	49	16.7	3.0	13.0-26.6
50	53	118	6.6	110-140	53	18.3	2.9	13.7-27.4
51	50	118	7.3	110-145	50	17.9	4.3	13.8-37.9
52	54	117	6.5	110-138	54	18.0	3.5	13.2-28.8
53	47	117	5.3	110-134	47	17.4	2.6	14.2-26.8
54	52	117	5.8	110-140	52	17.9	2.9	14.0-28.7
55	52	118	6.8	110-144	52	18.4	2.6	14.9-27.3
56	53	115	5.2	110-137	53	17.0	2.5	13.2-27.5
Overall:	2814	116	5.9	108-158	2814	16.5	3.0	13.0-37.9

Appendix 2: Burnham Tests 2 and 3

Table A2.1.-Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 40 paired releases of yearling Chinook salmon, spring 2003. Treatment fish were released at the top of the juvenile bypass at John Day Dam 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]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
3	Treatment		[a]	[a]		[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]	5	1.389	0.925
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		[a]	[a]		[a]	[a]
9	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
10	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
11	Treatment		[a]	[a]		[a]	[a]
	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		[a]	[a]		[a]	[a]
15	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
16	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
17	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
18	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
19	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
20	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 A2.1. (Continued).- Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 40 paired releases of yearling Chinook salmon, spring 2003. Treatment fish were released at the top of the juvenile bypass at John Day Dam and control fish were released in the tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
21	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
22	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
23	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
24	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
25	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
26	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
27	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
28	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
29	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
30	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
31	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
32	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
33	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
34	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
35	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
36	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
37	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
38	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
39	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
40	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 A2.2.-Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 21 paired releases of yearling Chinook salmon, spring 2003. Treatment fish were released into the John Day Dam turbine unit 4 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		a	a
	Control		a	a		a	a
3	Treatment		a	a		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		a	a		a	a
7	Treatment		a	a		a	a
	Control		a	a		a	a
8	Treatment		a	a		a	a
	Control		a	a		a	a
9	Treatment		a	a		a	a
	Control		a	a		a	a
10	Treatment		a	a		a	a
	Control		a	a		a	a
11	Treatment		a	a		a	a
	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		a	a		a	a
15	Treatment		a	a		a	a
	Control		a	a		a	a
16	Treatment		a	a		a	a
	Control		a	a		a	a
17	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 A2.2.-(Continued) Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 21 paired releases of yearling Chinook salmon, spring 2003. Treatment fish were released into the John Day Dam turbine unit 4 and control fish were released in the tailrace.

			Test 2			Test 3	
Release	Population	df	χ^2	P	df	χ^2	P
18	Treatment		a	a		a	A
	Control		a	a		a	A
19	Treatment		a	a		a	A
	Control		a	a		a	A
20	Treatment		a	a		a	A
	Control		a	a		a	A
21	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 A2.3.-Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 21 paired releases of yearling Chinook salmon, spring 2003. Treatment fish were released into the John Day Dam turbine unit 4 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		a	a
	Control		a	a		a	a
3	Treatment		a	a		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		a	a		a	a
7	Treatment		a	a		a	a
	Control		a	a		a	a
8	Treatment		a	a		a	a
	Control		a	a		a	a
9	Treatment		a	a		a	a
	Control		a	a		a	a
10	Treatment		a	a		a	a
	Control		a	a		a	a
11	Treatment		a	a		a	a
	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		a	a		a	a
15	Treatment		a	a		a	a
	Control		a	a		a	a
16	Treatment		a	a		a	a
	Control		a	a		a	a
17	Treatment		a	a		a	a
	Control		a	a		a	a
18	Treatment		a	a		a	a
	Control		a	a		a	a
19	Treatment		a	a		a	a
	Control		a	a		a	a
20	Treatment		a	a		a	a
	Control		a	a		a	a
21	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.

Appendix 3: Homogeneity of Arrival Times

Table A3.1.-Chi-square tests for homogeneity of arrival times of yearling Chinook salmon released from the top of the juvenile bypass facility at John Day Dam and the John Day Dam tailrace and detected at river kilometers 335, 324, and 308, spring 2003.

	River Kilometer 335			River Kilometer 324			River Kilometer 308		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	1	0.74	0.390	1	1.52	0.218
2	0	0	[a]	0	0	[a]	2	6.56	0.038
3	0	0	[a]	0	0	[a]	2	1.78	0.411
4	0	0	[b]	1	0.69	0.406	1	0.79	0.375
5	0	0	[a]	1	1.51	0.220	1	1.83	0.176
6	0	0	[a]	1	1.68	0.195	1	1.34	0.247
7	0	0	[a]	0	0	[a]	1	1.04	0.307
8	0	0	[a]	0	0	[a]	1	0.67	0.414
9	0	0	[a]	0	0	[a]	1	0.48	0.491
10	0	0	[a]	0	0	[a]	0	0	[a]
11	1	1.41	0.235	0	0	[a]	1	1.41	0.234
12	0	0	[a]	1	1.53	0.215	1	5.59	0.018
13	1	1.16	0.281	0	0	[a]	0	0	[a]
14	0	0	[a]	0	0	[a]	1	0.83	0.363
15	0	0	[a]	0	0	[a]	0	0	[a]
16	0	0	[a]	0	0	[a]	0	0	[a]
17	0	0	[a]	0	0	[a]	0	0	[a]
18	0	0	[a]	0	0	[a]	0	0	[a]
19	0	0	[a]	0	0	[a]	0	0	[a]
20	0	0	[a]	0	0	[a]	0	0	[a]
21	0	0	[a]	0	0	[a]	0	0	[a]
22	0	0	[a]	0	0	[a]	0	0	[a]
23	0	0	[a]	0	0	[a]	0	0	[a]
24	0	0	[a]	0	0	[a]	0	0	[a]
25	0	0	[a]	0	0	[a]	0	0	[a]
26	0	0	[a]	0	0	[a]	0	0	[a]
27	0	0	[a]	0	0	[a]	0	0	[a]
28	0	0	[a]	0	0	[a]	0	0	[a]
29	0	0	[a]	1	1.32	0.251	1	1.24	0.266
30	0	0	[a]	0	0	[a]	0	0	[a]
31	0	0	[a]	0	0	[a]	0	0	[a]
32	0	0	[a]	0	0	[a]	0	0	[a]
33	0	0	[a]	0	0	[a]	0	0	[a]
34	1	1.08	0.299	0	0	[a]	0	0	[a]
35	0	0	[a]	0	0	[a]	0	0	[a]
36	0	0	[a]	0	0	[a]	0	0	[a]
37	0	0	[a]	0	0	[a]	0	0	[a]
38	0	0	[a]	0	0	[a]	0	0	[a]
39	0	0	[a]	0	0	[a]	0	0	[a]
40	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array.
[b] - Fixed gear/downloading problems 05/01/03 12:27 to 05/03/03 11:00 prevented data collection.

Table A3.2.-Chi-square tests for homogeneity of arrival times of yearling Chinook salmon released from the top of the juvenile bypass facility at John Day Dam and the John Day Dam tailrace and detected at river kilometers 286 and 267, spring 2003.

	River Kilometer 286			River Kilometer 267		
		Chi-square			Chi-square	
Release	DF		P	DF		P
1	1	0.37	0.544	1	2.01	0.156
2	2	2.79	0.248	3	7.42	0.060
3	3	5.39	0.145	2	0.75	0.686
4	2	1.49	0.475	2	1.84	0.400
5	1	1.89	0.169	1	0.58	0.447
6	1	3.71	0.054	1	0.68	0.411
7	2	1.02	0.600	1	0.78	0.376
8	1	0.44	0.507	2	0.82	0.663
9	1	0.53	0.467	1	0.41	0.524
10	1	3.22	0.073	1	4.22	0.040
11	0	0	[a]	1	2.00	0.157
12	0	0	[b]	1	5.68	0.017
13	0	0	[b]	1	3.47	0.062
14	1	1.70	0.192	1	0.98	0.322
15	1	1.09	0.296	1	1.21	0.271
16	1	1.30	0.254	0	0	[a]
17	1	1.27	0.261	1	1.42	0.234
18	0	0	[a]	1	1.22	0.269
19	0	0	[a]	1	1.37	0.241
20	1	2.56	0.110	1	1.07	0.300
21	1	3.69	0.055	1	5.32	0.021
22	0	0	[a]	0	0	[a]
23	0	0	[a]	0	0	[a]
24	0	0	[a]	0	0	[a]
25	1	2.04	0.153	1	1.20	0.274
26	1	1.90	0.168	1	1.71	0.191
27	1	0.45	0.503	0	0	[a]
28	1	0.83	0.364	1	0.89	0.345
29	0	0	[a]	0	0	[a]
30	0	0	[a]	0	0	[a]
31	0	0	[a]	0	0	[a]
32	0	0	[a]	0	0	[a]
33	1	0.86	0.354	1	0.72	0.396
34	1	0.81	0.368	1	0.87	0.352
35	1	1.02	0.313	1	0.98	0.323
36	0	0	[a]	0	0	[a]
37	1	1.82	0.177	1	2.29	0.131
38	0	0	[a]	0	0	[a]
39	1	0.68	0.410	0	0	[a]
40	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array.
[b] - Fixed gear/downloading problems 05/10/03 15:45 to 05/12/03 17:10 prevented data collection.

Table A3.3.-Chi-square tests for homogeneity of arrival times of yearling Chinook salmon released from a turbine at John Day Dam and the John Day Dam tailrace and detected at river kilometers 335, 324, and 308, spring 2003.

	River Kilometer 335			River Kilometer 324			River Kilometer 308		
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	0	0	[a]	1	0.63	0.428
2	0	0	[b]	0	0	[a]	0	0	[a]
3	0	0	[a]	0	0	[a]	0	0	[a]
4	0	0	[a]	0	0	[a]	1	1.07	0.300
5	0	0	[a]	0	0	[a]	1	0.26	0.611
6	0	0	[a]	1	0.07	0.794	1	0.01	0.929
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]
10	0	0	[a]	0	0	[a]	0	0	[a]
11	0	0	[a]	0	0	[a]	0	0	[a]
12	1	1.51	0.220	0	0	[a]	1	1.38	0.241
13	0	0	[a]	0	0	[a]	0	0	[a]
14	1	1.21	0.272	0	0	[a]	0	0	[a]
15	0	0	[a]	0	0	[a]	0	0	[a]
16	0	0	[a]	0	0	[a]	0	0	[a]
17	0	0	[a]	0	0	[a]	0	0	[a]
18	0	0	[a]	0	0	[a]	1	0.73	0.394
19	0	0	[a]	0	0	[a]	0	0	[a]
20	0	0	[a]	0	0	[a]	0	0	[a]
21	0	0	[a]	0	0	[a]	0	0	[a]

[a] - All fish arrived on the same day at this detection array.
[b]- Fixed gear/downloading problems 05/01/03 12:27 to 05/03/03 11:00 prevented data collection.

Table A3.4.-Chi-square tests for homogeneity of arrival times of yearling Chinook salmon released from a turbine at John Day Dam and the John Day Dam tailrace and detected at river kilometers 286 and 267, spring 2003.

	River Kilometer 286			River Kilometer 267		
		Chi-square			Chi-square	
Release	DF		P	DF		P
1	2	0.58	0.750	2	0.63	0.729
2	2	0.86	0.650	2	1.79	0.409
3	2	0.69	0.710	1	0.34	0.558
4	1	1.20	0.274	1	0.03	0.863
5	1	0	0.975	1	0.40	0.525
6	2	2.01	0.366	2	2.07	0.355
7	0	0	[b]	2	4.48	0.106
8	0	0	[b]	1	0.01	0.939
9	0	0	[a]	1	3.47	0.063
10	0	0	[a]	0	0	[a]
11	0	0	[a]	1	1.63	0.202
12	0	0	[a]	1	0.85	0.356
13	1	0.49	0.483	0	0	[a]
14	0	0	[a]	0	0	[a]
15	0	0	[a]	0	0	[a]
16	2	2.20	0.333	2	0.94	0.624
17	1	0.35	0.553	1	0.36	0.547
18	1	0.63	0.426	0	0	[a]
19	0	0	[a]	0	0	[a]
20	0	0	[a]	0	0	[a]
21	1	0.88	0.348	1	1.21	0.271

[a] - All fish arrived on the same day at this detection array.
[b] - Fixed gear/downloading problems 05/10/03 15:45 to 05/12/03 17:10 prevented data collection.