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Survival Estimates of migrant Juvenile Salmonids in the Columbia River through John Day Dam using Radio Telemetry, 2002.

Final Report of Research

Investigators: Timothy D. Counihan, Glen S. Holmberg, and James H. Petersen

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

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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

The results of our evaluations of the survival of yearling and subyearling Chinook salmon and steelhead trout through the John Day Dam juvenile bypass and steelhead trout through the John Day Dam spillway did not suggest a survival benefit for fish passing during the 60% night spill operations. In all cases the point estimates of survival generated using the paired release recapture models were highest for fish passing during the 30% night spill operations. Statistically significant differences in the estimated survival were observed for yearling and subyearling Chinook salmon released into the juvenile bypass system; no statistically significant results were observed for steelhead trout released into the juvenile bypass or spillway.

The estimated survival probabilities generated using the Route Specific Survival Model also suggest no survival benefit for fish passing during the 0% day/60% night spill operations. The estimated dam survival probabilities for yearling Chinook salmon and steelhead trout during the 0% day/60% night spill were not significantly different than during the 30% day/ 30% night spill operations. Statistically significant differences were documented for yearling Chinook salmon passing the juvenile bypass, for guided and unguided subyearling Chinook salmon via the powerhouse (includes turbine and juvenile bypass fish), and for the estimated dam survival of subyearling Chinook salmon; the estimated survival through the spillway was not significantly different during the 0% day/60% night and 30% day/30% night spill operations for any of the salmonid species evaluated. For all of the noted statistically significant results, the estimated survival was greater during the 30% day/ 30% night spill operations.

Paired Release Recapture Model

Juvenile Bypass

Yearling Chinook salmon

We estimated that the survival of yearling Chinook salmon released through the John Day Dam juvenile bypass during 2002 ranged from 0.44 to 1.12 (Table 7). The average survival of yearling Chinook salmon released through the John Day Dam juvenile bypass during the 2002 migration season was 0.81 (± 0.066, 95% confidence interval). Survival of yearling Chinook through the juvenile bypass during the 60% night spill operations was estimated to be 0.695 (± 0.102, 95% confidence interval) and 0.904 (± 0.066, 95% confidence interval) during the 30% night spill operation. The estimated survival of yearling Chinook salmon during the 60% night spill operation was significantly different than the estimated survival during the 30% spill operation (two-tailed *t*-test, $P < 0.01$).

Wild steelhead trout

We estimated that the survival of juvenile wild steelhead trout released through the John Day Dam juvenile bypass during 2002 ranged from 0.68 to 1.12 (Table 8). The average survival of steelhead trout released through the John Day Dam juvenile bypass during the 2002 migration season was 0.90 (± 0.045, 95% confidence interval). Survival of steelhead trout through the juvenile bypass during the 60% night spill operations was estimated to be 0.882 (± 0.060, 95% confidence interval) and 0.926 (± 0.067, 95% confidence interval) during the 30% night spill operation. The estimated survival of steelhead trout during the 60% night spill operation was not significantly different than during the 30% spill operation (two-tailed *t*-test, $P = 0.36$).

Subyearling Chinook salmon

We estimated that the survival of juvenile subyearling Chinook salmon released through the John Day Dam juvenile bypass during 2002 ranged from 0.41 to 1.06 (Table 9). The average survival of subyearling Chinook salmon released through the John Day Dam juvenile bypass during the 2002 migration season was 0.846 (± 0.066, 95% confidence interval). Survival of subyearling Chinook through the juvenile bypass during the 60% night spill operations was estimated to be 0.511 (± 0.096, 95% confidence interval) and 0.940 (± 0.046, 95% confidence interval) during the 30% night spill operation. The estimated survival of subyearling Chinook salmon during the 60% night spill operation was significantly different than the estimated survival during the 30% spill operation (two-tailed *t*-test, $P < 0.01$).

Spillway

Wild steelhead trout

We estimated that the survival of juvenile wild steelhead trout released through spillbays at the John Day Dam spillway during 2002 ranged from 0.71 to 1.13 (Table 10). The average survival of steelhead released through the John Day Dam spillway during the 2002 migration season was 0.922 (± 0.037, 95% confidence interval). The estimated survival of steelhead trout through the spillway was 0.932 (± 0.050, 95% confidence interval) during the 60% night spill operations, 0.946 (± 0.062, 95% confidence interval) during the 30% night spill operation, and 0.870 (± 0.087, 95% confidence interval) during the 30% day spill operation. The estimated survival of steelhead during the 60% night spill operation was not significantly different than the estimated survival during the 30% night spill operation (two-tailed *t*-test, $P = 0.74$). The estimated survival during the 60% night spill operation was also not significantly different than the 30% day spill ($P = 0.21$) and similarly, the estimated survival during the 30% night and 30% day spill operation was not significantly different for steelhead passing during the 30% night spill operation and during the 30% day spill operations (two-tailed *t*-test, $P = 0.17$).

Route Specific Survival Model

Yearling Chinook salmon

During the 0% day/60% night spill operations, the survival of yearling Chinook salmon through the John Day Dam spillway was estimated to be 0.993 (SE = 0.0170; profile likelihood 95% confidence interval = [0.958, 1.026]). For yearling Chinook passing the juvenile bypass during the 0% day/60% night spill operations the estimated survival was 0.911 (SE = 0.026, profile likelihood 95% confidence interval [0.857, 0.959]) and for yearling Chinook passing via the turbines at John Day Dam the estimated survival was 0.778 (SE = 0.051, profile likelihood 95% confidence interval [0.673, 0.870]). Yearling Chinook salmon dam survival during the 0% day/60% night spill operations was estimated to be 0.929 (SE = 0.021).

During the 30% day/30% night spill operations, the survival of yearling Chinook salmon through the John Day Dam spillway was estimated to be 1.00 (SE = 0.018; profile likelihood 95% confidence interval = [0.966, 1.036]). For yearling Chinook passing the juvenile bypass during the 30% day/30% night spill operations the estimated survival was 0.991 (SE = 0.024, profile likelihood 95% confidence interval [0.940, 1.034]) and for yearling Chinook passing via the turbines at John Day Dam the estimated survival was 0.832 (SE = 0.042, profile likelihood 95% confidence interval [0.744, 0.909]). Yearling Chinook salmon dam survival during the 30% day/30% night spill operations was estimated to be 0.963 (SE = 0.018).

The estimated survival probabilities for yearling Chinook were found to be statistically different for fish passing the juvenile bypass during the 0% day/60% and the 30% day/30% night spill operations; the spillway, powerhouse, and dam survival probabilities were not significantly different.

Wild steelhead trout

Because of the fewer steelhead released near Rock Creek, WA, compared to yearling Chinook salmon, we were unable to generate estimates for fish passing via both the turbine and juvenile bypass using the USER program and the model developed for yearling Chinook salmon. That is, too few fish passed via the powerhouse to allow us to use the model developed for yearling Chinook salmon. Consequently we had to combine the capture histories for turbine and juvenile bypass passed fish into one category. Estimates are presented for steelhead passing via the spillway, via the powerhouse (both guided and unguided), and for all routes.

During the 0% day/60% night spill operations, the survival of wild steelhead trout through the John Day Dam spillway was estimated to be 0.958 (SE = 0.027; profile likelihood 95% confidence interval = [0.899, 1.008]). For steelhead trout passing the powerhouse (turbine and juvenile bypass) during the 0% day/60% night spill operations the estimated survival was 0.930 (SE = 0.037, profile likelihood 95% confidence interval

[0.847, 0.995]). Wild steelhead trout dam survival during the 0% day/60% night spill operations was estimated to be 0.940 (SE = 0.027).

During the 30%/day/30% night spill operations, the survival of steelhead trout through the John Day Dam spillway was estimated to be 0.932 (SE = 0.033; profile likelihood 95% confidence interval = [0.857, 0.988]). For steelhead trout passing via the powerhouse during the 30% day/30% night spill operations the estimated survival was 0.899 (SE = 0.041, profile likelihood 95% confidence interval [0.807, 0.967]). Steelhead trout dam survival during the 30% day/30% night spill operations was estimated to be 0.915 (SE = 0.027).

The estimated survival probabilities were not found to be significantly different for wild steelhead known to have passed via the spillway or powerhouse (juvenile bypass turbine, guided and unguided respectively), or for fish passing via all routes (dam survival) during the 0% day/60% and the 30% day/30% night spill operations.

Subyearling Chinook salmon

The results presented in this section are for subyearling Chinook salmon known to have passed during spill blocks 23-24. This subset of blocks drastically reduced the sample size available for our analyses. Similar to the RSSM analyses presented for wild steelhead trout, insufficient information was available to use the model developed for yearling Chinook salmon. Thus, we used a similar model as that for wild steelhead trout. Estimates are presented for subyearling Chinook salmon passing via the spillway, via the powerhouse (both guided and unguided), and for all routes.

During the 0% day/60% night spill operations, the survival of subyearling Chinook salmon through the John Day Dam spillway was estimated to be 0.985 (SE = 0.023; profile likelihood 95% confidence interval = [0.934, 1.027]). For subyearling Chinook passing via the powerhouse (juvenile bypass and turbine) during the 0% day/60% night spill operations the estimated survival was 0.866 (SE = 0.034, profile likelihood 95% confidence interval [0.795, 0.928]). Subyearling Chinook salmon dam survival during the 0% day/60% night spill operations was estimated to be 0.928 (SE = 0.022).

During the 30% day/30% night spill operations, the survival of subyearling Chinook salmon through the John Day Dam spillway was estimated to be 1.03 (SE = 0.024; profile likelihood 95% confidence interval = [0.983, 1.078]) (Figure 13, Table 19). For subyearling Chinook passing via the powerhouse (juvenile bypass and turbine) during the 30% day/30% night spill operations the estimated survival was 0.966 (SE = 0.037, profile likelihood 95% confidence interval [0.885, 1.031]). Subyearling Chinook salmon dam survival during the 30% day/30% night spill operations was estimated to be 0.992 (SE = 0.026).

The estimated survival probabilities for subyearling Chinook salmon passing via the John Day Dam powerhouse and for all routes combined (dam survival) during the 0% day/60% night spill operations than during the 30% day/30% night spill operations were

found to be significantly different; the survival probabilities for subyearling Chinook passing via the spillway were not found to be significantly different.

Executive Summary table. The estimated survival probabilities and 95% confidence intervals associated with releases of radio-tagged yearling and subyearling Chinook salmon and steelhead trout released directly into the juvenile bypass and spillway 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 report for details.

Paired release-recapture model						
Treatment	Yearling Chinook		Steelhead trout		Subyearling Chinook	
Juvenile bypass						
	S	95% CI	S	95% CI	S	95% CI
60% night spill	0.695	± 0.102	0.882	± 0.060	0.511	± 0.096
30% night spill	0.904	± 0.066	0.926	± 0.067	0.940	± 0.046
Spillway						
	S	95% CI	S	95% CI	S	95% CI
60% night spill	NA	NA	0.932	± 0.050	NA	NA
30% night spill	NA	NA	0.946	± 0.062	NA	NA
30% day spill	NA	NA	0.870	± 0.087	NA	NA

Route Specific Survival Model						
Treatment	Yearling Chinook		Steelhead trout		Subyearling Chinook	
Spillway						
	S	95% CI [B]	S	95% CI [B]	S	95% CI [B]
0% day/60% night	0.993	0.958, 1.026	0.958	0.899, 1.008	0.985	0.934, 1.027
30% day/30% night	1.000	0.966, 1.036	0.932	0.857, 0.988	1.030	0.983, 1.078
Powerhouse (unguided [A])						
	S	95% CI [B]	S	95% CI [B]	S	95% CI [B]
0% day/60% night	0.778	0.673, 0.870	0.930	0.847, 0.995	0.866	0.795, 0.928
30% day/30% night	0.832	0.744. 0.909	0.899	0.807, 0.967	0.966	0.885, 1.031
Juvenile bypass (guided)						
	S	95% CI [B]	S	95% CI [B]	S	95% CI [B]
0% day/60% night	0.911	0.857, 0.959	NA	NA	NA	NA
30% day/30% night	0.991	0.940, 1.034	NA	NA	NA	NA
Dam (all routes)						
	S	95% CI	S	95% CI	S	95% CI
0% day/60% night	0.929	± 0.041	0.940	± 0.053	0.928	± 0.043
30% day/30% night	0.963	± 0.035	0.915	± 0.053	0.992	± 0.051

[A] – The estimated powerhouse survival for steelhead trout and subyearling Chinook salmon includes both guided and unguided fish. The capture histories for these two routes (i.e., powerhouse unguided and juvenile bypass) were combined because too few fish passed through these routes to estimate the variance and standard errors of the point estimates. The reduction in the number of spill blocks that conformed to the prescribed treatments and the lower number of steelhead trout released compared to yearling Chinook salmon contributed to the manifestation of this computational difficulty.
[B] – 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, etc.) and indirect effects (e.g., predation, disease, and physiological stress) contribute to the total mortality of seaward migrating salmonids. Many studies have been conducted to determine the effects of hydroelectric dams on the survival of salmonid migrants (Raymond 1979, Stier and Kynard 1986, Iwamato et al. 1994, Muir et al. 1995, Smith et al. 1998). Based on this research and studies examining migrant salmonid behavior at dams in the Columbia River Basin, management actions are currently being implemented to improve the survival of salmonid migrants.

A primary objective of The National Marine Fisheries Service Federal Columbia River Power System (FCRPS) Biological Opinion is to increase survival of juvenile salmonid out-migrants through the federal hydrosystem (NMFS 2000). To help meet this objective, specific water management scenarios have been specified for the hydropower system in general and also, specifically for each project. Based on past research, the NMFS has determined that measures that 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. During 2002, we evaluated survival through the juvenile bypass system, the spillway, and the turbines. 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.

Methods

Study Area

During the 2002 spring and summer juvenile salmonid migration, radio-tagged juvenile salmonids 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 various spillbays at the spillway, and in the tailrace. The study area extended from the release location near Rock Creek downriver to the Hood River Bridge (Figure 1). 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).

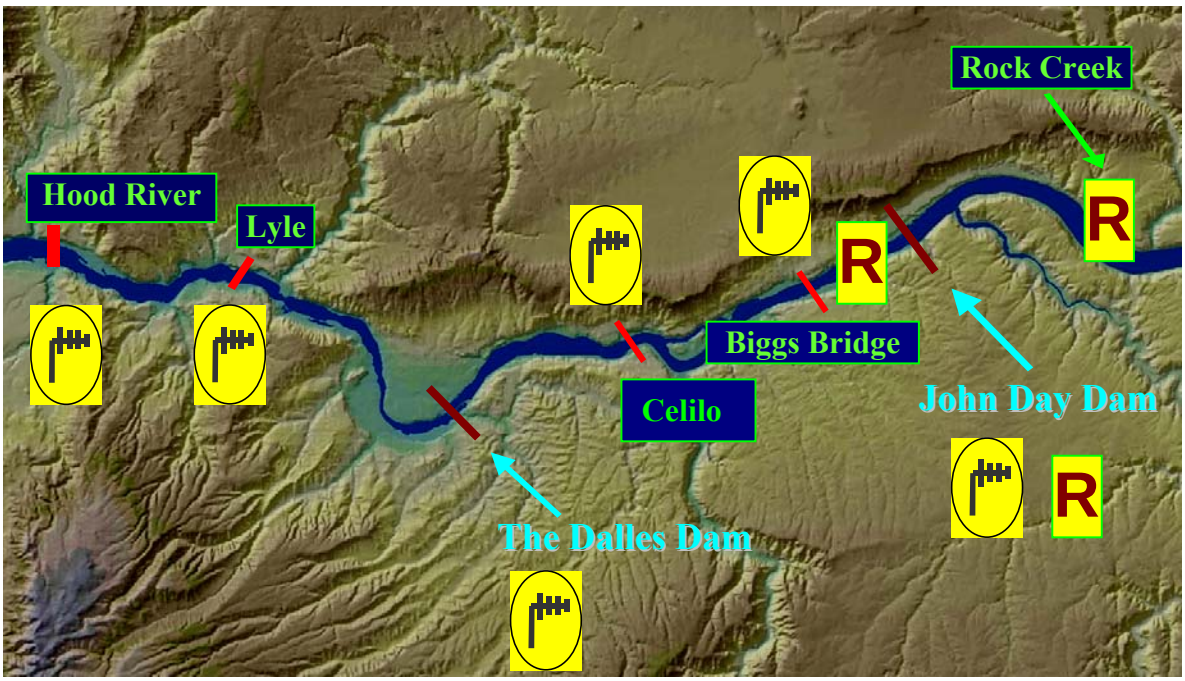

Figure 1. Release and detection locations for the John Day Dam survival evaluations, 2002. R = release location and locations of radio-telemetry arrays are shown as yellow antenna symbols.

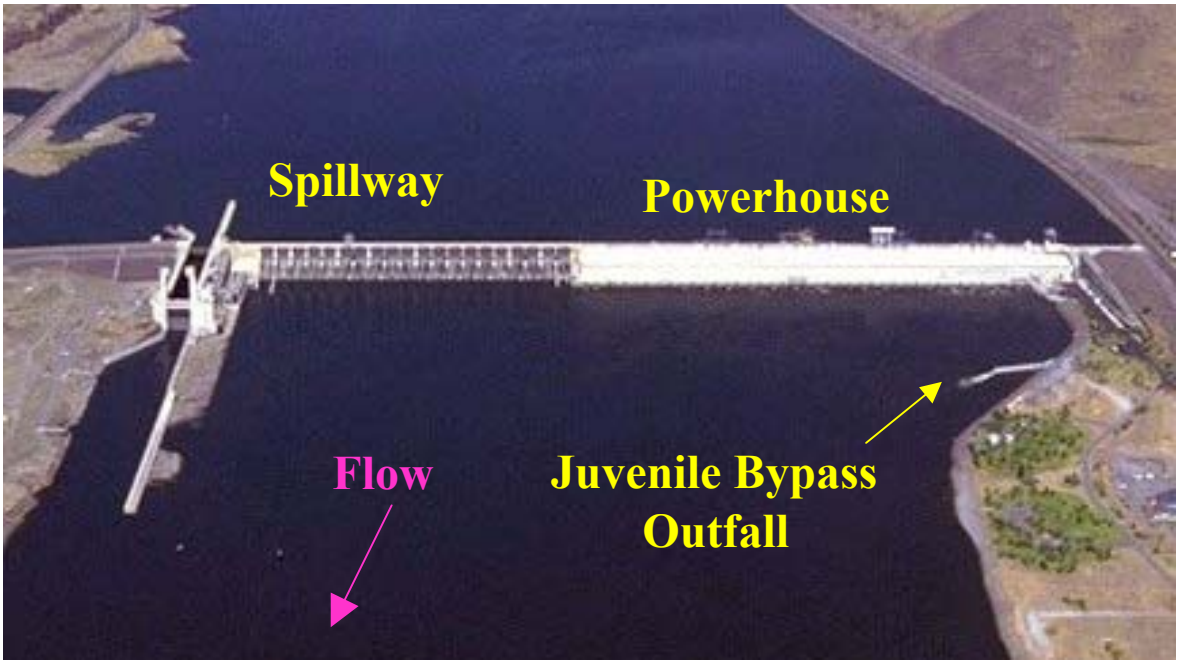

Figure 2. Aerial view of John Day Dam looking upriver (East).

John Day Dam

John Day Dam consists of a powerhouse, a spillway, and a navigational lock (Figure 2). The powerhouse consists of 16 horizontal-axis 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 out and 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 navigational 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 in the juvenile bypass system (Figure 3). We placed 10 aerial antennas on the forebay spillbays, and 10 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 45º away from the dam and provided coverage for two adjacent bays. We placed 10 aerial antennas on the tailrace spillway and 10 on the powerhouse. Detection range for aerial antennas was approximately 100 m but varies with the depth of the transmitter in the water column. A total of 40 underwater antennas were attached to the spillway pier noses, and 80 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 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 either an SRX-400 data logging telemetry receiver (Lotek Wireless, Newmarket, Ontario, Canada), a Digital Spectrum processor (Lotek Wireless), or Mutiprotocol Integrated Telemetry Acquisition System (MITAS; Grant Systems Engineering, King City, Ontario, Canada). Data logging devices stored detection histories for individual channel codes 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 36 4-day blocks, from 10 April to 31 August 2002. 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. The first prescribed treatment was to consist of no spill discharge from 0600 to 1759 h (day) and 60% discharge from 1800 to 0559 h (night)

Figure 3. Locations of radio-telemetry antennas at the John Day Dam during 2002. Black arrows represent aerial antennas and underwater antennas are represented as red dots. Schematic shows approximate locations.

and is referred to as 0% day/ 60% night. The second treatment was to consist of 30% spill discharge during the day and 30% discharge at night (30% day /30% night). Releases of radio-tagged yearling Chinook salmon, yearling wild steelhead trout, and subyearling Chinook salmon from near Rock Creek, WA were timed so that they arrived at John Day Dam during both the 0% day/ 60% night and 30% day/ 30% night spill operations. During 2002, the actual spill operations did not always conform to the prescribed conditions. A discussion of how this problem was dealt with in our analyses is included below in the statistical methods section.

Radio Transmitters

We used pulse-coded transmitters (tags) manufactured by Lotek Engineering, Inc, (Newmarket, Ont.). Transmitters that operate at frequencies between 150.320 and 150.760 MHz used the Lotek Wireless "2000 code set", a pulse-coding scheme with 212 unique codes per frequency that allow 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 juvenile steelhead and 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.

Converting radio signals into detection histories

Aerial and underwater antennas attached to data logging equipment will often 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. Some automated data processing was performed. For instance signals designated as noise were removed through the use of code in the Statistical Analysis System (SAS) software and signals with time stamps recorded before the release time of the release being processed were also discarded. Minimum power thresholds were established. Detection data was then merged with release data, records were manually examined by two separate proofing staff and designated with a passage location and time, and then reconciled by a third staff member if any disagreement in either the time of passage of passage location were noted. Travel times to downriver locations and geographic ranking were considered when manually proofing the radio-telemetry records.

Fish tagging

Juvenile wild steelhead trout and yearling and subyearling Chinook salmon that were implanted with radio transmitters were collected from the juvenile collection and bypass facility at John Day Dam. Low numbers of wild steelhead at the John Day Dam collection facility made it necessary to obtain additional wild steelhead from the upriver collection facility at McNary Dam (RK 469.8). Wild steelhead collected at McNary Dam

were held 2 to 5 h then transported to the John Day Dam collection facility. Fish collected at John Day Dam were typically held at the collection facility for 12 to 24 h prior to tagging. Fish collected from McNary were held up to 43 h after transport and before tagging. Fish were considered suitable for tagging if they were free of injuries, severe descaling, external signs of gas bubble trauma, or other abnormalities. Transmitters were gastrically implanted in both species using the methods of Martinelli et al. (1998).

Following tagging, fish were held in tanks 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. Radio-tagged juvenile steelhead were also released near the ogee crest of spillbays 2,3,10,12,14,16, and 18 through a tank and hose system that delivered fish to the ogee. Refer to Beeman, 2001, 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 through the spillbays, platforms were built to support 0.8 m diameter circular tanks approximately 1 m above the parapet wall on the spillway deck. Flexible hose (0.1 m diameter) was connected to the lower end of the tank, extended over the parapet wall, and routed to the pier nose on the north side of each spillbay. The flexible hose was protected from damage by securing it inside a 0.16 m steel pipe fastened to the north piernose wall. The steel pipe extended approximately 3 m above the forebay elevation to a position 1 m above the spillway crest. At its lower end, a sweeping 45° angle piece of conduit guided fish away from the piernose where they encountered capture velocity and were pulled through the tainter gate. A submersible pump in the forebay supplied water to the release tank at a rate of 200 L/min.

Prior to releasing fish, the pumps were activated to fill the release tanks and eliminate any air pockets within the release hoses. A single radio-tagged fish was placed into each release tank. Fish generally exited the release tank within 5 to 10 s. Water from the submersible pump was simultaneously routed through the tank and hose system to ensure that fish exited the hose at the bottom. Fish were released from all four sites within several minutes of each other.

Release Strategy

Releases at Rock Creek consisted of 32 groups of approximately 50 yearling Chinook, 34 groups of 17 yearling wild steelhead trout, and 59 groups of 50 subyearling Chinook salmon. Releases occurred at 0900 h and 2100 h. See Tables 1 and 2 for exact time and number of fish released at Rock Creek.

Releases at John Day Dam consisted of yearling Chinook, juvenile steelhead trout, and subyearling Chinook salmon (Tables 3-6). Releases were evaluated using the single-release model and also grouped with releases made in the tailrace to form paired releases that were evaluated using the paired release recapture model. Yearling Chinook were released into the bypass and tailrace during 31 separate releases of approximately 20 fish per release at each location. Releases occurred at 2300 h into the bypass and 0100 h into the tailrace See Table 3 for exact time and number of fish released. Juvenile steelhead trout were released into the bypass and tailrace during 30 separate releases of approximately 18 fish per release at each location (Table 4). Releases into the spillbays occurred at 2300 h and at 0100 h into the tailrace. Juvenile steelhead trout were also released into 7 different spillbays and the tailrace during 40 separate releases of approximately 20 fish per release at each location. Releases into the spillbays occurred at 1100 and 2300 h and at 1200 and 0100 h into the tailrace (Table 5). Subyearling Chinook were released into the bypass and tailrace during 31 separate releases of approximately 45 fish per release at each location. Releases occurred between 2300 and 0100 h (Table 6).

Table 1. Release dates and times of yearling Chinook salmon and wild steelhead trout into the Columbia River near Rock Creek, Washington, Spring 2002.

		Yearling Chinook salmon			Steelhead trout	
Release	N	Date	Time	N	Date	Time
1	46	29 April	22:37	11	29 April	22:37
2	45	30 April	09:12	6	30 April	09:12
3	48	1 May	21:41	12	1 May	21:41
4	44	2 May	09:05	15	2 May	09:05
5	47	3 May	21:23	19	3 May	21:23
6	54	4 May	09:50	18	4 May	09:50
7	51	5 May	20:48	12	5 May	20:48
8	44	6 May	09:47	12	6 May	09:47
9	46	7 May	20:40	22	7 May	20:40
10	48	8 May	08:58	16	8 May	08:58
11	49	9 May	20:58	18	9 May	20:58
12	48	10 May	08:56	18	10 May	08:56
13	50	11 May	20:35	9	11 May	20:35
14	45	12 May	09:10	10	12 May	09:10
15	55	13 May	20:28	20	13 May	20:28
16	47	14 May	09:23	24	14 May	09:23
17	49	15 May	21:12	18	15 May	21:12
18	49	16 May	09:07	18	16 May	09:07
19	46	17 May	20:31	20	17 May	20:31
20	48	18 May	08:55	19	18 May	08:55
21	46	19 May	20:35	17	19 May	20:35
22	54	20 May	08:58	20	20 May	08:58
23	53	21 May	20:49	19	21 May	20:49
24	49	22 May	08:58	19	22 May	08:58
25	52	23 May	21:01	20	23 May	21:01
26	52	24 May	09:03	18	24 May	09:03
27	49	25 May	20:53	17	25 May	20:53
28	49	26 May	09:02	20	26 May	09:02
29	52	27 May	20:50	20	27 May	20:50
30	53	28 May	08:59	18	28 May	08:59
31	49	29 May	20:45	21	29 May	20:45
32	52	30 May	08:45	20	30 May	08:45
33	[a]	[a]	[a]	27	3 June	20:47
34	[a]	[a]	[a]	29	4 June	09:07
Overall:	1569			602		

[a] Yearling Chinook salmon were not released

Table 2. Release dates and times of subyearling Chinook salmon into the Columbia River near Rock Creek, Washington, 2002.

Release	N	Date	Time	Release	N	Date	Time
1	52	24 June	21:47	31	39	9 July	19:16
2	29	25 June	09:35	32	38	10 July	09:05
3	65	25 June	21:50	33	46	10 July	20:05
4	62	26 June	09:05	34	43	11 July	09:05
5	58	26 June	21:25	35	46	11 July	19:34
6	61	27 June	09:00	36	49	12 July	08:57
7	60	27 June	20:56	37	44	12 July	20:32
8	61	28 June	09:42	38	39	13 July	08:56
9	52	28 June	20:47	39	45	13 July	20:20
10	64	29 June	09:20	40	48	14 July	08:40
11	54	29 June	20:38	41	46	14 July	19:07
12	55	30 June	09:05	42	48	15 July	08:57
13	58	30 June	20:35	43	50	15 July	20:43
14	59	1 July	08:50	44	47	16 July	09:10
15	37	1 July	20:28	45	46	16 July	20:29
16	50	2 July	09:28	46	48	17 July	08:48
17	42	2 July	20:51	47	44	17 July	20:33
18	32	3 July	08:43	48	51	18 July	08:54
19	41	3 July	21:10	49	50	18 July	20:37
20	29	4 July	08:56	50	39	19 July	08:41
21	41	4 July	20:44	51	50	19 July	20:50
22	41	5 July	09:02	52	51	20 July	08:46
23	40	5 July	20:42	53	45	20 July	20:32
24	41	6 July	08:50	54	46	21 July	08:35
25	45	6 July	21:00	55	48	21 July	20:10
26	40	7 July	08:39	56	46	22 July	08:50
27	38	7 July	20:33	57	51	23 July	08:47
28	33	8 July	09:55	58	75	24 July	09:07
29	59	8 July	20:28	59	89	25 July	08:53
30	44	9 July	09:02	Overall:	2880		

Table 3. Release dates and times for paired releases of yearling Chinook salmon into the John Day Dam juvenile bypass and tailrace, spring 2002.

Paired	Juvenile bypass			Tailrace		
Release	N	Date	Time	N	Date	Time
1	20	30 April	23:29	20	1 May	01:43
2	18	1 May	23:00	19	2 May	00:38
3	19	2 May	22:58	19	3 May	01:06
4	20	3 May	22:30	19	4 May	00:41
5	20	4 May	22:35	19	5 May	00:37
6	20	5 May	22:58	20	6 May	01:11
7	20	6 May	23:06	20	7 May	00:57
8	20	8 May	23:00	19	9 May	00:17
9	19	9 May	22:53	18	10 May	00:17
10	20	10 May	21:46	19	10 May	22:27
11	20	11 May	23:01	18	11 May	23:33
12	20	12 May	22:05	20	12 May	23:11
13	20	13 May	22:50	20	14 May	00:21
14	20	14 May	22:28	20	14 May	23:57
15	16	15 May	23:12	18	16 May	00:27
16	19	16 May	22:13	19	16 May	23:19
17	19	17 May	22:32	20	18 May	00:11
18	17	18 May	22:34	20	18 May	23:29
19	19	19 May	22:20	19	19 May	22:49
20	20	20 May	22:03	20	20 May	23:40
21	19	21 May	22:42	19	21 May	23:30
22	15	22 May	22:15	19	23 May	00:07
23	14	23 May	22:59	16	24 May	00:17
24	18	24 May	22:38	15	25 May	00:39
25	19	25 May	23:08	17	26 May	00:48
26	19	26 May	23:01	20	27 May	00:37
27	18	27 May	22:51	20	27 May	23:37
28	19	28 May	22:14	20	28 May	22:48
29	18	29 May	22:44	18	30 May	00:01
30	20	30 May	22:55	20	31 May	00:25
31	18	31 May	22:54	19	1 June	00:10
Overall:	583			589		

Table 4. Release dates and times for paired releases of wild steelhead trout released into the John Day Dam juvenile bypass and tailrace, spring 2002.

Paired	Juvenile bypass			Tailrace		
Release	N	Date	Time	N	Date	Time
1	19	30 April	23:37	19	1 May	01:44
2	20	1 May	23:00	19	2 May	00:36
3	17	2 May	22:58	19	3 May	01:06
4	19	3 May	22:28	20	4 May	00:38
5	20	4 May	22:32	20	5 May	00:37
6	18	5 May	23:17	20	6 May	01:09
7	20	6 May	23:05	20	7 May	00:54
8	16	7 May	23:01	15	8 May	00:33
9	18	8 May	23:00	18	9 May	00:15
10	18	9 May	22:54	20	10 May	00:15
11	19	12 May	22:04	18	12 May	23:12
12	20	13 May	22:49	20	14 May	00:18
13	20	14 May	22:41	20	14 May	23:58
14	18	15 May	23:13	20	16 May	00:24
15	19	16 May	22:15	20	16 May	23:21
16	10	18 May	22:02	20	18 May	23:27
17	18	20 May	22:05	17	20 May	23:28
18	20	22 May	22:18	19	23 May	00:08
19	20	23 May	22:58	20	24 May	00:14
20	18	24 May	22:40	15	25 May	00:38
21	18	25 May	23:07	16	26 May	00:46
22	19	26 May	23:04	19	27 May	00:39
23	10	28 May	22:12	18	28 May	22:46
24	20	29 May	22:42	20	29 May	23:59
25	18	30 May	22:53	19	31 May	00:28
26	19	31 May	22:52	19	1 June	00:11
27	10	3 June	22:18	20	3 June	23:10
28	10	4 June	22:16	18	4 June	23:09
29	18	5 June	22:20	19	5 June	23:37
30	20	6 June	22:32	17	6 June	23:52
Overall:	529			564		

Table 5. Release dates and times for paired releases of wild steelhead trout released into the John Day Dam spillway and tailrace, spring 2002. Spillway includes one or more of the following spill bays: SB02, SB03, SB10, SB12, SB14, SB16, and SB18.

Paired	Spillway			Tailrace		
Release	N	Date	Time	N	Date	Time
1	15	30 April	11:40	18	30 April	12:48
2	18	1 May	00:27	19	1 May	01:44
3	18	1 May	23:34	19	2 May	00:36
4	19	2 May	23:40	19	3 May	01:06
5	19	3 May	23:13	20	4 May	00:38
6	17	4 May	11:11	19	4 May	12:16
7	20	4 May	23:19	20	5 May	00:37
8	16	5 May	11:02	20	5 May	11:41
9	19	5 May	23:52	20	6 May	01:09
10	20	6 May	23:48	20	7 May	00:54
11	13	7 May	23:47	15	8 May	00:33
12	19	8 May	23:31	18	9 May	00:15
13	20	9 May	23:27	20	10 May	00:15
14	19	10 May	11:03	17	10 May	12:17
15	19	12 May	22:33	18	12 May	23:12
16	19	13 May	23:24	20	14 May	00:18
17	19	14 May	23:04	20	14 May	23:58
18	20	15 May	23:23	20	16 May	00:24
19	19	16 May	22:41	20	16 May	23:21
20	10	18 May	22:40	20	18 May	23:27
21	20	20 May	10:56	19	20 May	12:04
22	20	20 May	22:46	17	20 May	23:28
23	19	21 May	10:49	20	21 May	11:34
24	13	21 May	22:53	19	21 May	23:29
25	20	22 May	22:58	19	23 May	00:08
26	20	23 May	23:29	20	24 May	00:14
27	19	24 May	23:24	15	25 May	00:38
28	16	25 May	23:48	16	26 May	00:46
29	20	26 May	11:21	20	26 May	12:13
30	20	26 May	23:42	19	27 May	00:39
31	19	29 May	23:13	20	29 May	23:59
32	19	30 May	23:29	19	31 May	00:28
33	18	31 May	23:30	19	1 June	00:11
34	10	3 June	11:10	20	3 June	11:57
35	10	3 June	22:31	20	3 June	23:10
36	18	4 June	11:08	20	4 June	11:53
37	10	4 June	22:30	18	4 June	23:09
38	19	5 June	22:52	19	5 June	23:37
39	18	6 June	11:55	20	6 June	12:32
40	19	6 June	23:04	17	6 June	23:52
Overall:	705			883		

Table 6. Release dates and times for paired releases of subyearling Chinook salmon into the John Day Dam juvenile bypass and tailrace, summer 2002.

	Juvenile Bypass			Tailrace		
Release	N	Date	Time	N	Date	Time
1	52	21 June	23:19	60	22 June	00:13
2	48	22 June	23:23	60	23 June	00:32
3	54	24 June	00:33	53	24 June	01:31
4	57	25 June	00:03	52	25 June	01:06
5	49	25 June	23:29	59	26 June	00:32
6	53	27 June	00:18	56	27 June	01:50
7	52	27 June	23:12	59	28 June	00:06
8	60	29 June	01:09	60	29 June	02:13
9	48	29 June	23:27	50	30 June	00:13
10	48	30 June	22:48	49	30 June	23:44
11	49	1 July	22:42	50	1 July	23:42
12	34	2 July	23:04	40	3 July	00:00
13	36	3 July	22:58	47	3 July	23:53
14	49	4 July	22:42	53	4 July	23:40
15	58	5 July	22:34	57	5 July	23:36
16	40	6 July	23:23	43	7 July	00:37
17	53	7 July	23:35	59	8 July	00:37
18	44	8 July	22:51	48	8 July	23:41
19	39	9 July	22:51	42	9 July	23:44
20	38	10 July	23:22	43	11 July	00:12
21	39	11 July	23:01	43	12 July	00:20
22	35	12 July	22:49	44	12 July	23:42
23	38	13 July	22:52	39	13 July	22:46
24	39	14 July	22:26	44	14 July	23:17
25	40	15 July	23:01	41	15 July	23:51
26	34	16 July	23:02	43	16 July	23:52
27	39	17 July	23:06	37	18 July	00:00
28	40	18 July	22:27	43	18 July	23:10
29	39	19 July	22:59	44	20 July	00:00
30	37	20 July	23:14	43	21 July	00:02
31	40	21 July	22:17	43	21 July	23:29
Overall:	1381			1504		

Statistical methods

Paired-release recapture model

We used the paired-release recapture models of Burnham et al. (1987) to estimate the survival of juvenile yearling and subyearling Chinook salmon and steelhead trout 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 and steelhead trout 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 each downstream array. Tests were 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 and subyearling Chinook salmon and steelhead trout released through the John Day Dam juvenile bypass during the day and night. The specific hypotheses tested were as follows:

<u>Yearling Chinook</u>

$$H_0 : S_{JUVENILE\ BYPASS\ 60\%} = S_{JUVENILE\ BYPASS\ 30\%}$$
$$H_A : S_{JUVENILE\ BYPASS\ 60\%} \neq S_{JUVENILE\ BYPASS\ 30\%}$$

<u>Steelhead trout</u>

$$H_0 : S_{JUVENILE\ BYPASS\ 60\%} = S_{JUVENILE\ BYPASS\ 30\%}$$
$$H_A : S_{JUVENILE\ BYPASS\ 60\%} \neq S_{JUVENILE\ BYPASS\ 30\%}$$

<u>Subyearling Chinook</u>

$$H_0 : S_{JUVENILE\ BYPASS\ 60\%} = S_{JUVENILE\ BYPASS\ 30\%}$$
$$H_A : S_{JUVENILE\ BYPASS\ 60\%} \neq S_{JUVENILE\ BYPASS\ 30\%}$$

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 steelhead trout released through the John Day Dam spillway during the 30% day, 30% night, and 60% night spill operations. The specific hypotheses tested were as follows:

<u>Steelhead trout</u>

$$H_0 : S_{SPILLWAY\ 30\%\ NIGHT} = S_{SPILLWAY\ 30\%\ DAY}$$
$$H_A : S_{SPILLWAY\ 30\%\ NIGHT} \neq S_{SPILLWAY\ 30\%\ DAY}$$

$$H_0 : S_{SPILLWAY\ 60\%\ NIGHT} = S_{SPILLWAY\ 30\%\ DAY}$$
$$H_A : S_{SPILLWAY\ 60\%\ NIGHT} \neq S_{SPILLWAY\ 30\%\ DAY}$$

$$H_0 : S_{SPILLWAY\ 60\%\ NIGHT} = S_{SPILLWAY\ 30\%\ NIGHT}$$
$$H_A : S_{SPILLWAY\ 60\%\ NIGHT} \neq S_{SPILLWAY\ 60\%\ NIGHT}$$

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. Similar to the juvenile bypass evaluations, the hypotheses were formulated to address the assumption that the spill levels outlined in the NMFS Biological Opinion (60% night spill) would result in higher survival of juvenile salmonids passing John Day Dam. Additionally it was hypothesized that 30% night spill operation would have a higher estimated survival than the 30% day spill operation.

Estimable Parameters

The release and detection schemes used during 2002 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 2002.

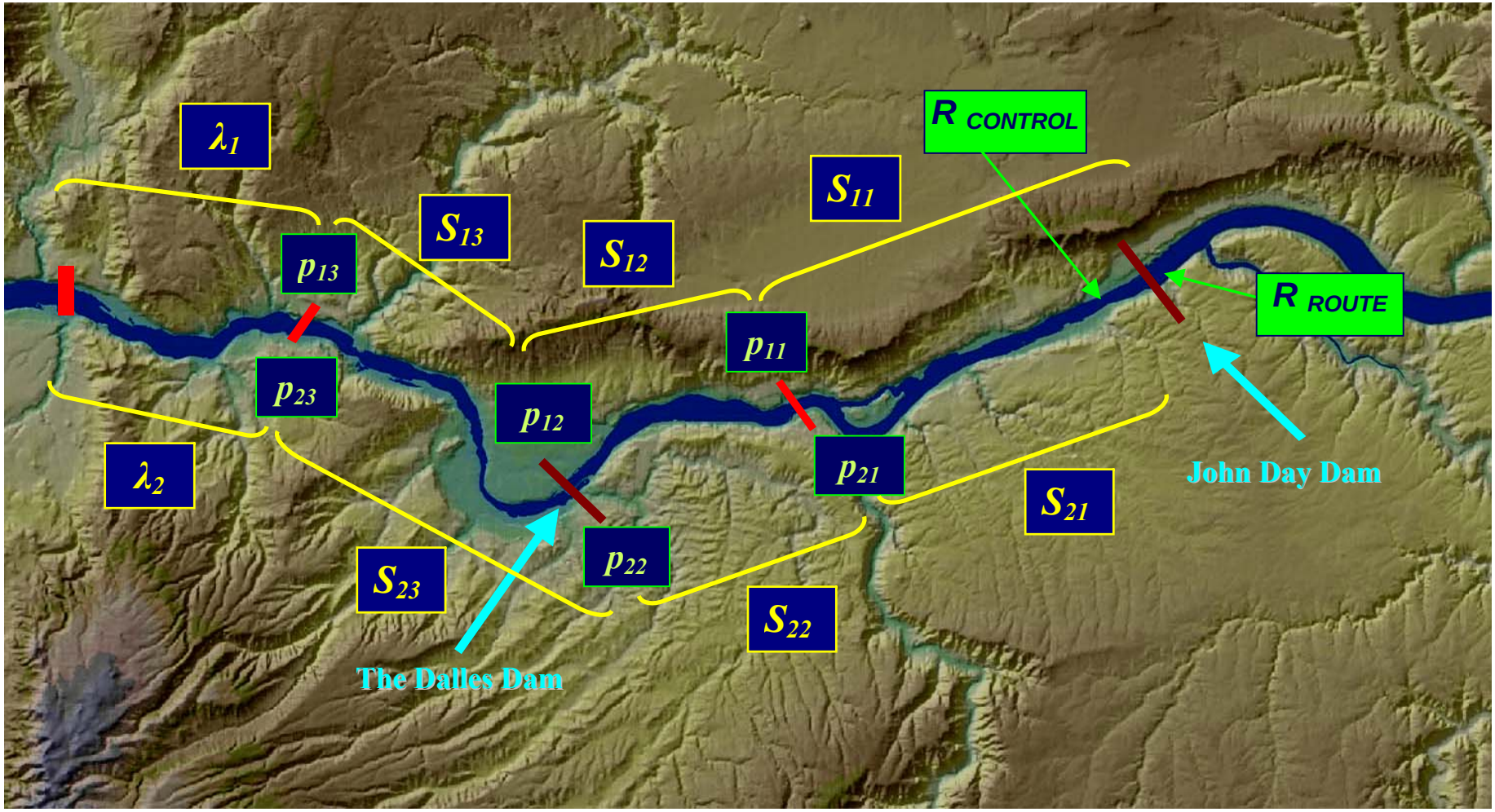

Figure 4. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) from site-specific releases (R_{ROUTE}) at John Day Dam and in the John Day Dam tailrace.

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 are 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

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

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 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 performed to assess the differences of route-specific survival estimates between treatments for each passage route (John Skalski, University of Washington, personal communication). The hypotheses tested for different stocks and all species are of the form:

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

Subsetting releases used for analyses

During 2002, we assessed the route specific survival of yearling and subyearling Chinook salmon and wild steelhead trout during two different dam operations (0% day spill/60% night spill; 30% day spill/30% night spill). However, there were difficulties in obtaining the prescribed treatment levels during both the spring and summer migration season. Consequently, some of our releases occurred during dam operations that did not reflect the prescribed conditions. To address these difficulties, meetings between the

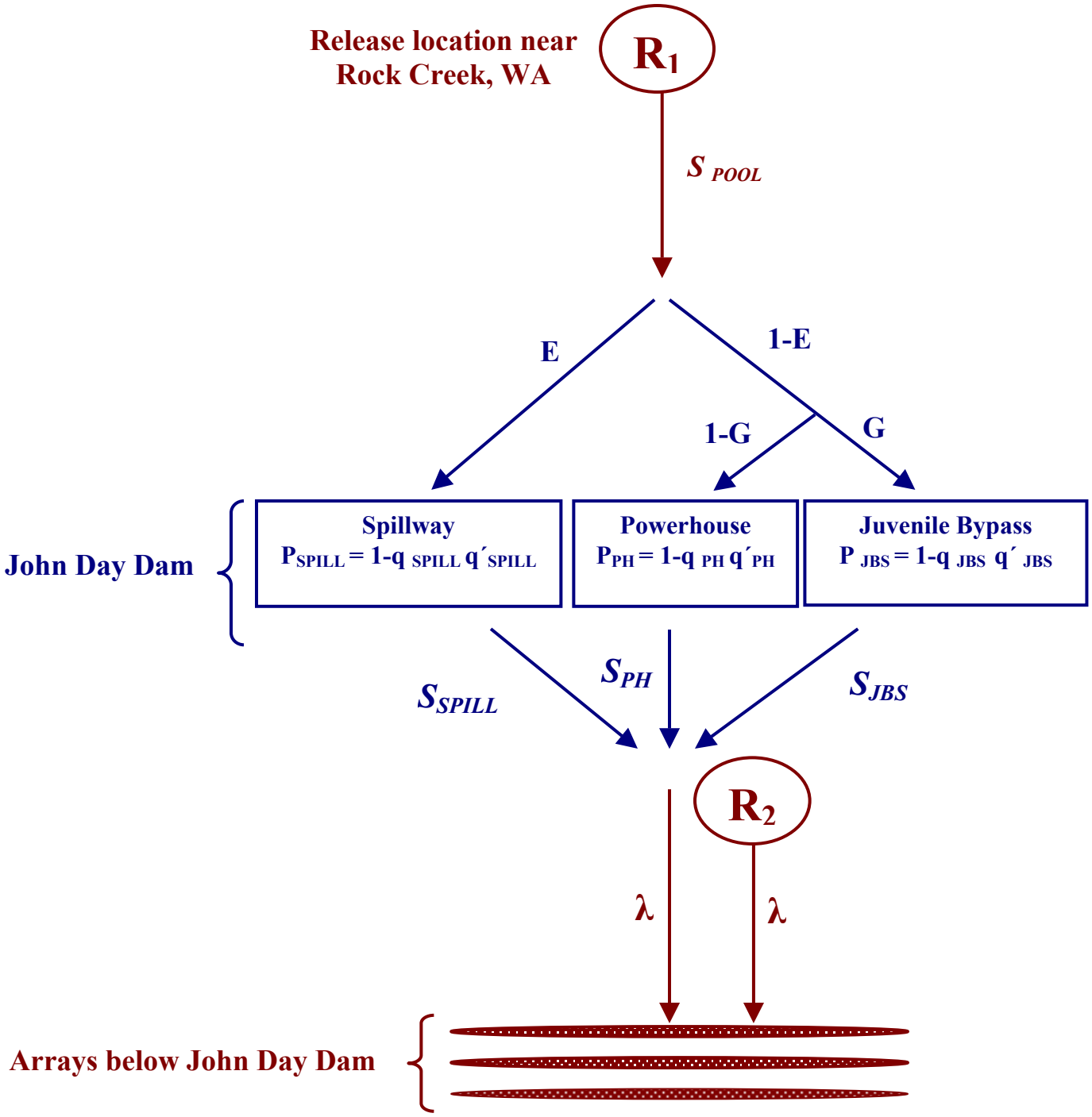

Figure 5. Schematic of route-specific passage and survival probabilities through John Day Dam for releases made near Rock Creek, WA (RK 367.7, John Day Reservoir) and in the tailrace of John Day Dam.

Army Corps of Engineers, Pacific Northwest National Laboratory, Dr. Cliff Perrira (statistician, Oregon State University), Dr. John Skalski (statistician, University of Washington), and the USGS were held to determine which releases should be included in the analyses. Days or treatment blocks that generally conformed to the prescribed treatments were identified during these meetings. The group decided that for the spring releases, blocks 6-13 should be included in the analysis and blocks 23 and 24 were to be included (Appendix 4). However, for the releases that were made directly into the juvenile bypass and spillway at John Day Dam, we applied the criterion that was established at the meeting that the actual treatment values should be ±10% of the prescribed spill levels. The reduction in the number of blocks that are to be included in the analysis reduced the sample size for all evaluations at John Day Dam during 2002. We will refer to the treatments as per the prescribed treatment levels (i.e., 0% day/60% night, 30% day/30% night) but these labels should be placed in the context of the actual treatment values that were present for each of the evaluations (Appendix 4), which we will summarize in this report.

Results

Juvenile Bypass – Paired-release recapture model

Yearling Chinook salmon

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 2002 ranged from 0.44 to 1.12 (Table 7). The average survival of yearling Chinook salmon released through the John Day Dam juvenile bypass during the 2002 migration season was 0.81 (± 0.066, 95% confidence interval). Survival of yearling Chinook through the juvenile bypass during the 60% night spill operations was estimated to be 0.695 (± 0.102, 95% confidence interval) and 0.904 (± 0.066, 95% confidence interval) during the 30% night spill operation. The estimated survival of yearling Chinook salmon during the 60% night spill operation was significantly different than the estimated survival during the 30% spill operation (two-tailed *t*-test, $P < 0.01$).

Wild Steelhead trout

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the wild steelhead trout 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 A2.2.

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 wild steelhead trout indicated that there were no significant differences in arrival times between the two release groups at the downstream radio-telemetry arrays (Appendix Tables A3.3 and A3.4).

Table 7. The estimated survival and standard error (SE) of yearling Chinook salmon released into the John Day Dam juvenile bypass during 2002. 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. Prescribed treatment is the spill percent that was scheduled to occur for a release. Actual treatment is the spill percent that actually occurred during the release. New treatment is the new treatment designation, given the actual spill percent that occurred, that was used to group the releases for statistical comparisons. All releases were made during night spill operations. The specific dates and times of the releases can be referenced in Table 4.

	Spill Treatment (%)				
Release	Prescribed	Actual	New	Survival estimate	SE
1	30	31.3	30	1.12	0.12
2	30	30.1	30	1.08	0.13
3	60	38.1	30[A]	0.97	0.09
4	60	50.5	60	0.84	0.11
5	30	29.7	30	0.95	0.09
6	30	29.7	30	0.95	0.09
7	60	55.6	60	0.84	0.06
8	60	50.2	60	0.88	0.13
9	30	29.6	30	0.82	0.13
10	30	29.0	30	0.92	0.11
11	30	31.5	30	1.00	0.07
12	30	29.4	30	0.67	0.14
13	60	59.4	60	0.78	0.13
14	60	58.0	60	0.52	0.16
15	60	60.3	60	0.87	0.17
16	60	56.0	60	0.44	0.12
17	30	29.6	30	1.04	0.09
18	30	29.2	30	0.77	0.21
19	30	29.3	30	0.68	0.12
20	30	29.0	30	0.95	0.09
21	60	51.9	60	0.55	0.16
22	60	55.7	60	0.57	0.20
23	60	53.0	60	0.83	0.12
24	60	58.9	60	0.50	0.14
25	30	29.5	30	0.90	0.10
26	30	25.7	30	1.05	0.10
27	30	29.4	30	0.79	0.11
28	30	25.9	30	0.72	0.11
29	60	46.6	[B]	0.70	0.12
30	60	46.6	[B]	0.59	0.12

[A] - New treatment designation is different than prescribed.

[B] - These estimates were not used in statistical comparisons because actual spill levels were not within ± 10% of prescribed spill levels but were included when calculating the overall average survival during 2002.

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 juvenile wild steelhead trout released through the John Day Dam juvenile bypass during 2002 ranged from 0.68 to 1.12 (Table 8). The average survival of steelhead trout released through the John Day Dam juvenile bypass during the 2002 migration season was 0.90 (± 0.045, 95% confidence interval). Survival of steelhead trout through the juvenile bypass during the 60% night spill operations was estimated to be 0.882 (± 0.060, 95% confidence interval) and 0.926 (± 0.067, 95% confidence interval) during the 30% night spill operation. The estimated survival of steelhead trout during the 60% night spill operation was not significantly different than during the 30% spill operation (two-tailed *t*-test, $P = 0.36$).

Table 8. The estimated survival and standard error (SE) of wild steelhead trout released into the John Day Dam juvenile bypass during 2002. 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. Prescribed treatment is the spill percent that was scheduled to occur for a release. Actual treatment is the spill percent that actually occurred during the release. New treatment is the new treatment designation, given the actual spill percent that occurred, that was used to group the releases for statistical comparisons. All releases were made during night spill operations. The specific dates and times of the releases can be referenced in Table 4.

	Spill treatment (%)				
Release	Prescribed	Actual	New	Survival estimate	SE
1	30	31.3	30	1.06	0.10
2	30	30.1	30	1.00	0.11
3	60	38.1	30[A]	0.94	0.10
4	60	50.5	60	0.98	0.10
5	30	29.7	30	0.96	0.05
6	30	29.7	30	0.82	0.10
7	60	55.6	60	1.12	0.14
8	60	50.2	60	0.78	0.15
9	30	31.5	30	1.06	0.11
10	30	29.4	30	0.89	0.12
11	60	59.4	60	1.00	0.07
12	60	58	60	0.84	0.10
13	60	60.3	60	0.89	0.10
14	30	29.6	30	0.78	0.17
15	30	29.3	30	1.01	0.12
16	60	51.9	60	0.84	0.11
17	60	55.7	60	0.76	0.14
18	60	53	60	0.89	0.12
19	60	58.9	60	0.89	0.14
20	30	29.5	30	0.81	0.15
21	30	29.4	30	1.08	0.16
22	30	25.9	30	0.95	0.09
23	60	46.6	[B]	0.78	0.17
24	60	46.6	[B]	0.89	0.18
25	30	44.5	[B]	0.78	0.17
26	30	29.5	30	0.68	0.18
27	30	59.9	60	0.78	0.12
28	30	58.3	60	0.80	0.12

[A] - New treatment designation is different than prescribed.
[B] - These estimates were not used in statistical comparisons because actual spill levels were not within ± 10% of prescribed spill levels but were included when calculating the overall average survival during 2002.

Subyearling Chinook salmon

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the subyearling 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 A2.3.

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 subyearling Chinook salmon indicated that there were no significant differences in arrival times between the two release groups at the downstream radio-telemetry arrays (Appendix Table A3.5 and A3.6).

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 juvenile subyearling Chinook salmon released through the John Day Dam juvenile bypass during 2002 ranged from 0.41 to 1.06 (Table 9). The average survival of subyearling Chinook salmon released through the John Day Dam juvenile bypass during the 2002 migration season was 0.846 (± 0.066, 95% confidence interval). Survival of subyearling Chinook through the juvenile bypass during the 60% night spill operations was estimated to be 0.511 (± 0.096, 95% confidence interval) and 0.940 (± 0.046, 95% confidence interval) during the 30% night spill operation. The estimated survival of subyearling Chinook salmon during the 60% night spill operation was significantly different than the estimated survival during the 30% spill operation (two-tailed *t*-test, $P < 0.01$).

Spillway – Paired-release recapture model

Wild Steelhead trout

Assumption Tests

Burnham Tests

The results of the Burnham Tests 2 and 3 testing assumptions A5 and A6 for the steelhead trout released into the juvenile bypass at John Day dam and their

Table 9. The estimated survival and standard error (SE) of subyearling Chinook salmon released into the John Day Dam juvenile bypass during 2002. 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. Prescribed treatment is the spill percent that was scheduled to occur for a release. Actual treatment is the spill percent that actually occurred during the release. New treatment is the new treatment designation, given the actual spill percent that occurred, that was used to group the releases for statistical comparisons. All releases were made during night spill operations. The specific dates and times of the releases can be referenced in Table 6.

	Treatment				
Release	Prescribed	Actual	New	Survival estimate	SE
1	60	33.6	30	0.91	0.06
2	60	44.0	A	0.93	0.04
3	30	29.5	30	1.03	0.09
4	30	30.5	30	1.04	0.04
5	30	30.8	30	0.97	0.08
6	30	26.0	30	0.97	0.06
7	60	49.5	A	0.87	0.06
8	60	46.0	A	0.58	0.07
9	60	45.2	A	0.95	0.06
10	60	49.3	A	0.84	0.06
11	30	27.3	30	1.00	0.06
12	30	27.3	30	0.90	0.07
13	60	48.9	A	1.03	0.06
14	60	48.8	A	0.71	0.08
15	30	29.4	30	1.06	0.06
16	30	28.0	30	0.89	0.07
17	30	28.7	30	0.91	0.07
18	30	28.2	30	1.06	0.09
19	60	58.2	60	0.65	0.08
20	60	59.7	60	0.61	0.09
21	60	46.3	A	0.83	0.08
22	60	45.8	A	0.94	0.09
23	30	29.0	30	0.86	0.06
24	30	28.0	30	1.05	0.06
25	60	55.9	60	0.42	0.09
26	60	60.0	60	0.41	0.09
27	30	30.6	30	0.74	0.08
28	30	29.7	30	0.95	0.06
29	30	29.5	30	0.78	0.08
30	30	30.1	30	0.86	0.06
31	60	56.9	60	0.47	0.08

[A] - These estimates were not used in statistical comparisons because actual spill levels were not within ± 10% of prescribed spill levels but were included when calculating the overall average survival during 2002.

corresponding tailrace releases were inconclusive (Appendix Table A2.4).

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 steelhead trout indicated that there were no significant differences in arrival times between the two release groups at the downstream radio-telemetry arrays (Appendix Tables A3.7 and A3.8).

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 juvenile wild steelhead trout released through spillbays at the John Day Dam spillway during 2002 ranged from 0.71 to 1.13 (Table 10). The average survival of steelhead released through the John Day Dam spillway during the 2002 migration season was 0.922 (± 0.037, 95% confidence interval). The estimated survival of steelhead trout through the spillway was 0.932 (± 0.050, 95% confidence interval) during the 60% night spill operations, 0.946 (± 0.062, 95% confidence interval) during the 30% night spill operation, and 0.870 (± 0.087, 95% confidence interval) during the 30% day spill operation. The estimated survival of steelhead during the 60% night spill operation was not significantly different than the estimated survival during the 30% night spill operation (two-tailed *t*-test, $P = 0.74$). The estimated survival during the 60% night spill operation was also not significantly different than the 30% day spill ($P = 0.21$) and similarly, the estimated survival during the 30% night and 30% day spill operation was not significantly different for steelhead passing during the 30% night spill operation and during the 30% day spill operations (two-tailed *t*-test, $P = 0.17$).

Route Specific Survival Model

Yearling Chinook salmon

Using capture histories generated from the detections of radio-tagged yearling 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 spill/60% night spill; 30% day spill/30% night spill) along with associated standard errors and profile likelihood 95% confidence intervals. As stated in the methods (see pp. 22-23, this report), the results are based on a subset of the releases of yearling Chinook during 2002.

Table 10. The estimated survival and standard error (SE) of wild steelhead trout released into spillbays at the John Day Dam spillway during 2002. Releases were made directly into the spillbays 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. Prescribed treatment is the spill percent that was scheduled to occur for a release. Actual treatment is the spill percent that actually occurred during the release. New treatment is the new treatment designation, given the actual spill percent that occurred, that was used to group the releases for statistical comparisons. All releases were made during night spill operations. The specific dates and times of the releases can be referenced in Table 5.

	Treatment				
Release	Prescribed	Actual	New	Survival estimate	SE
1	30 day	30	30 day	0.73	0.13
2	30 night	31.3	30 night	0.93	0.12
3	30 night	30.1	30 night	1.12	0.13
4	60 night	38.1	30 night	0.95	0.10
5	60 night	50.5	60 night	0.90	0.10
6	30 day	32	30 day	0.93	0.10
7	30 night	29.7	30 night	0.91	0.10
8	30 day	29.6	30 day	1.07	0.13
9	30 night	29.7	30 night	0.90	0.10
10	60 night	55.6	60 night	1.12	0.13
11	60 night	50.2	60 night	1.06	0.13
12	30 day	28.8	30 day	0.84	0.14
13	30 night	31.5	30 night	0.95	0.09
14	30 night	29.4	30 night	0.94	0.12
15	60 night	59.4	60 night	0.82	0.13
16	60 night	58	60 night	0.85	0.11
17	60 night	60.3	60 night	0.94	0.09
18	30 night	29.6	30 night	0.89	0.16
19	30 day	29.2	30 day	0.79	0.12
20	30 night	29.3	30 night	1.13	0.14
21	30 day	27.9	30 day	1.00	0.07
22	30 night	29	30 night	0.81	0.13
23	60 night	51.9	60 night	0.90	0.09
24	60 night	55.7	60 night	0.94	0.14
25	60 night	53	60 night	0.85	0.12
26	60 night	58.9	60 night	1.00	0.13
27	30 day	29.2	30 day	0.90	0.10
28	30 night	29.5	30 night	0.77	0.15
29	30 night	25.9	30 night	0.89	0.10
30	30 day	30	30 day	0.73	0.13

[A] - New treatment designation is different than prescribed.
[B] - These estimates were not used in statistical comparisons because actual spill levels were not within ± 10% of prescribed spill levels but were included when calculating the overall average survival during 2002.

Table 10. (continued)

	Treatment				
Release	Prescribed	Actual	New	Survival estimate	SE
31	60 night	46.6	[B]	1.01	0.17
32	60 night	46.6	[B]	0.93	0.17
33	30 day	46.3	[B]	0.89	0.16
34	30 night	44.5	[B]	0.67	0.18
35	30 day	30.3	30 day	0.71	0.14
36	30 night	29.5	30 night	1.12	0.19
37	30 night	59.9	60 night	0.90	0.12
38	30 day	43.2	[B]	0.95	0.10
39	30 night	58.3	60 night [A]	0.90	0.11

[A] - New treatment designation is different than prescribed.
[B] - These estimates were not used in statistical comparisons because actual spill levels were not within ± 10% of prescribed spill levels but were included when calculating the overall average survival during 2002.

Table 11. 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
$R_1 = 662$	100		48			
	101		11			
	110	Spillway	15	236	28	33
	111		282			
	110	Powerhouse [B]	21	23	27	39
	111		68			
	110	Juvenile bypass	28	116	99	2
	111		189			
$R_2 = 407$	010		18			
	011		389			

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

Table 12. 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 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
$R_1 = 674$	100		42			
	101		13			
	110	Spillway	19	288	14	33
	111		316			
	110	Powerhouse [B]	24	39	38	41
	111		94			
	110	Juvenile bypass	11	86	78	2
	111		155			
$R_2 = 465$	010		27			
	011		438			

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

The results presented in this section are for yearling Chinook that passed John Day Dam during spill blocks 6-13 (Appendix Tables A4.1 – A4.9).

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 0.993 (SE = 0.0170; profile likelihood 95% confidence interval = [0.958, 1.026]) (Figure 6, Table 13). For yearling Chinook passing the juvenile bypass during the 0% day/60% night spill operations the estimated survival was 0.911 (SE = 0.026, profile likelihood 95% confidence interval [0.857, 0.959]) and for yearling Chinook passing via the turbines at John Day Dam the estimated survival was 0.778 (SE = 0.051, profile likelihood 95% confidence interval [0.673, 0.870]) (Figure 6, Table 13). Yearling Chinook salmon dam survival (see p. 19, this report) during the 0% day/60% night spill operations was estimated to be 0.929 (SE = 0.021).

30% day/30% night spill operations

During the 30% day/30% night spill operations, the survival of yearling Chinook salmon through the John Day Dam spillway was estimated to be 1.00 (SE = 0.018; profile likelihood 95% confidence interval = [0.966, 1.036]) (Figure 7, Table 13). For yearling Chinook passing the juvenile bypass during the 30% day/30% night spill operations the estimated survival was 0.991 (SE = 0.024, profile likelihood 95% confidence interval [0.940, 1.034]) and for yearling Chinook passing via the turbines at John Day Dam the estimated survival was 0.832 (SE = 0.042, profile likelihood 95% confidence interval [0.744, 0.909]) (Figure 7, Table 13). Yearling Chinook salmon dam survival (see p. 19, this report) during the 30% day/30% night spill operations was estimated to be 0.963 (SE = 0.018).

Comparisons of estimators generated during the 0% day/60% night and 30% day/30% night spill operations

The estimated survival probabilities for yearling Chinook passing the juvenile bypass were found to be statistically different for fish passing during the 0% day/60% and the 30% day/30% night spill operations (Table 13); the spillway, powerhouse, and dam survival probabilities were not significantly different.

Wild Steelhead trout

Using capture histories generated from the detections of radio-tagged wild steelhead trout (Tables 14 and 15), maximum likelihood estimates of the route-specific passage and survival probabilities were calculated for fish passing during the prescribed spill operation treatments (0% day spill/60% night spill; 30% day spill/30% night spill) along with associated standard errors and profile likelihood 95% confidence intervals. As stated in the methods (see p. 22-23), data will be presented for a subset of the releases

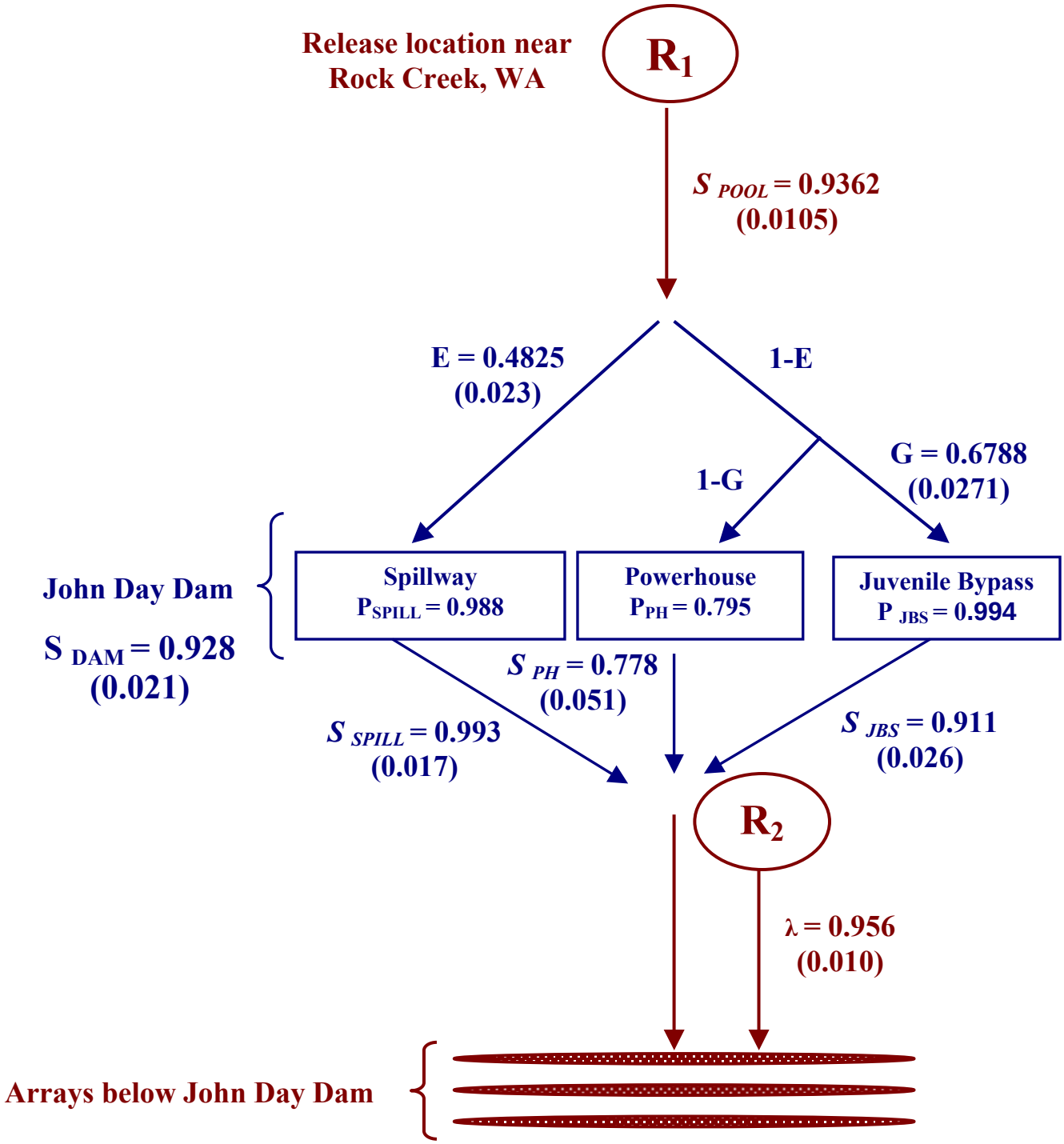

Figure 6. Schematic of estimated route-specific passage and survival probabilities for yearling Chinook salmon through John Day Dam during 0% day/60% night spill operations during 2002. Estimated standard errors are in parentheses.

Table 13. Summary table of estimated route specific survival probabilities and the maximum likelihood estimate of yearling Chinook salmon survival through John Day Dam (Dam survival) during spill blocks 6-13 generated from the Route Specific Survival Model of John Day Dam during 2002. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 0% day/60% night spill operations were greater than for estimated survival probabilities during the 30% day/ 30% night spill operations. Significant results for a two-tailed comparison at $\alpha = 0.10$ are indicated where $Z > 1.64$.

Passage route	0 % day/ 60% night		30% day/30% night		*Z*
	S	SE	S	SE	
Powerhouse	0.778	0.051	0.832	0.042	0.83
Spillway	0.993	0.017	1.000	0.018	0.33
Juvenile bypass	0.911	0.026	0.991	0.024	2.30
Dam Survival	0.928	0.021	0.963	0.018	1.25

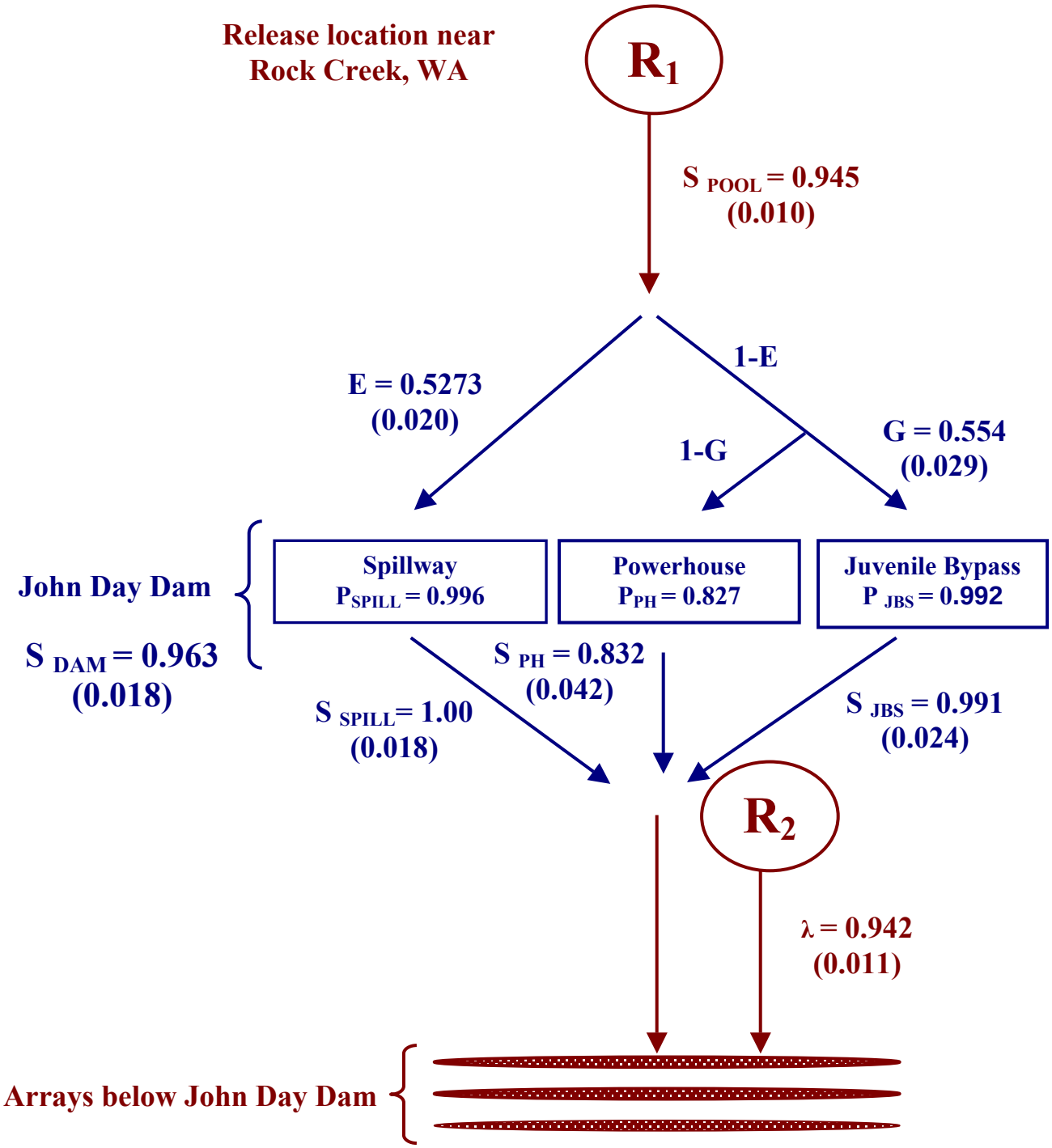

Figure 7. Schematic of estimated route-specific passage and survival probabilities for yearling Chinook salmon through John Day Dam during 30% day/30% night spill operations during 2002. Estimated standard errors are in parentheses.

Table 14. Counts of radio-tagged wild steelhead trout 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.

Release	Detection History [A]	Route	Counts	Within-route histories at John Day Dam [A]		
				11	01	10
R_1 = 263	100		20			
	101		1			
	110	Spillway	13	107	32	12
	111		138			
	110	Powerhouse [B]	10	34	51	6
	111		81			
R_2 = 299	010		14			
	011		285			

[A] - Detection history recorded as: 1, detected; 0, not detected
[B] - Unguided and guided passage

Table 15. Counts of radio-tagged wild steelhead trout 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.

Release	Detection History [A]	Route	Counts	Within-route histories at John Day Dam [A]		
				11	01	10
R_1 = 176	100		7			
	101		1			
	110	Spillway	9	79	10	2
	111		82			
	110	Powerhouse [B]	10	38	35	4
	111		67			
R_2 = 584	010		20			
	011		564			

[A] - Detection history recorded as: 1, detected; 0, not detected
[B] - Unguided and guided passage

that were made by the USGS. The results presented in this section are for wild steelhead known to have passed during spill blocks 6-13 (Appendix 4).

Because of the fewer steelhead released near Rock Creek, WA, compared to yearling Chinook salmon, we were unable to generate estimates for fish passing via both the turbine and juvenile bypass using the USER program and the branching process developed for yearling Chinook salmon. That is, too few fish passed via the powerhouse to allow us to use the model developed for yearling Chinook salmon. Consequently we had to combine the capture histories for turbine and juvenile bypass passed fish into one category. A modified branching process was used to model the migration and survival of wild steelhead releases R_1 and R_2 (Figure 8).

Similar to the model used for yearling Chinook salmon, the wild steelhead trout route specific survival and passage probabilities from this modified branching process can be combined using maximum likelihood estimation to estimate survival through the dam. The survival through John Day dam was estimated from the expression

$$\hat{S}_{DAM} = (1 - \hat{E})\ \hat{S}_{PH} + E\ \hat{S}_{SPILL}$$

0% day/60% night spill operations

During the 0% day/60% night spill operations, the survival of wild steelhead trout through the John Day Dam spillway was estimated to be 0.958 (SE = 0.027; profile likelihood 95% confidence interval = [0.899, 1.008]) (Figure 9, Table 16). For steelhead trout passing the powerhouse (turbine and juvenile bypass) during the 0% day/60% night spill operations the estimated survival was 0.930 (SE = 0.037, profile likelihood 95% confidence interval [0.847, 0.995]) (Figure 9, Table 16). Wild steelhead trout dam survival during the 0% day/60% night spill operations was estimated to be 0.940 (SE = 0.027).

30% day/30% night spill operations

During the 30%/day/30% night spill operations, the survival of steelhead trout through the John Day Dam spillway was estimated to be 0.932 (SE = 0.033; profile likelihood 95% confidence interval = [0.857, 0.988]) (Figure 10, Table 16). For steelhead trout passing via the powerhouse during the 30% day/30% night spill operations the estimated survival was 0.899 (SE = 0.041, profile likelihood 95% confidence interval [0.807, 0.967]) (Figure 10, Table 16). Steelhead trout dam survival during the 30% day/30% night spill operations was estimated to be 0.915 (SE = 0.027).

Comparisons of estimators generated during the 0% day/60% night and 30% day/30% night spill operations

The estimated survival probabilities were not found to be significantly different for wild steelhead known to have passed via the spillway or powerhouse (juvenile bypass

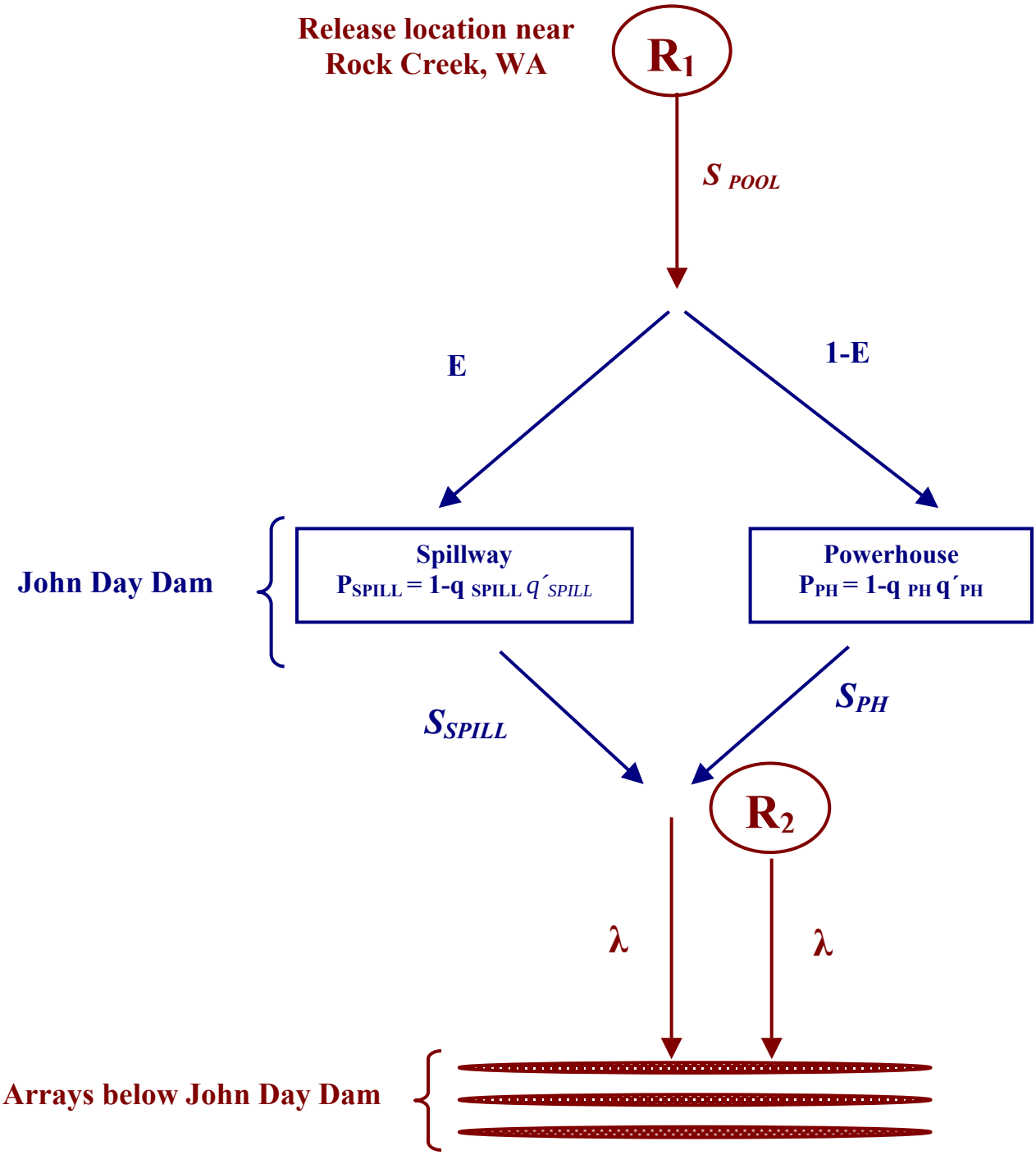

Figure 8. Schematic of route-specific passage and survival probabilities through John Day Dam for releases of wild steelhead trout made near Rock Creek, WA (RK 367.7, John Day Reservoir) and in the tailrace of John Day Dam.

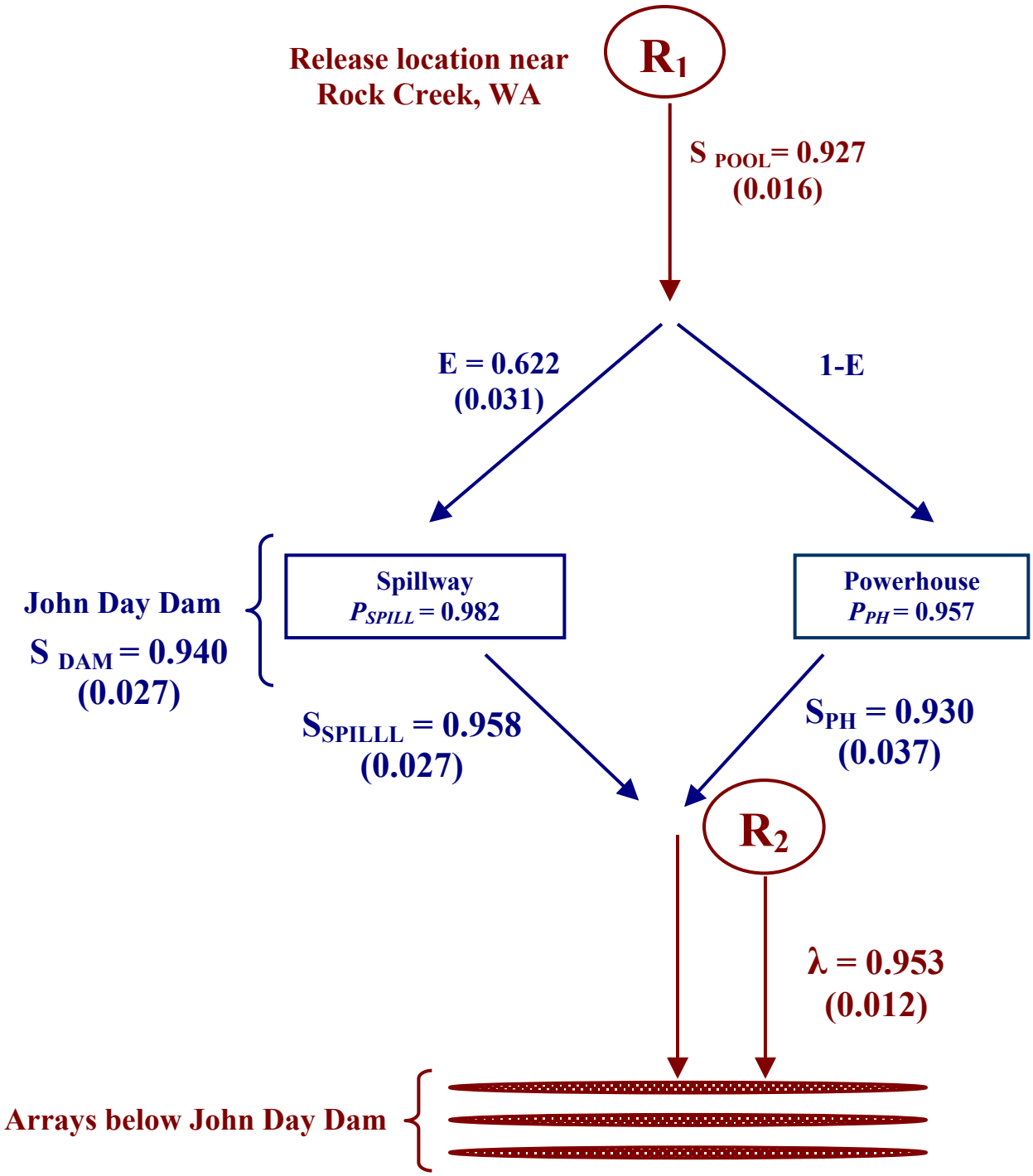

Figure 9. Schematic of estimated route-specific passage and survival probabilities for wild steelhead trout through John Day Dam during 0% day/60% night spill operations during 2002. Estimated standard errors are in parentheses.

Table 16. Summary table of estimated route specific survival probabilities and the maximum likelihood estimate of wild steelhead trout survival through John Day Dam (Dam survival) during spill blocks 6-13 generated from the Route Specific Survival Model of John Day Dam during 2002. Powerhouse survival probabilities include survival of subyearling Chinook salmon passing through both the juvenile bypass and turbines at the John Day Dam powerhouse. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 0% day/60% night spill operations were greater than for estimated survival probabilities during the 30% day/ 30% night spill operations. Significant results for a two-tailed comparison at $\alpha = 0.10$ are indicated where $Z > 1.64$.

	0 % day/ 60% night		30% day/30% night		
Passage route	S	SE	S	SE	*Z*
Powerhouse	0.930	0.037	0.899	0.041	0.56
Spillway	0.958	0.027	0.933	0.033	0.57
Dam Survival	0.940	0.027	0.915	0.027	0.68

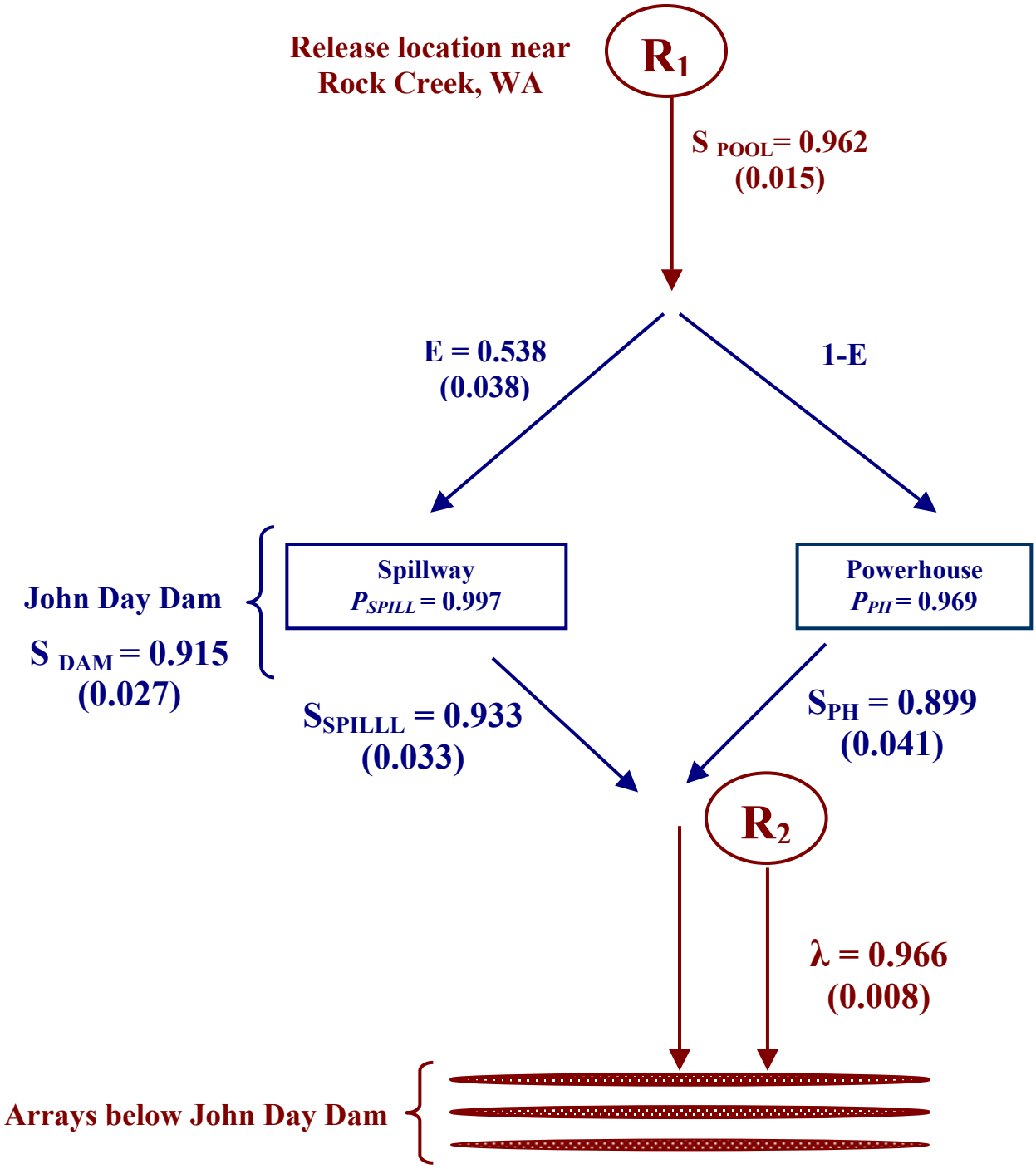

Figure 10. Schematic of estimated route-specific passage and survival probabilities for wild steelhead trout through John Day Dam during 30% day/30% night spill operations during 2002. Estimated standard errors are in parentheses.

turbine, guided and unguided respectively), or for fish passing via all routes (dam survival) (Table 16) during the 0% day/60% and the 30% day/30% night spill operations.

Subyearling Chinook salmon

Using capture histories generated from the detections of radio-tagged subyearling Chinook salmon (Tables 17 and 18), maximum likelihood estimates of the route-specific passage and survival probabilities were calculated for fish passing during the prescribed spill operation treatments (0% day spill/60% night spill; 30% day spill/30% night spill) along with associated standard errors and profile likelihood 95% confidence intervals. As mentioned in the methods (see pp 22-23), data will be presented for a subset of the releases that were made by the USGS. The results presented in this section are for subyearling Chinook salmon known to have passed during spill blocks 23-24 (Appendix 4). This subset of blocks drastically reduced the sample size available for our analyses. Similar to the RSSM analyses presented for wild steelhead trout (see above), insufficient information was available to use the branching process as was used for yearling Chinook salmon. Thus, we used a similar process as that for wild steelhead trout (Figure 10).

Similar to the model used for the wild steelhead trout, subyearling Chinook salmon route specific survival and passage probabilities from this modified branching process can be combined using maximum likelihood estimation to estimate survival through the dam. The survival through John Day dam was estimated from the expression

$$\hat{S}_{DAM} = (1-\hat{E})\ \hat{S}_{PH} + E\ \hat{S}_{SPILL}$$

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 0.985 (SE = 0.023; profile likelihood 95% confidence interval = [0.934, 1.027]) (Figure 12, Table 19). For subyearling Chinook passing via the powerhouse (juvenile bypass and turbine) during the 0% day/60% night spill operations the estimated survival was 0.866 (SE = 0.034, profile likelihood 95% confidence interval [0.795, 0.928]) (Figure 12, Table 19). Subyearling Chinook salmon dam survival during the 0% day/60% night spill operations was estimated to be 0.928 (SE = 0.022).

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 1.03 (SE = 0.024; profile likelihood 95% confidence interval = [0.983, 1.078]) (Figure 13, Table 19). For subyearling Chinook passing via the powerhouse (juvenile bypass and turbine) during the 30% day/30% night spill operations the estimated survival was 0.966 (SE = 0.037, profile likelihood 95% confidence interval [0.885, 1.031]) (Figure 13, Table 19).

Table 17. 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.

Release	Detection History [A]	Route	Counts	Within-route histories at John Day Dam [A] 11	01	10
R_1 = 384	100		50			
	101		30			
	110	Spillway	9	96	27	30
	111		144			
	110	Powerhouse [B]	26	61	61	29
	111		125			
R_2 = 337	010		15			
	011		322			

[A] - Detection history recorded as: 1, detected; 0, not detected
[B] - Unguided and guided passage

Table 18. 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.

Release	Detection History [A]	Route	Counts	Within-route histories at John Day Dam [A] 11	01	10
R_1 = 171	100		42			
	101		11			
	110	Spillway	7	127	19	15
	111		154			
	110	Powerhouse [B]	10	37	42	20
	111		89			
R_2 = 341	010		25			
	011		316			

[A] - Detection history recorded as: 1, detected; 0, not detected
[B] - Unguided and guided passage

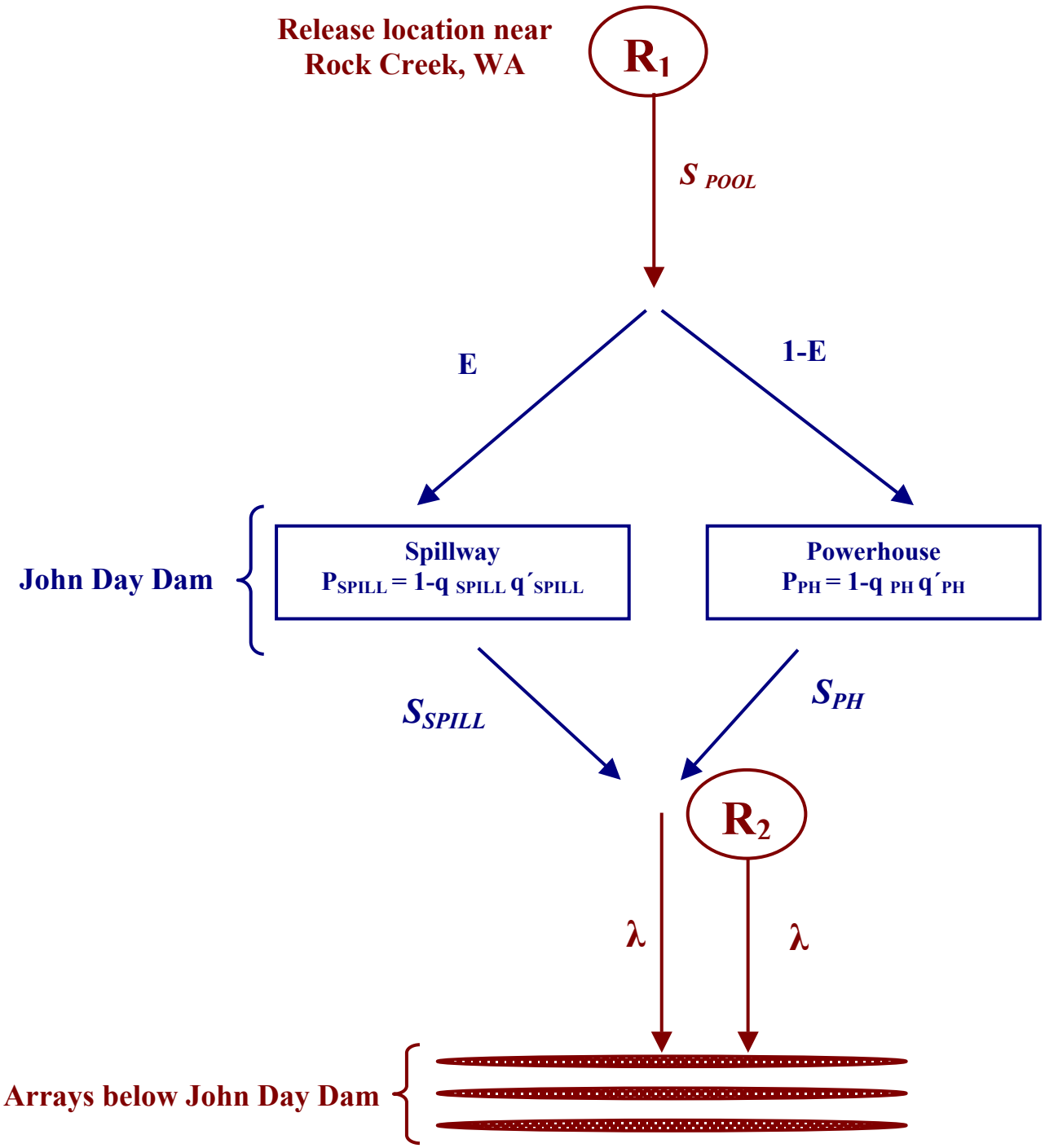

Figure 11. Schematic of route-specific passage and survival probabilities through John Day Dam for releases of subyearling Chinook made near Rock Creek, WA (RK 367.7, John Day Reservoir) and in the tailrace of John Day Dam.

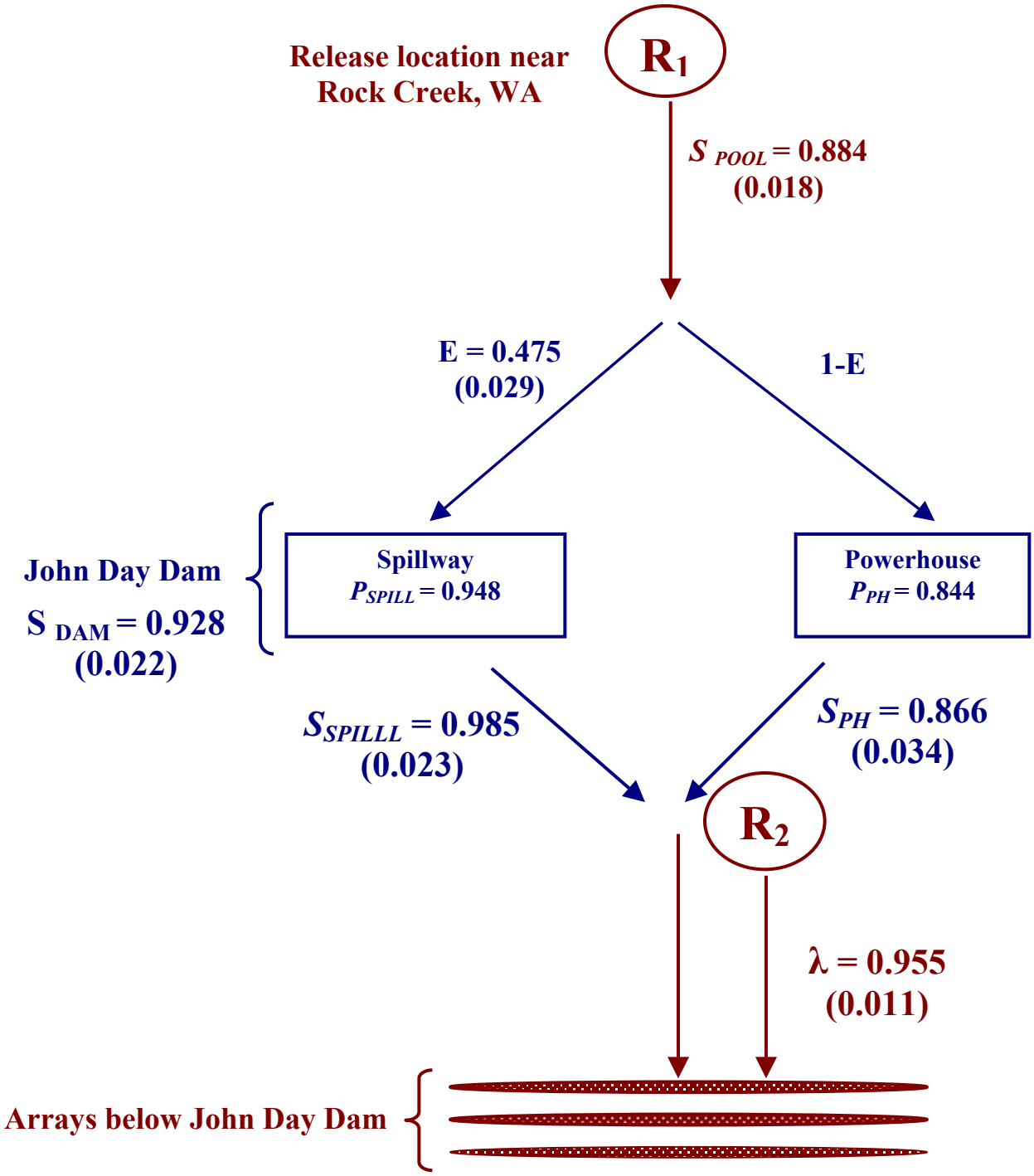

Figure 12. Schematic of estimated route-specific passage and survival probabilities for subyearling Chinook salmon through John Day Dam during 0% day/60% night spill operations during 2002. Estimated standard errors are in parentheses.

Table 19. Summary table of estimated route specific survival probabilities and the maximum likelihood estimate of subyearling Chinook salmon survival through John Day Dam (Dam survival) during spill blocks 23-24 generated from the Route Specific Survival Model of John Day Dam during 2002. Powerhouse survival probabilities include survival of subyearling Chinook salmon passing through both the juvenile bypass and turbines at the John Day Dam powerhouse. The results of *Z*-tests (i.e., *Z*-statistic) structured to assess whether the estimated survival probabilities during the 0% day/60% night spill operations were greater than for estimated survival probabilities during the 30% day/ 30% night spill operations. Significant results for a two-tailed comparison at $\alpha = 0.10$ are indicated where $Z > 1.64$.

	0 % day/ 60% night		30% day/30% night		
Passage route	S	SE	S	SE	Z
Powerhouse	0.866	0.034	0.966	0.037	2.00
Spillway	0.985	0.023	1.032	0.0235	1.43
Dam Survival	0.928	0.022	0.992	0.026	1.89

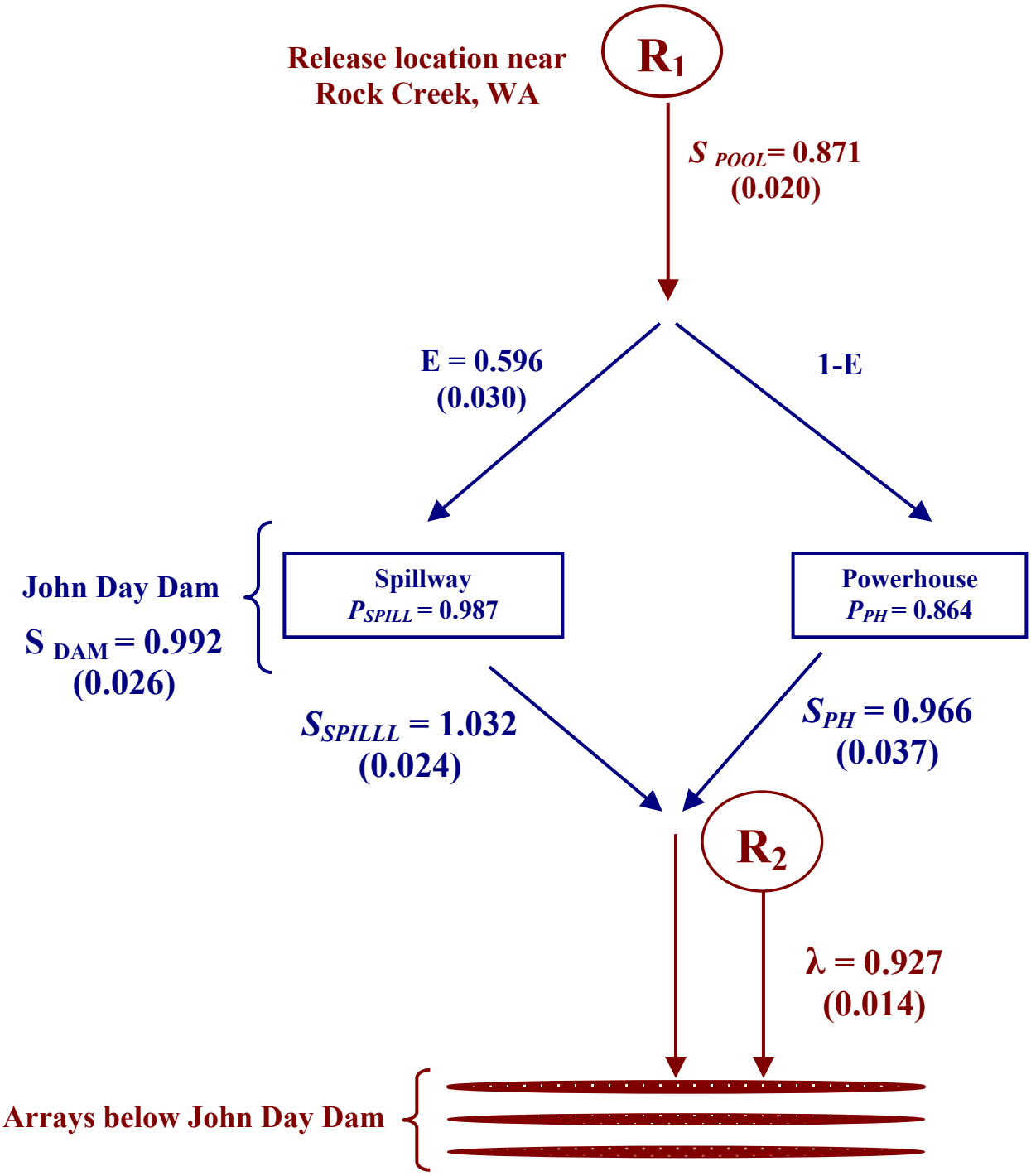

Figure 13. Schematic of estimated route-specific passage and survival probabilities for subyearling Chinook salmon through John Day Dam during 30% day/30% night spill operations during 2002. Estimated standard errors are in parentheses.

Subyearling Chinook salmon dam survival during the 30% day/30% night spill operations was estimated to be 0.992 (SE = 0.026).

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 John Day Dam powerhouse and for all routes combined (dam survival) during the 0% day/60% night spill operations than during the 30% day/30% night spill operations (Table 19) were found to be significantly different; the survival probabilities for subyearling Chinook passing via the spillway were not found to be significantly different.

Discussion

The results of our evaluations of the survival of yearling and subyearling Chinook salmon and steelhead trout through the John Day Dam juvenile bypass and steelhead trout through the John Day Dam spillway did not suggest a survival benefit for fish passing during the 60% night spill operations. In all cases the point estimates of survival generated using the paired release recapture models were highest for fish passing during the 30% night spill operations. Statistically significant differences in the estimated survival were observed for yearling and subyearling Chinook salmon released into the juvenile bypass system.

The estimated survival probabilities generated using the Route Specific Survival Model also suggest no survival benefit for fish passing during the 0% day/60% night spill operations. The estimated dam survival probabilities for yearling Chinook salmon and steelhead trout during the 0% day/60% night spill were not significantly different than during the 30% day/ 30% night spill operations. Statistically significant differences were documented for yearling Chinook salmon passing the juvenile bypass, for guided and unguided subyearling Chinook salmon via the powerhouse (includes turbine and juvenile bypass fish), and for the estimated dam survival of subyearling Chinook salmon; the estimated survival through the spillway was not significantly different during the 0% day/60% night and 30% day/30% night spill operations for any of the salmonid species evaluated. For all of the noted statistically significant results, the estimated survival was greater during the 30% day/30% night spill operations.

Research conducted by the USGS at John Day Dam included evaluations of egress and residence times of radio-tagged fish released into the juvenile bypass. Smith et al. (2004), reported that travel times for yearling and subyearling Chinook salmon and steelhead trout were all longer during the 60% night spill operation. Additionally, Smith et al. (2004) also present data that suggest egress routes for fish passing during the two spill operations were different. Smith et al. (2004) report that while no radio-tagged fish were detected upriver of the JBS outfall during 30% spill operations, 12% of radio-tagged yearling Chinook salmon and 26% of the juvenile steelhead were detected during 57% spill conditions. During the summer, 4% of subyearling Chinook salmon were detected upriver of the JBS outfall during 30% spill operations, and 10% were detected during

60% spill. Fish with increased residence time within this area influenced the mean travel time in the tailrace. Yearling Chinook salmon that were detected upriver of the juvenile bypass had travel times that were on average 5% longer when compared to yearling Chinook not detected upriver of the juvenile bypass, and juvenile steelhead had average travel times that were 11% longer. The subyearling Chinook salmon that were detected upriver of the JBS outfall had average travel times that were 52% longer during 30% spill conditions and 30% longer during 52% spill.

Smith et al. (2004) also observed fish exiting the tailrace from the JBS outfall via a northerly route from the JBS towards the spillway-stilling basin. The percent of fish taking this egress route were higher during the 60% spill operations than for 30% spill operations, though the differences were not evaluated statistically. The differences observed in the residence times and egress routes taken by yearling and subyearling Chinook salmon may account for the relatively lower estimated survival during the 60% night spill operations (paired-release recapture evaluations) and the 0% day /60% night spill operations (RSSM evaluations). The increased residence times and atypical egress routes may have resulted in increased predation risk.

The hydraulic conditions near the juvenile bypass outfall created by the dam operations at John Day Dam during 2002 may have also contributed to the lower than expected survival during both the 60% night spill operations and the 0% day/ 60% night spill operations. 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 (Mike Langeslay, ACOE Portland District, personal communication). During model simulations of dam operations with known delays of juvenile steelhead during 2002, it was discovered that discharge through the turbine units at the John Day Dam powerhouse were not "bulked south" (i.e., discharge concentrated towards the south end of the powerhouse), as was stipulated as an operation in the Fish Passage Plan to promote good egress from the outfall of the JBS. The model simulations 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 deviation of the dam operations with respect to the planned prescribed treatments (see: Appendix A4) during the 2002 spring and summer migration season affected our ability to evaluate the effects of the treatments. For instance, we made releases of subyearling Chinook salmon on each of 31 days during 2002. A post-hoc analysis of the spill operations during these releases indicated that only 8 of the 31 days conformed adequately to the prescribed treatments. Thus, the reduction in the number of releases during days that conformed to the prescribed treatments reduced the number of subyearling Chinook salmon included in the analyses from 5462 to 1375.

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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) of yearling Chinook salmon and steelhead smolts released into the Columbia River near Rock Creek, Washington, spring 2002.

Paired Release	Yearling Chinook				Steelhead			
	N	Mean	SD	Range	N	Mean	SD	Range
1	46	150	10.3	134-179	11	193	16.8	164-223
2	45	151	15.4	128-191	6	190	12.4	178-212
3	48	151	12.2	125-179	12	187	22.4	158-235
4	44	149	12.4	133-194	15	192	12.9	167-214
5	47	149	11.8	116-175	19	191	14.5	168-223
6	54	151	10.9	129-181	18	182	13.6	157-205
7	51	151	10.9	132-180	12	189	24.5	152-234
8	44	148	11.8	124-188	12	191	24.6	158-257
9	46	148	11.4	124-175	22	187	22.0	155-242
10	48	152	12.6	129-196	16	190	18.7	167-231
11	49	146	11.6	130-176	18	201	35.1	157-275
12	48	149	13.2	127-185	18	190	19.8	158-242
13	50	148	14.7	120-182	9	199	28.0	163-245
14	45	147	14.0	126-186	10	180	18.7	143-200
15	55	144	13.0	121-177	20	195	25.2	146-241
16	47	146	12.1	124-186	24	193	17.4	161-240
17	49	140	15.0	120-186	18	190	17.7	157-218
18	49	144	13.8	120-176	18	182	13.1	160-207
19	46	145	15.2	124-191	20	192	19.0	157-226
20	48	142	15.6	120-205	19	185	18.4	159-224
21	46	142	10.4	120-175	17	199	22.4	154-238
22	54	141	12.9	125-191	20	187	16.1	154-212
23	53	149	17.8	122-204	19	190	17.9	160-227
24	49	149	17.5	120-190	19	187	20.0	154-227
25	52	150	19.0	123-192	20	200	24.2	160-255
26	52	147	17.2	124-187	18	188	11.9	169-210
27	49	153	18.3	130-205	17	192	19.2	154-232
28	49	149	16.4	122-196	20	185	17.5	161-217
29	52	148	16.2	121-185	20	191	28.0	155-275
30	53	157	16.5	126-190	18	192	19.4	146-224
31	49	155	18.2	124-200	21	184	13.8	156-207
32	52	158	18.1	128-201	20	189	29.8	143-260
33	[a]				27	194	22.0	160-258
34	[a]				29	184	14.4	153-223
Overall	1569	148	15.0	116-205	602	190	20.4	143-275

[a] No fish released.

Table A1.2.-The sample size (N), mean, standard deviation (SD), and range of weights (g) of yearling Chinook salmon and steelhead smolts released at Rock Creek during spring 2002.

Paired	Yearling Chinook				Steelhead			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	46	33.7	7.3	24-58	11	65.7	15.5	43-96
2	45	34.9	11.3	24-69	6	58.7	13.3	45-82
3	48	34.9	9.3	20-62	12	63.2	24.6	34-125
4	44	33.6	9.2	23-75	15	62.7	13.9	34-85
5	47	33.0	7.6	16-52	19	60.6	15.5	43-92
6	54	33.8	7.9	22-59	18	54.2	12.8	32-75
7	51	33.7	8.1	23-58	12	60.4	21.4	31-98
8	44	33.9	9.3	30-71	12	65.7	28.3	35-140
9	46	31.5	7.4	18-55	22	60.7	22.6	35-127
10	48	34.2	10.0	19-76	16	64.2	19.0	44-109
11	49	31.5	8.1	22-54	18	79.1	49.2	38-203
12	48	33.6	9.0	19-63	18	61.4	19.7	35-111
13	50	34.1	10.1	19-58	9	78.7	38.2	42-165
14	45	29.5	9.7	18-60	10	52.3	15.9	24-72
15	55	28.7	8.2	17-51	20	67.2	26.1	26-121
16	47	30.7	8.8	18-65	24	62.5	17.2	32-112
17	49	28.8	10.4	16-66	18	62.2	16.5	35-90
18	49	30.0	8.8	17-55	18	57.2	13.6	39-96
19	46	30.4	10.9	18-68	20	65.0	16.6	37-99
20	48	28.5	11.6	18-83	19	58.6	18.2	34-110
21	46	27.5	6.7	17-51	17	78.9	24.1	30-121
22	54	25.7	8.6	17-66	20	61.9	17.5	33-90
23	53	31.3	12.8	17-81	19	62.4	20.6	33-110
24	49	33.1	12.7	18-73	19	63.3	23.1	34-114
25	52	35.0	12.7	19-66	20	75.9	28.9	31-147
26	52	33.2	11.7	20-65	18	62.7	13.1	36-81
27	49	37.6	15.0	22-85	17	66.7	19.8	33-115
28	49	33.6	11.8	19-72	20	57.0	15.1	36-90
29	52	31.0	10.6	17-62	20	65.9	29.5	30-162
30	53	38.6	11.7	18-65	18	63.8	17.6	27-90
31	49	36.8	12.5	19-65	21	58.2	14.9	33-89
32	52	39.8	14.0	18-83	20	65.4	34.9	29-157
33	[a]				27	68.3	24.1	35-147
34	[a]				29	56.6	15.9	27-91
Overall	1569	33	10.7	15.8-85.4	602	63.6	22.6	24-203

[a] No fish released.

Table A1.3.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weights (g) of subyearling Chinook salmon released into the Columbia River near Rock Creek, Washington, during summer 2002.

Paired Release	Fork Length (mm)				Weight (g)			
	N	Mean	SD	Range	N	Mean	SD	Range
1	52	114	2.9	110-124	52	15.6	1.3	13.3-20.7
2	59	115	4.1	111-128	59	16.9	2.2	12.8-20.9
3	65	114	3.1	110-122	65	16.9	1.6	13.8-22.2
4	62	113	2.8	110-123	62	15.7	1.4	13.0-19.4
5	58	114	3.1	110-126	58	16.0	1.9	12.5-23.8
6	61	113	2.4	110-121	61	15.2	1.4	13.1-20.3
7	60	115	3.5	110-126	60	15.5	1.6	13.0-20.9
8	61	114	3.8	110-128	61	17.0	1.9	14.0-23.3
9	52	114	2.6	110-120	52	15.4	1.3	13.5-19.1
10	64	115	4.2	110-132	64	16.4	2.6	11.9-25.7
11	54	114	4.9	110-137	54	17.1	2.4	14.3-28.8
12	55	113	5.0	110-143	55	15.5	3.0	12.7-32.6
13	58	114	4.7	110-134	58	15.1	1.9	12.1-23.0
14	59	112	2.5	110-119	59	14.9	1.2	12.9-18.1
15	37	114	7.0	110-149	37	16.1	3.9	12.9-35.7
16	50	113	3.0	110-125	50	15.2	1.6	13.2-21.2
17	42	114	3.7	110-128	42	17.8	2.1	14.1-22.3
18	32	115	4.6	110-125	32	16.4	2.4	12.4-21.3
19	41	114	3.5	110-126	41	15.3	1.6	13.0-20.6
20	29	115	6.2	110-143	29	17.3	3.1	13.5-31.4
21	41	114	4.4	110-136	41	15.3	2.2	12.3-25.7
22	41	115	5.7	110-135	41	15.9	2.6	13.1-25.6
23	40	115	6.4	110-145	40	17.9	3.5	14.5-34.1
24	41	115	5.8	110-141	41	16.0	2.8	12.9-28.6
25	45	114	5.2	110-138	45	16.2	3.1	11.6-30.3
26	40	116	6.4	110-136	40	17.7	3.2	14.1-26.5
27	38	114	6.2	110-145	38	15.8	3.2	13.2-31.3
28	33	115	5.5	110-135	33	17.0	2.9	14.1-29.2
29	59	116	7.7	110-149	59	18.5	3.8	15.0-34.3
30	44	117	7.2	110-151	44	16.5	3.5	13.1-34.4
31	39	117	6.1	110-137	39	18.0	3.5	13.4-29.4
32	38	119	8.6	110-146	38	18.3	4.3	13.0-33.3
33	46	117	6.7	111-140	46	17.3	3.6	13.8-31.3
34	43	118	7.8	110-148	43	19.9	4.8	14.9-37.4
35	46	116	6.0	110-138	46	17.3	3.2	13.9-29.6
36	49	114	4.5	110-128	49	16.1	2.3	13.3-22.6
37	44	117	6.2	110-133	44	18.0	3.0	13.9-25.5
38	39	117	6.2	110-132	39	19.0	3.2	14.7-27.1
39	45	119	6.4	110-137	45	17.4	2.9	13.9-28.2
40	48	120	6.3	110-139	48	18.3	3.0	14.0-29.2

Table A1.3.-Continued.

Paired Release	Fork Length (mm)				Weight (g)			
	N	Mean	SD	Range	N	Mean	SD	Range
41	46	117	5.1	110-138	46	18.4	2.4	14.7-27.4
42	48	117	7.4	110-140	48	17.0	4.2	13.3-31.0
43	50	119	6.3	112-141	50	18.7	3.6	14.4-29.2
44	47	116	6.0	110-135	47	16.8	3.2	12.4-25.5
45	46	118	6.9	111-142	46	18.8	3.8	13.4-31.3
46	48	119	7.0	111-145	48	19.6	3.8	14.7-33.0
47	44	119	8.4	110-146	44	18.5	4.5	13.9-33.8
48	51	121	6.1	110-137	51	20.1	3.3	14.4-28.7
49	50	119	7.5	110-142	50	19.0	3.8	13.7-28.6
50	39	125	7.4	112-145	39	21.4	3.9	14.8-33.7
51	50	123	10.7	111-153	50	21.6	6.2	15.0-40.7
52	51	121	9.0	111-152	51	19.1	4.5	13.3-34.6
53	45	119	8.1	110-141	45	19.5	3.8	13.7-30.0
54	46	120	7.8	110-139	46	19.9	3.6	14.1-28.1
55	48	120	8.8	110-144	48	19.1	4.4	13.8-33.3
56	46	116	4.5	110-128	46	17.2	2.4	12.9-24.4
57	51	121	8.6	111-147	51	18.8	4.2	14.0-35.1
58	75	121	8.1	110-145	75	20.3	4.2	14.3-37.1
59	89	123	8.5	110-146	89	22.0	5.0	15.6-43.6
Overall	2880	117	6.8	110-153	2880	17.6	3.7	11.6-43.6

Table A1.4.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of yearling Chinook salmon released into the John Day Dam juvenile bypass and tailrace during spring 2002.

	Juvenile Bypass				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	20	155	9.6	134-176	20	154	11.3	133-182
2	18	150	13.5	133-180	19	149	12.0	132-172
3	19	150	15.0	123-190	19	153	14.1	136-186
4	20	149	12.6	119-176	19	146	12.8	121-165
5	20	142	8.6	127-167	19	147	9.7	125-163
6	20	151	8.8	139-169	20	149	10.4	132-178
7	20	150	11.3	133-177	20	156	13.8	133-191
8	20	145	11.6	125-168	19	152	16.5	127-185
9	19	149	15.1	132-199	18	146	7.3	128-160
10	20	145	15.5	126-183	19	142	12.1	121-175
11	20	143	13.9	120-174	18	150	19.9	128-204
12	20	147	13.0	130-179	20	145	11.6	127-172
13	20	140	9.8	119-170	20	143	10.0	125-168
14	20	141	12.7	122-178	20	139	9.4	129-172
15	16	151	20.8	122-201	18	146	13.8	126-176
16	19	144	12.1	127-172	19	143	13.2	123-177
17	19	143	13.3	126-184	20	137	10.5	124-166
18	17	149	17.3	131-198	20	158	22.2	132-203
19	19	149	14.6	130-189	19	147	14.6	125-179
20	20	147	18.8	124-186	20	156	20.6	128-189
21	19	145	17.3	123-186	19	152	15.0	127-184
22	15	141	14.5	120-170	19	139	14.2	120-165
23	14	147	15.3	124-182	16	154	15.2	126-182
24	18	153	21.7	127-195	15	152	18.5	120-186
25	19	145	15.5	129-184	17	148	18.5	122-195
26	19	151	17.0	125-181	20	153	13.3	131-178
27	18	152	17.0	128-191	20	160	19.0	127-187
28	19	165	20.2	126-200	20	164	27.6	127-215
29	18	148	17.9	130-195	18	151	15.6	134-189
30	20	146	17.4	128-193	20	155	19.6	126-194
31	18	151	19.3	132-190	19	143	10.1	133-172
Overall:	583	148	15.6	119-201	589	149	16.1	120-215

Table A1.5.-The sample size (N), mean, standard deviation (SD), and range of weights (g) of yearling Chinook salmon released into the John Day Dam juvenile bypass and tailrace during spring 2002.

	Juvenile Bypass				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	20	36.9	7.8	23.5-58.8	20	35.8	8.5	22.0-61.3
2	18	34.8	9.8	23.8-56.8	19	33.1	8.1	20.9-51.9
3	19	34.5	11.2	23.3-69.7	19	35.6	10.3	25.1-65.4
4	20	33.6	8.6	16.0-54.3	19	31.3	7.9	15.7-44.7
5	20	29.0	5.5	20.6-44.2	19	31.8	5.9	20.4-43.0
6	20	34.9	7.2	25.4-52.0	20	33.9	7.8	22.2-56.5
7	20	33.1	7.6	21.9-48.8	20	35.8	11.3	24.2-70.0
8	20	29.0	6.7	19.2-43.6	19	34.3	11.0	18.6-59.0
9	19	32.7	12.3	22.7-78.3	18	30.1	4.2	20.5-37.3
10	20	30.7	10.6	19.5-60.1	19	28.9	8.4	17.3-52.1
11	20	27.1	7.7	16.8-43.7	18	32.7	16.3	18.7-77.8
12	20	31.9	8.6	21.3-55.6	20	30.6	7.6	20.3-48.5
13	20	29.6	7.4	16.1-48.9	20	29.5	4.8	18.6-40.2
14	20	28.6	8.3	20.0-58.1	20	28.0	6.1	21.3-48.1
15	16	35.0	15.9	17.3-76.9	18	30.5	8.5	19.1-49.8
16	19	29.6	9.5	18.9-51.9	19	28.3	7.9	18.1-50.5
17	19	30.5	9.5	18.4-57.8	20	27.5	6.6	20.2-50.6
18	17	32.2	14.4	20.8-77.1	20	39.5	18.4	19.2-78.8
19	19	33.9	10.9	23.3-63.5	19	31.8	9.6	17.5-53.8
20	20	31.5	13.3	19.1-65.2	20	38.3	16.5	20.5-69.9
21	19	30.8	12.5	17.0-61.5	19	34.8	10.2	20.6-59.2
22	15	28.5	8.6	19.6-49.0	19	28.0	8.4	16.1-46.0
23	14	32.5	10.1	21.9-57.4	16	36.7	9.6	23.4-54.7
24	18	36.7	15.9	21.3-69.1	15	35.5	13.5	17.4-63.0
25	19	30.3	10.3	19.9-56.6	17	31.6	13.3	19.7-70.2
26	19	33.7	11.6	19.5-55.9	20	35.1	10.0	20.2-59.7
27	18	33.1	11.8	18.7-61.5	20	38.6	13.6	19.8-61.3
28	19	45.1	14.9	22.1-73.9	20	47.3	23.8	21.6-107.3
29	18	35.9	12.3	22.7-68.5	18	37.1	11.5	25.0-68.7
30	20	28.8	11.5	20.1-64.4	20	35.5	14.5	19.1-71.8
31	18	35.2	13.0	23.8-60.7	19	29.4	6.4	23.4-47.0
Overall:	583	32.5	11.0	16-78.3	589	33.5	11.7	15.7-107.3

Table A1.6.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of steelhead smolts released into the John Day Dam juvenile bypass and tailrace during spring 2002.

	Juvenile Bypass				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	19	191	15.0	165-224	19	193	20.5	161-224
2	20	181	24.4	120-215	19	188	16.0	155-220
3	17	186	17.7	156-217	19	182	18.7	134-209
4	19	192	18.8	155-216	20	182	19.1	150-230
5	20	194	19.3	161-228	20	187	13.2	161-205
6	18	194	30.9	156-260	20	184	25.5	151-230
7	20	181	12.9	165-205	20	189	21.0	164-229
8	16	196	21.5	154-230	15	182	17.0	150-218
9	18	189	17.5	161-227	18	190	20.7	162-230
10	18	183	18.5	160-246	20	184	13.1	155-210
11	19	186	23.7	118-231	18	187	26.7	155-275
12	20	184	13.8	160-214	20	192	19.7	148-231
13	20	195	19.6	163-238	20	192	20.1	160-226
14	18	188	19.0	162-225	20	185	19.7	148-217
15	19	183	16.4	155-224	20	191	16.4	159-223
16	10	198	20.8	166-238	20	192	14.3	163-220
17	18	197	17.5	170-230	17	182	15.5	160-218
18	20	197	21.0	163-244	19	197	27.3	151-250
19	20	194	13.5	169-210	20	189	23.0	154-247
20	18	193	22.4	164-253	15	197	21.0	161-239
21	18	185	19.3	135-227	16	187	24.8	151-235
22	19	184	18.2	152-221	19	182	16.5	154-222
23	10	186	21.8	154-224	18	194	21.2	160-234
24	20	192	21.4	155-234	20	196	27.9	150-258
25	18	190	22.4	159-238	19	197	23.6	161-240
26	19	180	17.9	160-220	19	184	20.2	159-228
27	10	180	13.7	161-204	20	185	20.2	160-222
28	10	181	18.7	155-206	18	191	22.4	153-230
29	18	182	18.5	144-213	19	185	13.8	162-216
30	20	183	14.6	161-220	17	177	14.5	153-210
Overall:	529	188	19.6	118-260		188	20.3	134-275

Table A1.7.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of steelhead smolts released into the John Day Dam spillway and tailrace during spring 2002.

	Spillway				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	15	189	26.2	156-245	18	188	22.5	158-235
2	18	190	19.4	161-245	19	193	20.5	161-224
3	18	185	13.0	162-206	19	188	16.0	155-220
4	19	192	17.5	156-216	19	182	18.7	134-209
5	19	188	19.3	150-229	20	182	19.1	150-230
6	17	189	17.3	156-217	19	187	21.4	150-228
7	20	179	28.5	102-218	20	187	13.2	161-205
8	16	180	16.1	154-206	20	194	19.2	150-230
9	19	187	18.8	154-212	20	184	25.5	151-230
10	20	183	18.8	156-236	20	189	21.0	164-229
11	13	185	14.5	168-218	15	182	17.0	150-218
12	19	190	20.4	164-255	18	190	20.7	162-230
13	20	189	16.9	145-217	20	184	13.1	155-210
14	19	183	18.9	150-231	17	185	21.2	157-241
15	19	183	23.3	141-252	18	187	26.7	155-275
16	19	191	22.8	156-236	20	192	19.7	148-231
17	19	199	24.0	170-270	20	192	20.1	160-226
18	20	192	20.0	162-229	20	185	19.7	148-217
19	19	192	19.7	158-240	20	191	16.4	159-223
20	10	189	23.5	165-233	20	192	14.3	163-220
21	20	199	31.8	160-260	19	185	23.2	137-226
22	20	200	25.3	151-254	17	182	15.5	160-218
23	19	194	23.5	153-250	20	201	20.6	158-225
24	13	187	15.1	157-207	19	194	18.8	159-226
25	20	187	17.2	151-211	19	197	27.3	151-250
26	20	198	25.1	152-241	20	189	23.0	154-247
27	19	187	17.3	158-215	15	197	21.0	161-239
28	16	183	20.1	158-211	16	187	24.8	151-235
29	20	186	28.0	142-240	20	185	19.1	158-225
30	20	192	19.3	145-221	19	182	16.5	154-222
31	19	190	29.1	145-264	20	196	27.9	150-258
32	19	179	15.3	149-208	19	197	23.6	161-240
33	18	200	26.1	160-245	19	184	20.2	159-228
34	10	183	13.8	155-200	20	181	19.8	138-227
35	10	187	15.3	168-208	20	185	20.2	160-222
36	18	175	16.1	145-203	20	194	29.2	149-264
37	10	187	29.5	148-240	18	191	22.4	153-230
38	19	188	23.1	155-251	19	185	13.8	162-216
39	18	191	16.8	161-218	20	189	18.3	162-230
40	19	183	15.7	157-224	17	177	14.5	153-210
Overall:	705	188	21.5	102-270	758	188	20.7	134-275

Table A1.8.-The sample size (N), mean, standard deviation (SD), and range of weights (g) of steelhead smolts released into the John Day Dam juvenile bypass and tailrace during spring 2002.

	Juvenile Bypass				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	19	59.6	14.7	38.6-96.9	19	67.3	20.6	36.9-110.4
2	20	57.7	19.5	25.4-94.7	19	60.7	14.6	31.2-87.9
3	17	60.4	15.3	33.3-82.6	19	54.6	14.9	22.7-81.7
4	19	63.2	19.5	31.6-87.4	20	53.5	18.3	27.3-105.7
5	20	63.9	20.5	26.7-104.3	20	58.5	11.8	38.0-76.8
6	18	68.5	37.2	33.3-175.8	20	58.4	26.7	32.1-113.0
7	20	54.3	13.7	37.4-79.0	20	60.5	21.2	35.2-108.4
8	16	68.0	24.1	31.2-120.9	15	54.6	15.5	29.2-85.9
9	18	60.8	15.9	35.2-91.7	18	64.1	23.6	33.5-117.5
10	18	55.5	24.6	32.8-145.2	20	53.9	12.3	29.3-78.2
11	19	64.0	21.0	36.4-122.9	18	63.0	33.9	32.0-186.6
12	20	54.4	13.8	33.1-95.7	20	64.9	22.6	29.8-128.2
13	20	67.2	20.7	35.1-112.6	20	63.8	22.0	34.3-109.5
14	18	60.9	19.6	36.6-105.0	20	56.4	17.2	26.4-89.1
15	19	54.2	18.8	29.3-107.9	20	63.6	18.2	33.8-98.5
16	10	69.0	22.9	26.3-109.3	20	65.3	16.4	36.4-98.3
17	18	67.2	20.5	40.9-109.1	17	53.6	20.5	21.5-105.0
18	20	68.5	20.8	34.5-112.4	19	73.4	30.4	26.6-136.2
19	20	63.8	15.5	38.0-86.6	20	67.1	27.4	30.3-144.2
20	18	62.4	23.5	34.1-132.7	15	65.0	21.0	36.1-107.4
21	18	56.3	18.8	22.3-110.3	16	59.0	26.3	28.0-107.5
22	19	57.1	18.2	29.8-104.2	19	52.5	18.0	27.2-101.6
23	10	58.5	20.5	30.5-89.9	18	67.6	21.0	38.4-109.9
24	20	60.7	20.9	29.1-108.0	20	68.8	32.0	28.0-159.1
25	18	61.1	25.6	29.1-129.1	19	67.9	23.8	35.2-107.1
26	19	49.7	16.8	34.8-97.0	19	54.8	19.2	30.9-99.9
27	10	51.5	10.7	37.6-73.2	20	56.9	21.2	32.9-107.8
28	10	52.9	18.2	29.6-87.8	18	63.5	22.3	30.8-101.8
29	18	54.3	15.7	23.9-76.8	19	57.9	14.4	35.3-96.8
30	20	55.2	13.8	37.7-81.8	17	50.4	14.3	31.8-85.1
Overall:	529	60.1	20.1	22.3-175.8	564	60.8	21.7	21.5-186.6

Table A1.9.-The sample size (N), mean, standard deviation (SD), and range of weights (g) of steelhead smolts released into the John Day Dam spillway and tailrace during spring 2002.

	Spillway				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	15	62.3	28.0	31.7-131.3	18	62.8	24.1	35.1-116.4
2	18	64.6	24.9	33.1-147.6	19	67.3	20.6	36.9-110.4
3	18	54.9	11.0	35.1-73.8	19	60.7	14.6	31.2-87.9
4	19	62.6	15.1	38.3-86.6	19	54.6	14.9	22.7-81.7
5	19	58.8	18.0	32.5-106.6	20	53.5	18.3	27.3-105.7
6	17	59.3	16.3	30.8-91.9	19	58.6	21.1	27.9-105.2
7	20	54.4	21.7	23.2-95.9	20	58.5	11.8	38.0-76.8
8	16	52.7	13.9	29.6-74.5	20	64.6	20.0	30.3-110.5
9	19	59.5	20.0	32.0-96.4	20	58.4	26.7	32.1-113.0
10	20	56.0	18.5	32.4-114.0	20	60.5	21.2	35.2-108.4
11	13	57.0	13.8	43.6-85.1	15	54.6	15.5	29.2-85.9
12	19	63.0	23.5	43.8-150.8	18	64.1	23.6	33.5-117.5
13	20	60.4	14.9	27.0-84.3	20	53.9	12.3	29.3-78.2
14	19	56.2	21.3	27.1-127.1	17	58.1	21.0	37.4-120.8
15	19	56.3	21.2	21.7-123.6	18	63.0	33.9	32.0-186.6
16	19	65.7	26.0	33.8-123.3	20	64.9	22.6	29.8-128.2
17	19	69.2	29.9	41.7-168.0	20	63.8	22.0	34.3-109.5
18	20	66.4	20.5	41.1-106.1	20	56.4	17.2	26.4-89.1
19	19	63.1	20.4	30.7-118.0	20	63.6	18.2	33.8-98.5
20	10	59.3	27.1	23.6-110.5	20	65.3	16.4	36.4-98.3
21	20	74.2	37.4	35.5-151.7	19	57.0	21.5	21.7-100.1
22	20	73.2	30.3	27.4-156.3	17	53.6	20.5	21.5-105.0
23	19	70.0	26.0	29.3-146.8	20	75.1	22.0	35.1-110.6
24	13	59.7	14.0	34.4-77.6	19	67.7	21.1	33.6-111.2
25	20	56.9	19.1	73.7-83.5	19	73.4	30.4	26.6-136.2
26	20	70.6	26.1	26.5-122.5	20	67.1	27.4	30.3-144.2
27	19	57.3	16.8	30.9-94.5	15	65.0	21.0	36.1-107.4
28	16	56.9	18.6	32.6-86.9	16	59.0	26.3	28.0-107.5
29	20	59.5	27.1	23.4-114.1	20	57.1	19.1	33.9-92.4
30	20	69.0	25.5	37.7-144.3	19	52.5	18.0	27.2-101.6
31	19	60.8	28.0	24.7-141.7	20	68.8	32.0	28.0-159.1
32	19	49.7	15.0	27.2-91.1	19	67.9	23.8	35.2-107.1
33	18	70.9	29.7	33.4-130.9	19	54.8	19.2	30.9-99.9
34	10	55.4	14.0	29.2-74.3	20	51.7	15.6	21.3-91.8
35	10	57.8	14.6	39.5-78.4	20	56.9	21.2	32.9-107.8
36	18	47.6	14.2	24.2-79.1	20	69.1	37.6	26.8-181.2
37	10	62.0	31.2	27.8-128.8	18	63.5	22.3	30.8-101.8
38	19	59.6	24.6	31.2-135.9	19	57.9	14.4	35.3-96.8
39	18	60.8	14.9	35.7-83.5	20	61.2	19.9	33.5-109.5
40	19	54.9	16.6	31.4-103.0	17	50.4	14.3	31.8-85.1
Overall:	705	61	21.6	21.7-168	758	61	22.1	21-187

Table A1.10.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of subyearling Chinook salmon released into the John Day Dam juvenile bypass and tailrace during summer 2002.

	Juvenile Bypass				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	52	116	4.8	110-132	60	116	5.2	110-131
2	48	114	3.8	108-128	60	114	5.0	108-132
3	54	116	3.7	110-126	53	115	3.7	110-125
4	57	115	4.2	110-139	52	115	3.5	111-125
5	49	114	2.9	110-122	59	115	4.1	110-131
6	53	115	3.9	110-132	56	115	3.0	110-121
7	52	115	5.1	110-135	59	115	5.1	110-137
8	60	114	3.1	110-130	60	114	3.7	110-125
9	48	113	2.7	110-120	50	113	2.6	110-124
10	48	113	3.9	109-128	49	113	5.3	109-135
11	49	113	3.2	110-124	50	114	4.3	110-131
12	34	113	3.1	110-122	40	115	4.7	110-127
13	35	114	3.5	110-121	46	114	4.3	110-130
14	49	118	9.4	108-145	53	116	7.4	109-144
15	58	116	6.1	110-142	57	116	6.5	110-138
16	40	116	7.7	109-142	43	117	5.9	109-133
17	53	116	8.0	110-142	59	116	5.9	110-138
18	44	119	8.6	110-140	48	115	6.4	109-135
19	39	118	8.4	110-142	42	120	9.2	110-142
20	38	117	4.9	110-133	43	120	8.2	110-141
21	39	117	5.2	110-128	43	114	4.7	110-131
22	35	117	8.2	110-140	44	118	7.8	110-140
23	38	121	7.9	110-143	39	120	5.9	110-136
24	39	116	6.7	110-136	44	117	6.4	110-139
25	39	117	7.2	110-138	40	116	6.4	110-138
26	34	117	6.7	110-135	43	117	6.0	110-138
27	39	119	8.4	110-143	37	119	10.6	110-143
28	40	125	10.4	110-146	43	123	18.0	109-228
29	39	119	7.1	111-137	44	122	8.8	110-145
30	37	120	8.0	112-146	43	118	6.3	110-134
31	40	121	7.8	111-143	43	120	7.4	111-146
Overall:	1379	116	6.7	108-146	2654	116	7.0	107-228

Table A1.11.-The sample size (N), mean, standard deviation (SD), and range of weights (g) of subyearling Chinook salmon released into the John Day Dam juvenile bypass and tailrace during summer 2002.

	Juvenile Bypass				Tailrace			
Release	N	Mean	SD	Range	N	Mean	SD	Range
1	52	16.7	2.5	13.6-25.7	60	16.7	2.5	14.0-24.2
2	48	14.9	1.8	12.7-22.3	60	16.0	5.2	12.6-50.8
3	54	16.0	1.6	13.1-20.5	53	15.4	1.3	13.1-20.4
4	57	16.1	2.1	14.0-27.9	52	16.8	1.9	14.4-22.8
5	49	15.3	1.5	13.1-18.7	59	15.7	2.1	13.2-24.0
6	53	16.7	2.1	14.0-26.9	56	16.3	1.5	13.6-21.1
7	52	15.6	2.4	12.7-25.3	59	15.6	2.4	13.0-29.0
8	60	16.0	1.5	13.7-24.5	60	16.4	1.9	13.2-21.1
9	48	15.2	1.4	13.1-19.2	50	15.2	1.3	13.0-20.6
10	48	16.2	2.1	13.4-23.1	49	16.4	3.0	13.3-28.0
11	49	15.1	1.7	13.1-21.4	50	15.4	2.1	13.0-23.2
12	34	16.0	1.6	13.7-21.3	40	16.9	2.6	13.2-23.7
13	35	15.5	1.9	13.0-20.3	46	15.8	2.2	13.2-22.6
14	49	17.9	4.7	13.1-30.1	53	17.1	4.0	13.4-35.0
15	58	16.5	3.0	13.1-31.2	57	16.7	3.2	13.1-26.6
16	40	16.9	5.8	13.0-46.7	43	16.9	3.0	13.6-25.3
17	53	17.4	4.1	13.0-31.1	59	17.0	3.0	14.1-29.2
18	44	19.1	4.0	13.4-28.8	48	17.2	3.2	13.8-27.8
19	39	17.7	4.0	13.4-28.6	42	18.5	4.6	13.5-30.1
20	38	18.2	2.9	14.6-29.0	43	19.4	4.2	14.1-29.4
21	39	17.2	3.0	13.8-25.2	43	16.5	2.4	14.0-26.2
22	35	18.6	4.3	13.3-28.9	44	18.9	4.5	14.6-34.8
23	38	20.0	4.2	13.9-32.1	39	19.5	2.9	14.2-26.2
24	39	16.6	3.2	13.2-27.7	44	16.8	2.9	13.2-27.0
25	39	17.9	3.7	13.9-29.6	40	17.5	3.1	13.8-29.1
26	34	18.5	3.1	13.5-26.5	43	18.4	3.1	14.4-29.2
27	39	18.4	4.0	13.9-29.5	37	18.5	5.4	13.9-31.9
28	40	21.3	5.3	13.1-33.3	43	19.1	3.7	13.5-30.8
29	39	18.6	3.2	14.3-26.4	44	20.1	4.3	13.9-31.3
30	37	19.0	4.4	14.0-33.3	43	18.3	3.3	13.8-25.6
31	40	19.5	3.7	14.0-30.8	43	19.1	4.2	14.2-37.0
Overall:	1379	17.1	3.5	12.7-46.7	2652	17.1	3.5	12.6-50.8

Table A1.12.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weight (g) of yearling Chinook salmon released into the John Day Dam tailrace during spring 2002. Releases are in addition to bypass and tailrace releases and used as a control for fish released at Rock Creek.

		Fork length (mm)			Weight (g)		
Release	N	Mean	SD	Range	Mean	SD	Range
1	18	148	10.8	130-165	31	6.4	20-41
2	19	146	7.1	132-160	30	4.4	23-39
3	20	145	12.0	124-178	30	8.7	18-54
4	20	138	13.1	126-189	26	8.9	18-61
5	19	144	15.9	126-184	29	11.0	19-68
6	20	140	12.3	127-177	25	9.4	19-56
7	18	147	12.7	130-183	28	8.0	21-54
8	20	152	11.7	134-179	34	10.1	24-61
Overall:	154	145	12.6	124-189	29	8.9	18-68

Table A1.13.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) and weight (g) of steelhead smolts released into the John Day Dam tailrace during spring 2002. Releases are in addition to bypass and tailrace releases and used as a control for fish released at Rock Creek.

		Fork length (mm)			Weight (g)		
Release	N	Mean	SD	Range	Mean	SD	Range
1	19	193	24.9	148-254	69	35.7	28-181
2	19	189	26.8	117-222	63	18.0	29-93
3	19	191	17.2	160-225	64	17.1	37-94
4	11	184	13.5	158-196	59	11.3	37-72
5	20	182	19.1	153-221	54	18.3	31-100
6	19	196	21.1	165-240	70	23.2	41-129
Overall:	107	189	21.4	117-254	63	22.7	28-181

Table A1.14.-The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of subyearling Chinook salmon released into the John Day Dam tailrace during summer 2002. Releases are in addition to bypass and tailrace releases and used as a control for fish released at Rock Creek.

		Fork length (mm)			Weight (g)		
Release	N	Mean	SD	Range	Mean	SD	Range
5	59	117	4.7	111-132	16.0	2.2	13.3-22.9
7	45	113	2.9	110-123	15.1	1.3	13.1-18.7
9	48	115	3.4	110-125	15.8	1.6	13.0-20.2
11	46	113	3.3	110-123	16.4	1.7	14.0-21.1
13					15.2	1.2	13.5-19.0
15	53	113	2.6	110-121	15.6	1.4	13.3-19.3
17	48	113	2.5	110-120	14.9	1.3	13.0-18.7
19	44	114	6.1	110-138	16.3	3.2	14.0-29.5
21	32	113	3.5	107-121	14.9	1.6	13.0-19.9
23	38	113	2.8	110-120	15.6	1.3	13.4-18.1
25	41	116	6.9	110-143	16.4	3.5	13.0-29.8
27	35	117	7.4	110-137	17.3	3.4	13.8-27.5
29					17.3	4.1	13.1-30.6
31	34	117	7.1	110-140	17.1	3.4	14.2-29.0
33	40	117	7.5	110-147	16.9	3.7	13.4-32.0
35	44	118	7.6	110-137	18.2	3.5	14.4-27.3
37	42	117	4.8	111-133	17.2	2.7	13.8-25.7
39	39	116	6.1	110-135	16.8	3.2	12.8-29.8
41	42	125	10.9	111-150	20.8	5.7	13.8-36.5
43	44	120	6.0	110-137	19.3	2.9	15.4-29.0
45	41	116	5.5	110-129	16.4	2.6	13.7-23.1
48	41	119	9.6	111-153	19.6	5.0	14.0-37.4
50	43	118	7.7	110-144	18.6	3.9	14.6-32.8
52	42	121	6.8	112-139	19.7	3.4	15.4-31.8
54	43	121	9.8	111-160	18.8	5.3	13.8-43.6
56	43	118	7.7	110-137	18.6	4.1	13.5-30.1
58	43	120	7.7	111-149	19.4	3.9	14.8-37.0
Overall:							

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 31 paired releases of yearling Chinook salmon, spring 2002. Treatment fish were released at the top of the juvenile bypass at John Day Dam and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
2	Treatment		[a]	[a]		[a]	[a]
	Control	3	1.853	0.604		[a]	[a]
3	Treatment		[a]	[a]		[a]	[a]
	Control	3	4.902	0.179	3	0.227	0.973
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]	3	0.315	0.957
7	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
8	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]	3	1.294	0.731
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]

[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.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
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
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

[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.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
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]

[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 30 paired releases of steelhead, spring 2002. Treatment fish were released at the top of the juvenile bypass at John Day Dam and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
2	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
3	Treatment		[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]

[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.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
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]
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]

[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.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
30	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 31 paired releases of subyearling Chinook, summer 2002. Treatment fish were released at the top of the juvenile bypass at John Day Dam and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
2	Treatment		[a]	[a]	3	1.778	0.620
	Control	3	4.421	0.219		[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]

[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.-Continued.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
15	Treatment		[a]	[a]		[a]	[a]
	Control	3	0.397	0.941		[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]	3	0.710	0.871
	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]
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]	3	15.599	0.001
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]

[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.-Continued.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
30	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
31	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 A2.4.-Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 40 paired releases of steelhead, spring 2002. Treatment fish were released into the spillway at John Day Dam and control fish were released in the John Day Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
2	Treatment		[a]	[a]		[a]	[a]
	Control		[a]	[a]		[a]	[a]
3	Treatment		[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]

[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 A2.4.-Continued.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
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]
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]

[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 A2.4.-Continued.

		Test 2			Test 3		
Releas	Population	df	χ^2	P	df	χ^2	P
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.

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 John Day Dam juvenile bypass system and the John Day Dam tailrace and detected at the radio telemetry detection arrays at river kilometers 335 and 324, 2002. During releases 1 through 5 equipment problems at river kilometer 335 and 324 prevented us from detecting fish.

	River Kilometer 335			River Kilometer 324			% Spill
Release	DF	Chi-square	P	DF	Chi-square	P	Day/ Night
1	**			**			30 / 30
2	**			**			30 / 30
3	**			**			00 / 60
4	**			1	0.67	0.411	00 / 60
5	**			0	0	[a]	30 / 30
6	0	0*	[a]	0	0	[a]	30 / 30
7	0	0	[a]				00 / 60
8	0	0	[a]	0	0	[a]	00 / 60
9	0	0	[a]	0	0	[a]	00 / 60
10							30 / 30
11	0	0	[a]	0	0	[a]	30 / 30
12	0	0	[a]	0	0	[a]	30 / 30
13	0	0	[a]	0	0	[a]	30 / 30
14	0	0	[a]	0	0	[a]	00 / 60
15	0	0	[a]	0	0	[a]	00 / 60
16	0	0	[a]	0	0	[a]	00 / 60
17	0	0	[a]	0	0	[a]	00 / 60
18	0	0	[a]	0	0	[a]	30 / 30
19	0	0	[a]	0	0	[a]	30 / 30
20	0	0	[a]	0	0	[a]	30 / 30
21	0	0	[a]	0	0	[a]	30 / 30
22	1	0.35	0.553	1	0.48	0.485	00 / 60
23	0	0	[a]	0	0	[a]	00 / 60
24	0	0	[a]	0	0	[a]	00 / 60
25	0	0	[a]	0	0	[a]	00 / 60
26	0	0	[a]	0	0	[a]	30 / 30
27	0	0	[a]	0	0	[a]	30 / 30
28	1	1.22	0.268	0	0	[a]	30 / 30
29	0	0	[a]	0	0	[a]	30 / 30
30	0	0	[a]	0	0	[a]	00 / 60
31	0	0	[a]	0	0	[a]	00 / 60

[a] - All fish arrived on the same day at this detection array.
* - Only one fish arrived at array.
** - Problems with equipment on these dates prevented data collection.

Table A3.2. Chi-square tests for homogeneity of arrival times of yearling Chinook salmon released from the top of the John Day Dam juvenile bypass system and the John Day Dam tailrace and detected at the radio telemetry detection arrays at river kilometers 308, 286 and 264, 2002.

	River Kilometer 308			River Kilometer 286			River kilometer 264			
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P	% Spill Day/Night
1	1	1.88	0.169	1	1.57	0.210	2	2.00	0.367	30 / 30
2	0	0	[a]	2	3.07	0.215	1	0.19	0.657	30 / 30
3	1	3.10	0.078	1	1.81	0.177	2	1.33	0.513	00 / 60
4	2	1.48	0.476	2	2.28	0.318	2	5.00	0.082	00 / 60
5	2	2.00	0.367	1	1.45	0.228	1	1.32	0.250	30 / 30
6	1	3.27	0.070	2	3.85	0.145	2	2.35	0.307	30 / 30
7	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
8	2	2.00	0.367	1	2.94	0.086	1	0.22	0.633	00 / 60
9	1	1.18	0.276	1	0.59	0.439	1	1.52	0.216	00 / 60
10	0	0	[a]	1	1.25	0.262	0	0	[a]	30 / 30
11	0	0	[a]	2	1.58	0.451	1	0.87	0.349	30 / 30
12	0	0	[a]	0	0	[a]	1	0.90	0.342	30 / 30
13	1	0.09	0.763	2	4.11	0.127	1	0.74	0.389	30 / 30
14	1	0.85	0.356	1	2.22	0.136	1	1.40	0.235	00 / 60
15	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
16	0	0	[a]	1	0.94	0.331	0	0	[a]	00 / 60
17	1	0.46	0.496	0	0	[a]	0	0	[a]	00 / 60
18	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
19	1	1.35	0.243	0	0	[a]	0	0	[a]	30 / 30
20	0	0	[a]	1	1.51	0.218	1	1.25	0.262	30 / 30
21	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
22	1	2.10	0.147	1	2.11	0.145	1	1.73	0.187	00 / 60
23	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
24	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
25	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
26	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
27	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
28	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
29	1	0.74	0.387	1	0.10	0.741	1	0.95	0.329	30 / 30
30	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
31	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60

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

Table A3.3. Chi-square tests for homogeneity of arrival times of juvenile steelhead trout released from John Day Dam juvenile bypass system and John Day Dam tailrace and detected at the radio telemetry arrays at river kilometers 335 and 324, 2002.

	River Kilometer 335			River kilometer 324			% Spill
Release	DF	Chi-square	P	DF	Chi-square	P	Day / Night
1	**			0	0	[a]	30 / 30
2	**			0	0	[a]	30 / 30
3	**			0	0	[a]	00 / 60
4	**			0	0	[a]	00 / 60
5	*			0	0	[a]	30 / 30
6	*			0	0	[a]	30 / 30
7	0	0	[a]	0	0	[a]	00 / 60
8	2	1.83	0.399	*			00 / 60
9	2	2.05	0.358	3	5.25	0.154	00 / 60
10	1	2.74	0.097	2	4.90	0.085	00 / 60
11	1	0.96	0.324	1	0.97	0.324	30 / 30
12	1	1.03	0.309	1	1.25	0.262	30 / 30
13	3	2.92	0.403	4	6.01	0.198	00 / 60
14	1	0.62	0.430	1	0.06	0.793	00 / 60
15	0	0	[a]	0	0	[a]	00 / 60
16	0	0	[a]	0	0	[a]	30 / 30
17	1	1.11	0.290	0	0	[a]	30 / 30
18	1	1.16	0.279	1	0.00	0.964	00 / 60
19	1	0.83	0.362	0	0	[a]	00 / 60
20	0	0	[a]	0	0	[a]	00 / 60
21	1	1.25	0.262	1	1.11	0.290	00 / 60
22	1	1.12	0.288	0	0	[a]	30 / 30
23	1	2.28	0.130	1	1.83	0.175	30 / 30
24	0	0	[a]	1	1.03	0.308	30 / 30
25	0	0	[a]	1	1.95	0.162	00 / 60
26	0	0	[a]	0	0	[a]	00 / 60
27	0	0	[a]	0	0	[a]	30 / 30
28	0	0	[a]	0	0	[a]	30 / 30
29	0	0	[a]	0	0	[a]	30 / 30
30	0	0	[a]	0	0	[a]	30 / 30

[a] - All fish arrived on the same day at this detection array.
*- Only one fish arrived at this detection array.
** - Problems with equipment on these dates prevented data collection.

Table A3.4. Chi-square tests for homogeneity of arrival times of juvenile steelhead trout released from John Day Dam juvenile bypass system and John Day Dam tailrace and detected at the radio telemetry arrays at river kilometers 308, 286, and 264, 2002.

	River Kilometer 308			River Kilometer 286			River Kilometer 264			
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P	% Spill Day/ Night
1	1	3.23	0.071	2	2.05	0.358	2	2	0.367	30 / 30
2	1	1.08	0.296	2	2.15	0.340	2	1.55	0.458	30 / 30
3	2	2.39	0.302	1	1.04	0.307	2	3.28	0.193	00 / 60
4	0	0	[a]	0	0	[a]	1	1.14	0.285	00 / 60
5	2	7.55	0.022	1	0.77	0.377	1	4.31	0.037	30 / 30
6	2	1.57	0.455	2	0.73	0.692	2	3.98	0.136	30 / 30
7	0	0	[a]	2	2.15	0.340	2	1.83	0.399	00 / 60
8	3	3.69	0.296	2	2.87	0.237	2	4.50	0.105	00 / 60
9	3	3.18	0.364	3	4.39	0.221	4	5.81	0.213	00 / 60
10	2	1.75	0.415	1	4.84	0.027	1	2.62	0.105	00 / 60
11	1	0.92	0.337	2	0.97	0.615	2	1.50	0.472	30 / 30
12	1	1.77	0.182	3	3.06	0.382	3	2.65	0.447	30 / 30
13	3	5.29	0.151	3	6.69	0.082	3	5.77	0.123	00 / 60
14	1	0.15	0.693	2	1.33	0.511	2	1.33	0.513	00 / 60
15	1	1.30	0.253	3	1.64	0.649	2	0.91	0.632	00 / 60
16	0	0	[a]	0	0	[a]	1	0.48	0.485	30 / 30
17	0	0	[a]	1	1.10	0.292	1	1.19	0.274	30 / 30
18	1	0.01	0.894	2	0.87	0.644	1	0.71	0.399	00 / 60
19	1	0.73	0.392	1	0.74	0.387	2	2.18	0.335	00 / 60
20	1	1.03	0.309	1	1.12	0.288	1	1.12	0.288	00 / 60
21	1	0.00	1	1	1.01	0.314	1	0.39	0.531	00 / 60
22	1	2.64	0.103	1	2.75	0.096	1	0.74	0.389	30 / 30
23	1	1.73	0.187	1	4.12	0.042	0	0	[a]	30 / 30
24	1	1.08	0.296	2	1.86	0.393	2	1.19	0.549	30 / 30
25	1	3.26	0.070	1	0.16	0.683	1	0.32	0.396	00 / 60
26	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
27	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
28	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
29	0	0	[a]	1	2.87	0.090	1	1.06	0.301	30 / 30
30	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30

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

Table A3.5. Chi-square tests for homogeneity of arrival times of subyearling Chinook salmon released from the top of the John Day Dam juvenile bypass system and the John Day Dam tailrace and detected at the radio telemetry detection arrays at river kilometers 335 and 324, 2002.

	River kilometer 335			River kilometer 324			% Spill
Release	DF	Chi-square	P	DF	Chi-square	P	Day / Night
1	0	0	[a]	0	0	[a]	00 / 60
2	0	0	[a]	0	0	[a]	00 / 60
3	1	1.30	0.253	1	1.06	0.302	30 / 30
4	0	0	[a]	0	0	[a]	30 / 30
5	0	0	[a]	0	0	[a]	30 / 30
6	1	0.89	0.343	0	0	[a]	30 / 30
7	1	1.60	0.204	0	0	[a]	00 / 60
8	0	0	[a]	0	0	[a]	00 / 60
9	0	0	[a]	0	0	[a]	00 / 60
10	0	0	[a]	0	0	[a]	30 / 30
11	0	0	[a]	0	0	[a]	30 / 30
12	0	0	[a]	0	0	[a]	30 / 30
13	1	1.20	0.273	0	0	[a]	00 / 60
14	1	0.87	0.350	0	0	[a]	30 / 30
15	0	0	[a]	0	0	[a]	30 / 30
16							30 / 30
17	0	0	[a]	0	0	[a]	30 / 30
18	0	0	[a]	0	0	[a]	30 / 30
19	1	2.14	0.143	1	1.64	0.199	00 / 60
20	0	0	[a]	0	0	[a]	00 / 60
21	1	0.63	0.426	1	1.79	0.180	00 / 60
22	0	0	[a]	0	0	[a]	00 / 60
23	0	0	[a]	0	0	[a]	30 / 30
24	1	0.00	0.942	0	0	[a]	30 / 30
25	0	0	[a]	0	0	[a]	00 / 60
26	0	0	[a]	1	3.17	0.074	00 / 60
27	0	0	[a]	0	0	[a]	30 / 30
28	1	2.89	0.088	1	2.62	0.105	30 / 30
29	1	1.27	0.259	0	0	[a]	30 / 30
30	0	0	[a]	0	0	[a]	30 / 30
31	0	0	[a]	0	0	[a]	00 / 60

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

Table A3.6. Chi-square tests for homogeneity of arrival times of subyearling Chinook salmon released from the top of the John Day Dam juvenile bypass system and the John Day Dam tailrace and detected at the radio telemetry detection arrays at river kilometers 308, 286 and 264, 2002.

	River kilometer 308			River Kilometer 286			River Kilometer 264			
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P	% Spill Day / Night
1	0	0	[a]	0	0	[a]	1	1.50	0.219	00 / 60
2	1	0.55	0.458	1	2.16	0.141	0	0	[a]	00 / 60
3	0	0	[a]	1	1.01	0.313	2	2.11	0.348	30 / 30
4	1	1.20	0.272	3	3.27	0.350	3	5.31	0.150	30 / 30
5	2	1.35	0.508	2	2.22	0.329	2	3.05	0.216	30 / 30
6	1	0.28	0.595	0	0	[a]	2	1.34	0.511	30 / 30
7	0	0	[a]	0	0	[a]	1	1.34	0.245	00 / 60
8	1	1.77	0.183	1	0.66	0.413	1	1.46	0.225	00 / 60
9	1	1.10	0.292	3	2.00	0.571	1	1.22	0.268	00 / 60
10	1	0.78	0.376	1	0.92	0.337	0	0	[a]	30 / 30
11	1	1.86	0.171	1	0.31	0.572	1	1.74	0.187	30 / 30
12	1	1.33	0.248	3	2.00	0.571	3	3.73	0.291	30 / 30
13	0	0	[a]	0	0	[a]	1	4.25	0.039	00 / 60
14	1	2.98	0.084	2	4.15	0.125	2	5.06	0.079	30 / 30
15	0	0	[a]	2	1.62	0.443	2	1.22	0.541	30 / 30
16	1	0.07	0.786	1	0.18	0.668	2	1.41	0.493	30 / 30
17	1	2.39	0.121	1	0.55	0.456	1	0.48	0.486	30 / 30
18	2	3.28	0.193	2	2.12	0.345	1	0.23	0.628	30 / 30
19	1	5.59	0.01	2	4.39	0.111	1	3.77	0.052	00 / 60
20	0	0	[a]	2	2.45	0.292	1	0.10	0.744	00 / 60
21	2	2.94	0.229	2	0.13	0.932	2	0.17	0.915	00 / 60
22	1	0.02	0.872	1	0.01	0.919	1	0.00	0.938	00 / 60
23	1	1.24	0.264	2	1.44	0.485	2	1.06	0.586	30 / 30
24	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
25	1	2.29	0.129	1	0.30	0.582	1	0.33	0.560	00 / 60
26	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
27	0	0	[a]	1	0.97	0.323	2	2.01	0.365	30 / 30
28	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
29	1	1.46	0.225	1	1.63	0.201	1	1.45	0.227	30 / 30
30	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
31	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60

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

Table A3.7. Chi-square tests for homogeneity of arrival times of juvenile steelhead trout released from John Day Dam spillway and John Day Dam tailrace and detected at the radio telemetry arrays at river kilometers 335 and 324, 2002.

	River kilometer 335			River kilometer 324			% Spill
Release	DF	Chi-square	P	DF	Chi-square	P	Day / Night
1	**			2	1.27	0.529	30 / 30
2	**			0	0	[a]	30 / 30
3	**			0	0	[a]	30 / 30
4	**			0	0	[a]	00 / 60
5	**			1	1.22	0.268	00 / 60
6	**			1	0.91	0.339	30 / 30
7	**			0	0	[a]	30 / 30
8	**			1	0.91	0.339	30 / 30
9	0	0	[a]	0	0	[a]	30 / 30
10	0	0	[a]				00 / 60
11	0	0	[a]				00 / 60
12	1	0.74	0.388	2	1.33	0.513	00 / 60
13	0	0	[a]	0	0	[a]	00 / 60
14	1	1.72	0.188	2	2.00	0.366	30 / 30
15	0	0	[a]	0	0	[a]	30 / 30
16	2	2.44	0.293	2	2.41	0.298	30 / 30
17	1	0.90	0.341	2	2.00	0.366	00 / 60
18	1	0.91	0.339	1	0.82	0.364	00 / 60
19	1	1.25	0.262	1	1.15	0.281	00 / 60
20	0	0	[a]	0	0	[a]	30 / 30
21	3	3.70	0.295	2	2.87	0.237	30 / 30
22	0	0	[a]	0	0	[a]	30 / 30
23	1	2.24	0.133	1	2.24	0.133	30 / 30
24	0	0	[a]	0	0	[a]	30 / 30
25	1	0.89	0.343	1	1.03	0.310	00 / 60
26	1	0.96	0.326	1	1.03	0.309	00 / 60
27	0	0	[a]	1	0.91	0.339	00 / 60
28	0	0	[a]	0	0	[a]	00 / 60
29	1	0.30	0.580	1	0.00	0.931	30 / 30
30	1	0.89	0.343	1	1.19	0.274	30 / 30
31	0	0	[a]	0	0	[a]	30 / 30
32	1	0.96	0.326	0	0	[a]	00 / 60
33	0	0	[a]	0	0	[a]	00 / 60
34	1	2.38	0.122	1	2.28	0.130	30 / 30
35	0	0	[a]	0	0	[a]	30 / 30
36	0	0	[a]	0	0	[a]	30 / 30
37	0	0	[a]	0	0	[a]	30 / 30
38	0	0	[a]	0	0	[a]	30 / 30
39	0	0	[a]	0	0	[a]	30 / 30
40	0	0	[a]	0	0	[a]	30 / 30

[a] - All fish arrived on the same day at this detection array.
** - Problems with equipment on these dates prevented data collection.

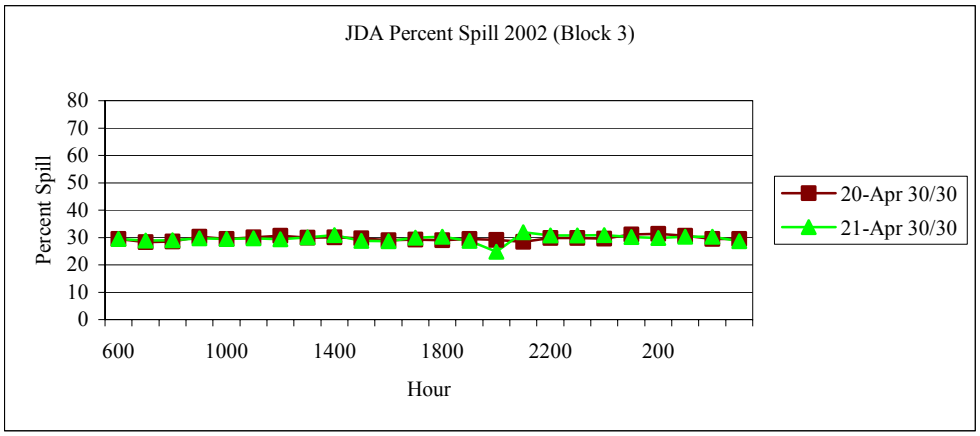
Table A3.8. Chi-square tests for homogeneity of arrival times of juvenile steelhead trout released from John Day Dam spillway and John Day Dam tailrace and detected at the radio telemetry arrays at river kilometers 308, 286, and 267, 2002.

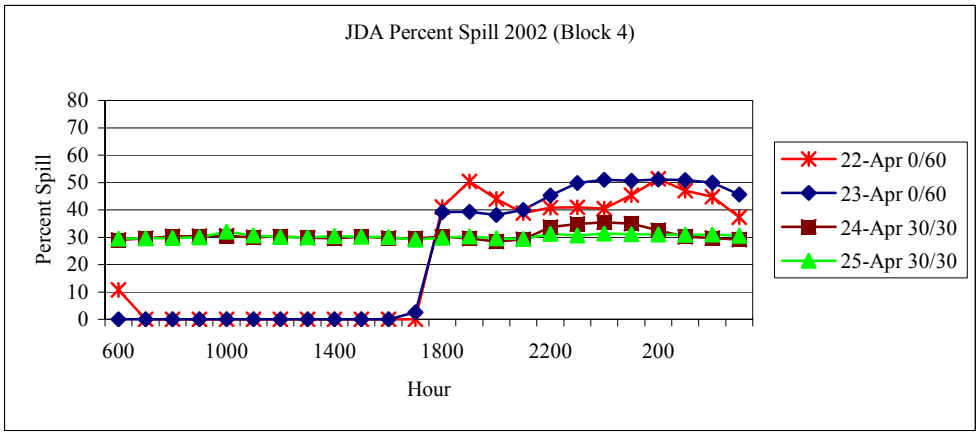
	River Kilometer 308			River kilometer 286			River Kilometer 264			% Spill
Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P	Day / Night
1	2	0.74	0.687	2	2.48	0.288	2	2.27	0.320	30 / 30
2	1	2.61	0.106	2	2.96	0.227	2	2.17	0.336	30 / 30
3	1	1.08	0.296	3	3.04	0.385	3	3.04	0.385	30 / 30
4	0	0	[a]	2	2.00	0.366	1	0.48	0.485	00 / 60
5	1	1.08	0.296	1	1.66	0.197	1	1.25	0.262	00 / 60
6	1	0.96	0.324	1	0.14	0.702	1	1.58	0.207	30 / 30
7	0	0	[a]	2	1.11	0.573	2	2.43	0.296	30 / 30
8	1	0.72	0.395	2	2.22	0.329	2	2.04	0.360	30 / 30
9	1	0.87	0.349	2	1.35	0.508	2	1.37	0.503	30 / 30
10	0	0	[a]	2	1.76	0.414	2	1.83	0.399	00 / 60
11	1	1.23	0.266	0	0	[a]	1	1.17	0.278	00 / 60
12	2	2.51	0.283	3	3.87	0.275	3	2.00	0.570	00 / 60
13	0	0	[a]	0	0	[a]	0	0	[a]	00 / 60
14	2	2.00	0.366	2	3.52	0.171	4	5.24	0.262	30 / 30
15	0	0	[a]	1	1.74	0.186	1	0.74	0.387	30 / 30
16	2	5.21	0.073	3	4.04	0.256	3	5.34	0.148	30 / 30
17	1	0.80	0.370	2	2.23	0.327	2	2.04	0.360	00 / 60
18	1	0.25	0.614	1	0.23	0.625	1	0.37	0.539	00 / 60
19	1	1.14	0.283	3	2.04	0.563	2	0.97	0.615	00 / 60
20	0	0	[a]	1	0.49	0.480	1	0.40	0.523	30 / 30
21	0	0	[a]	1	0.63	0.426	1	0.72	0.394	30 / 30
22	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
23	1	2.23	0.135	1	0.44	0.505	1	0.29	0.584	30 / 30
24	1	1.76	0.183	1	0.55	0.455	1	0.11	0.732	30 / 30
25	1	0.91	0.338	2	1.24	0.536	1	0.17	0.674	00 / 60
26	3	2.28	0.515	2	1.34	0.511	2	2.64	0.267	00 / 60
27	1	0.91	0.339	2	1.86	0.393	1	0.96	0.326	00 / 60
28	1	1.21	0.270	1	1.14	0.285	1	0.39	0.531	00 / 60
29	1	0.25	0.614	1	0.64	0.421	1	1.40	0.236	30 / 30
30	0	0	[a]	2	1.34	0.510	2	1.05	0.591	30 / 30
31	1	2.39	0.122	1	2.16	0.141	1	0.82	0.362	30 / 30
32	2	2.14	0.342	2	1.05	0.589	1	0.64	0.422	00 / 60
33	1	1.10	0.292	0	0	[a]	0	0	[a]	00 / 60
34	1	2.21	0.136	1	0.57	0.449	1	0.44	0.505	30 / 30
35	0	0	[a]	0	0	[a]	0	0	[a]	30 / 30
36	1	0.51	0.472	0	0	[a]	0	0	[a]	30 / 30
37	1	1.73	0.187	0	0	[a]	0	0	[a]	30 / 30
38	0	0	[a]				0	0	[a]	30 / 30
39	0	0	[a]				1	0.67	0.411	30 / 30
40	0	0	[a]					0	[a]	30 / 30

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

Appendix 4: Percent spill at John Day Dam

(These data were provided by Dan Feil, ACOE, Portland District)





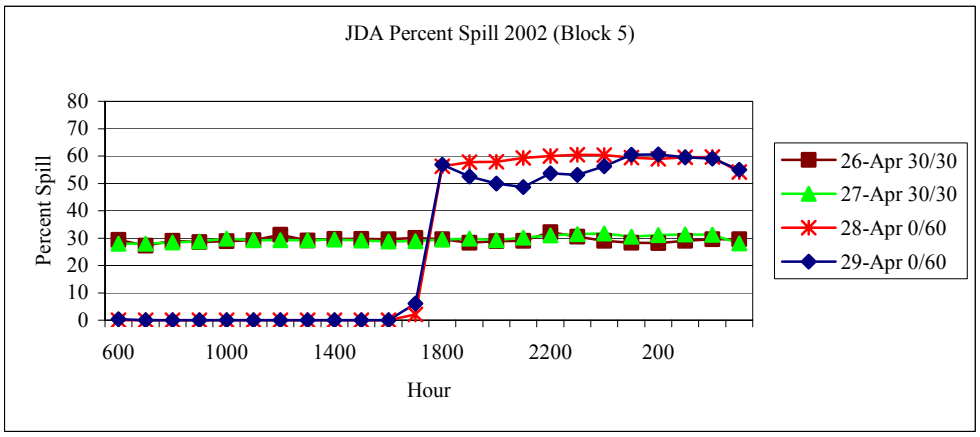
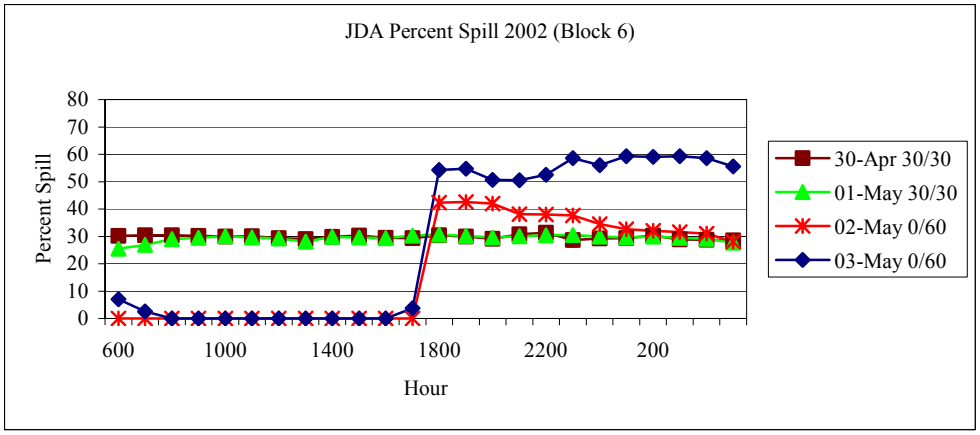
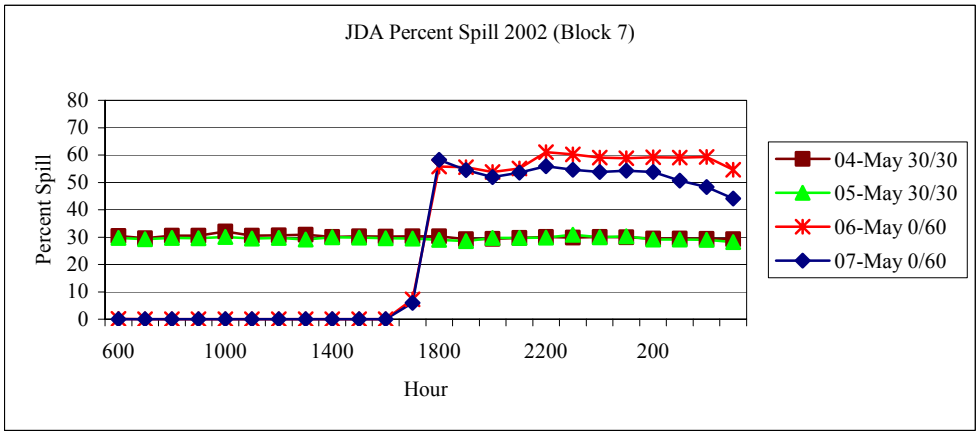


Figure A4.1. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 20 April to 29 April, 2002.





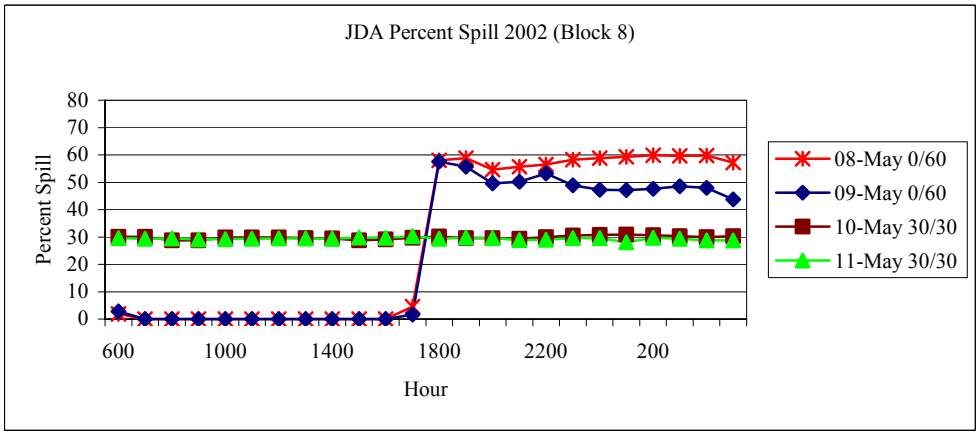
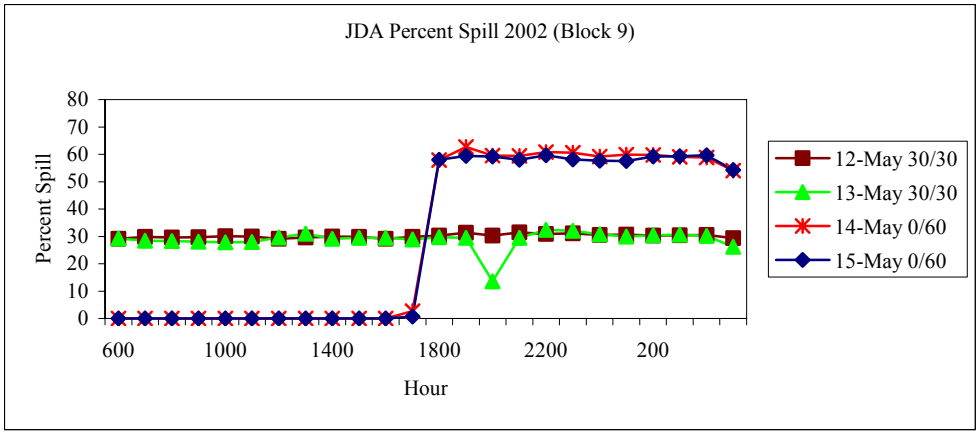
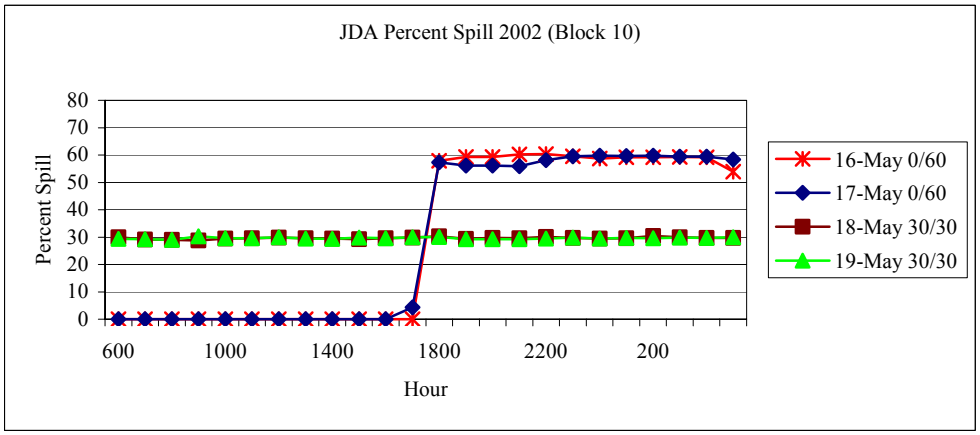


Figure A4.2. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 30 April to 11 May, 2002.





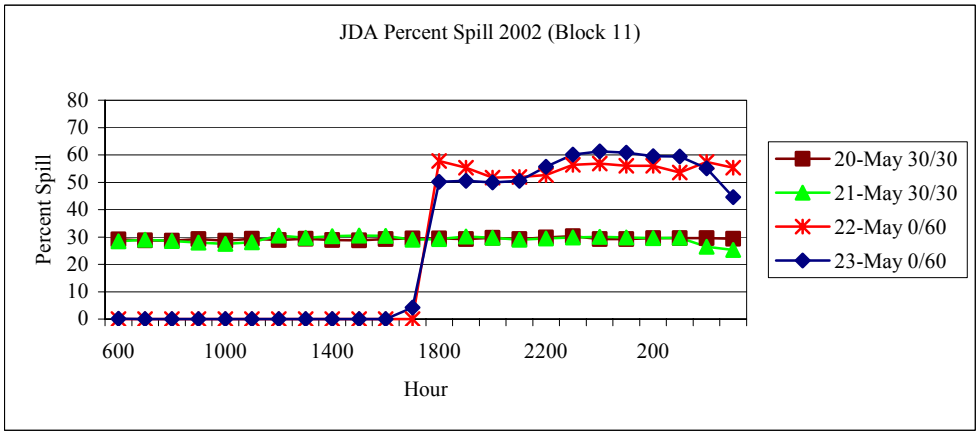
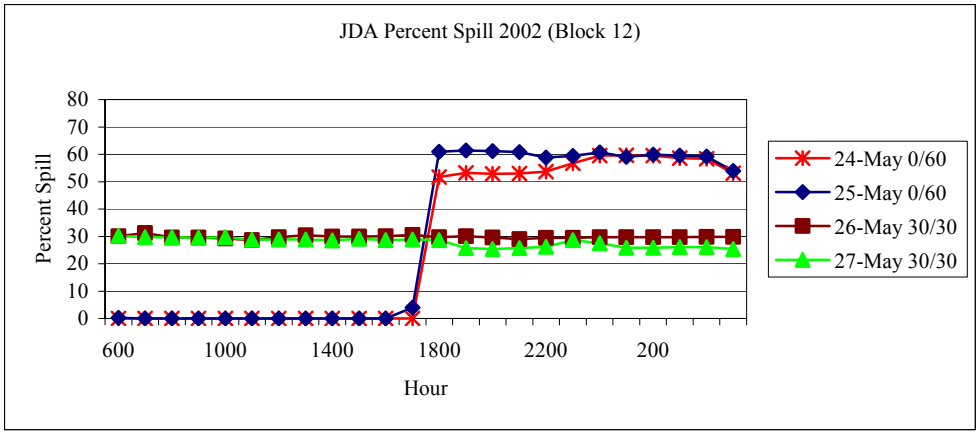
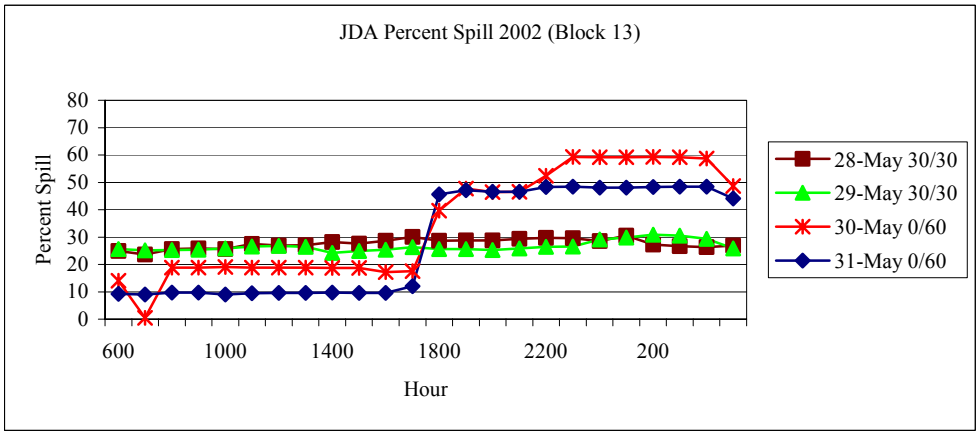


Figure A4.3. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 12 May to 23 May, 2002.





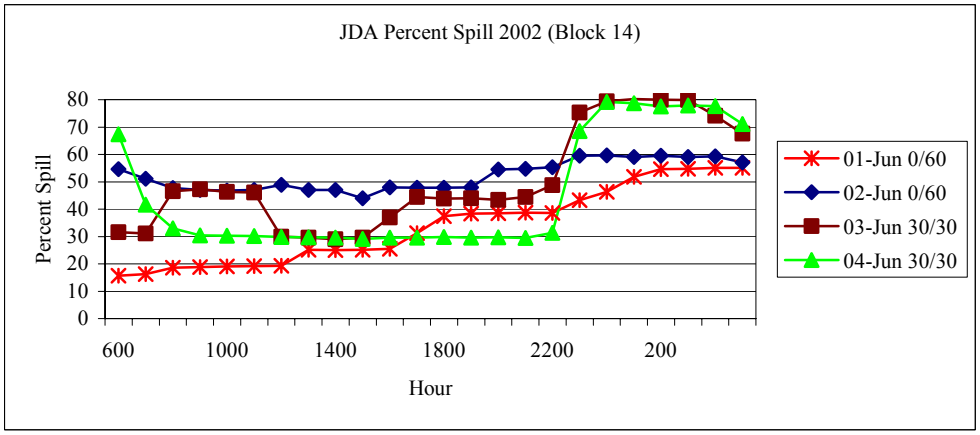


Figure A4.4. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 24 May to 04 June, 2002.

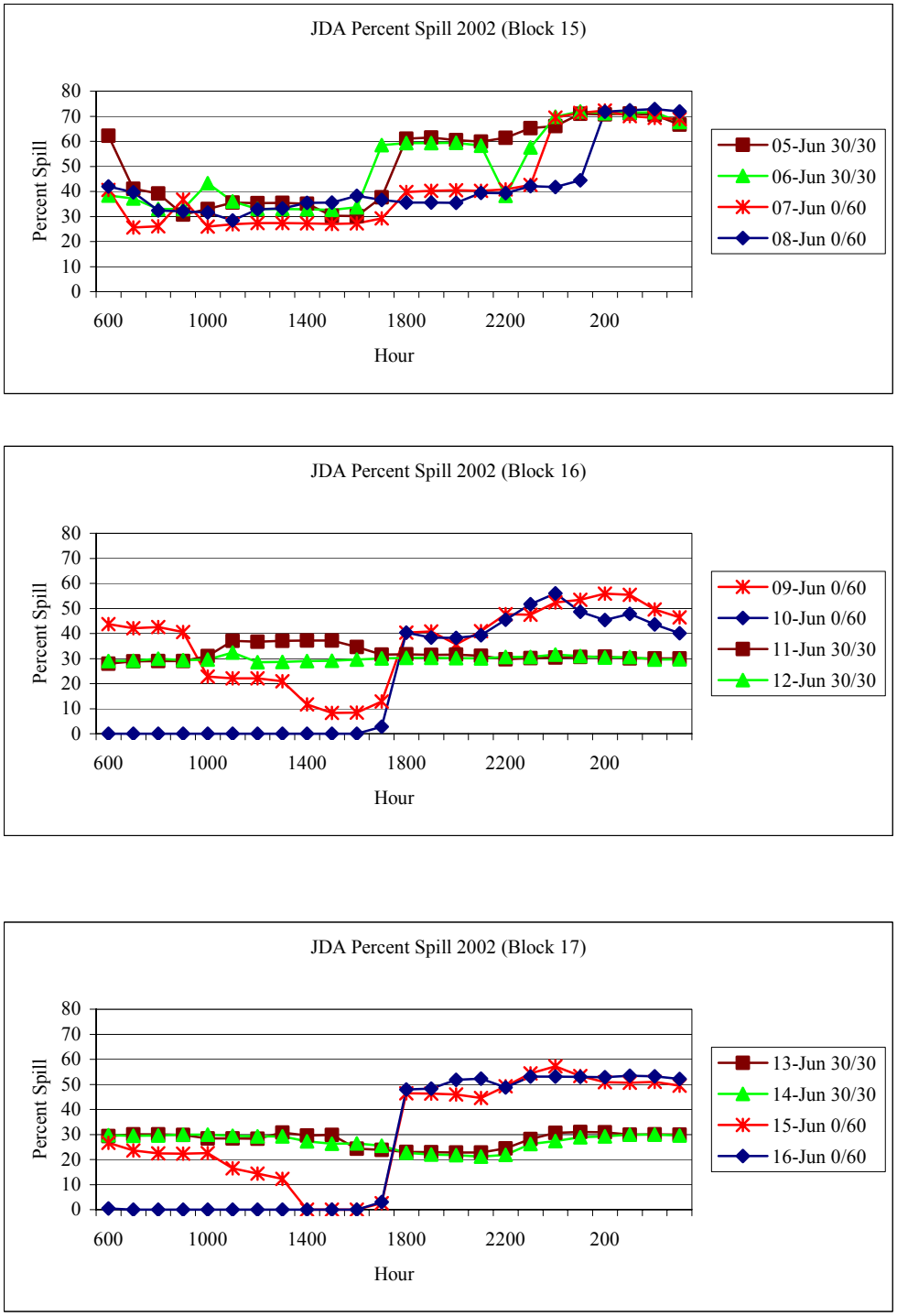
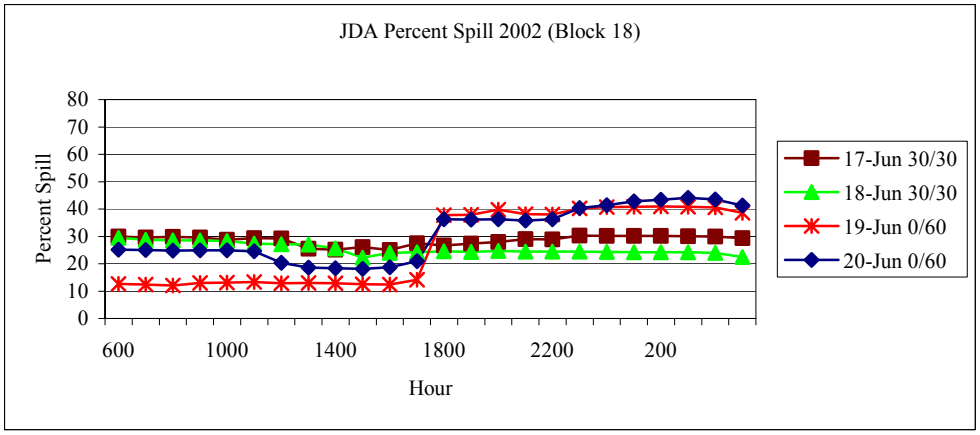
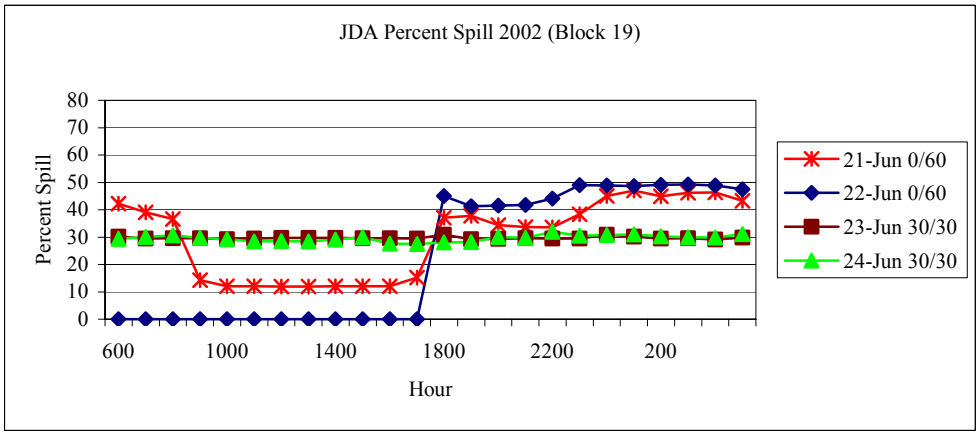


Figure A4.5. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 05 June to 16 June, 2002.





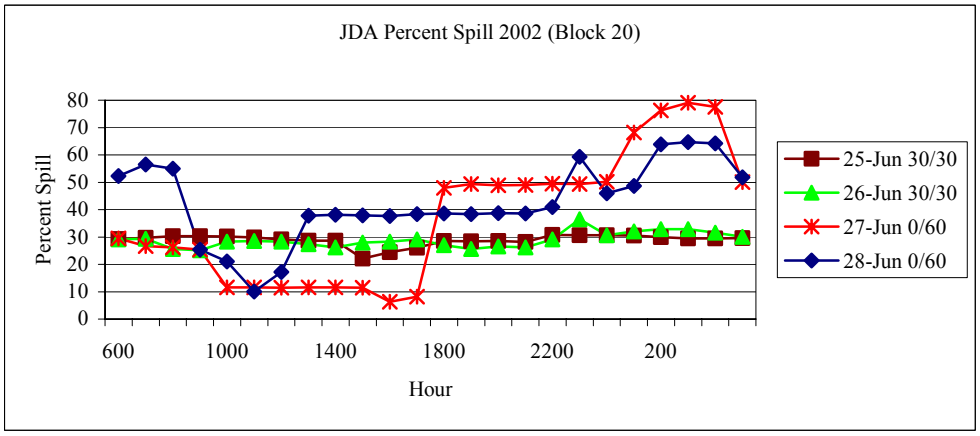
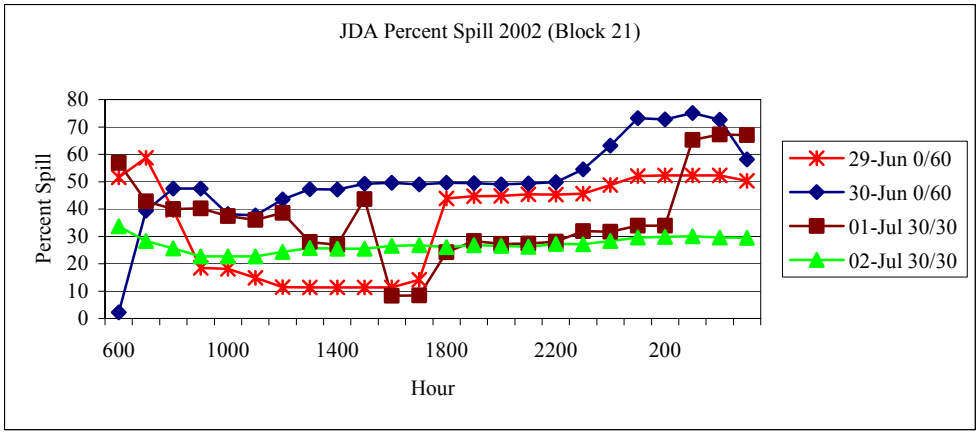
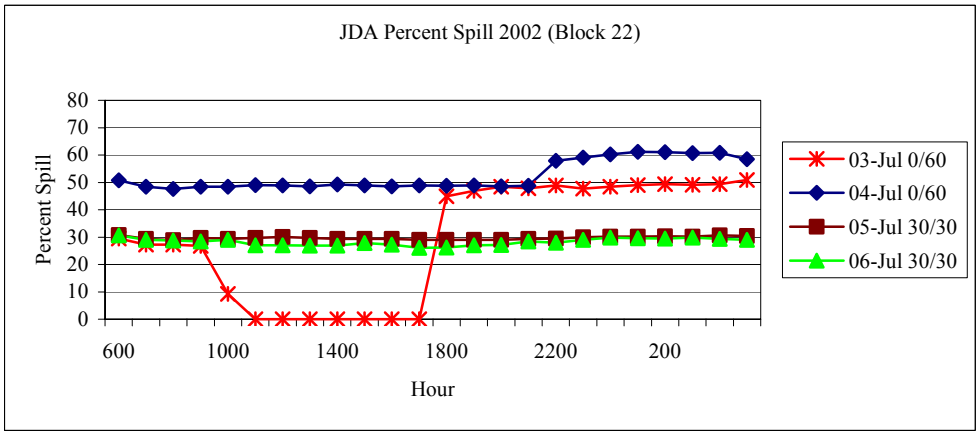


Figure A4.6. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 17 June to 28 June, 2002.





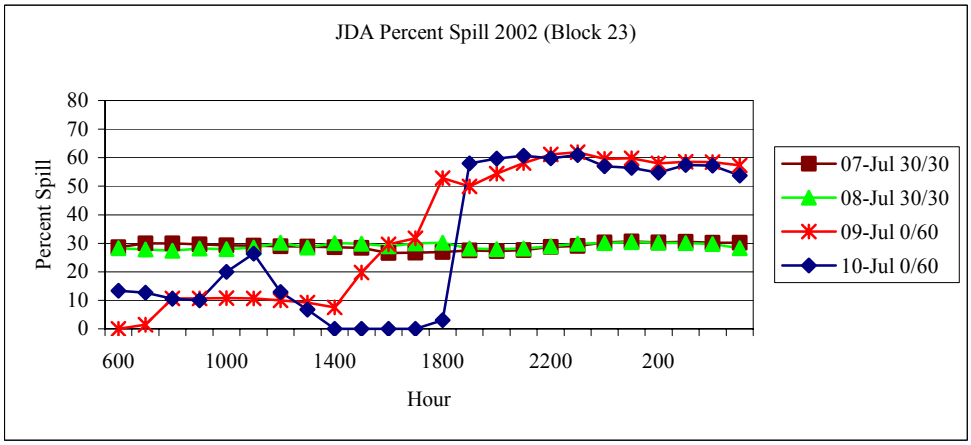


Figure A4.7. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 29 June to 10 July, 2002.

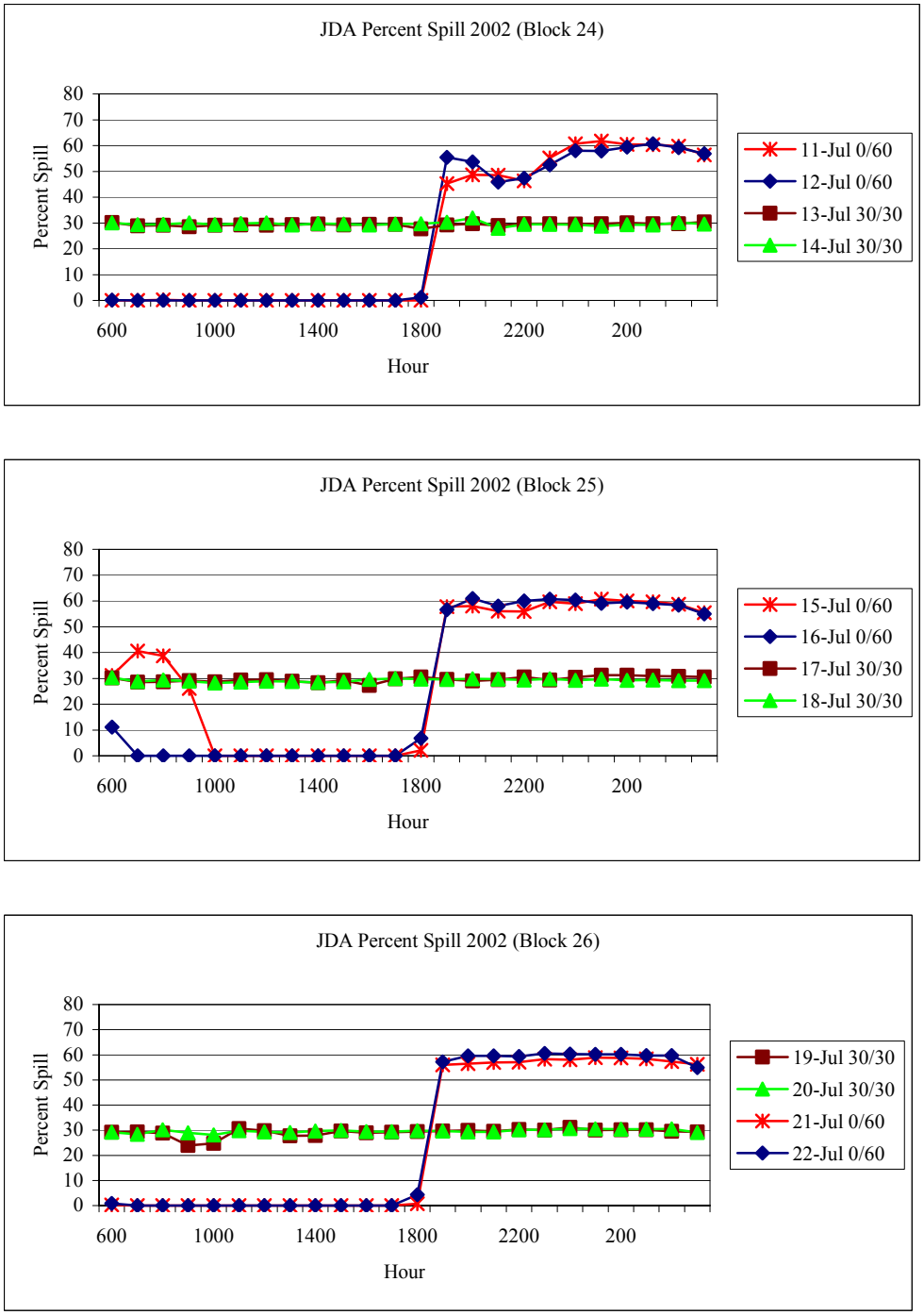


Figure A4.8. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 11 July to 22 July, 2002.

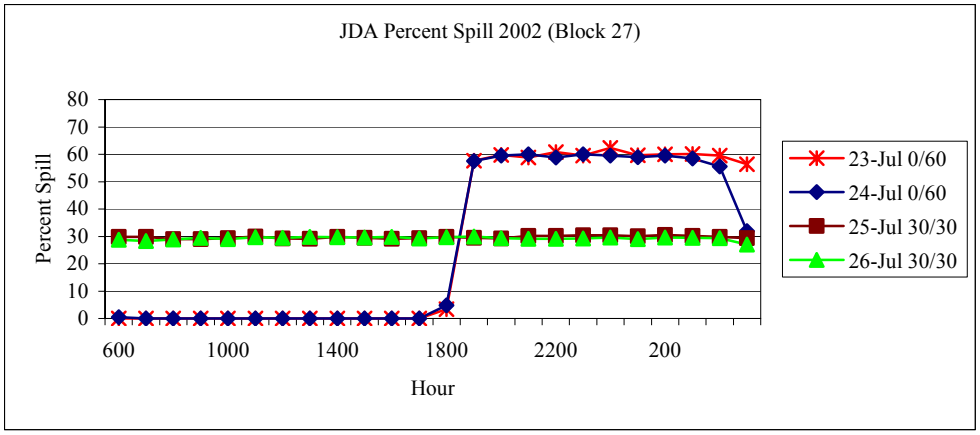


Figure A4.9. Mean hourly percent of total river discharge that passed over the spillway at John Day Dam from 23 July to 26 July, 2002.