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Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival at John Day Dam with Emphasis on the Prototype Surface Flow Outlet, 2008

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FINAL REPORT

December 2009

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Preface

The study reported herein was funded as part of the Anadromous Fish Evaluation Program, which is managed by the U.S. Army Corps of Engineers (USACE). The Anadromous Fish Evaluation Program study code is SPE-P-08-03: Studies of Surface Spill at John Day Dam. The study was led by the Pacific Northwest National Laboratory (PNNL) for the USACE Portland District. The USACE technical leads were Robert Wertheimer and Brad Eppard. The PNNL study project manager was Mark Weiland (509 427-5923). The data are archived at PNNL offices in North Bonneville, Washington.

Executive Summary

Improving survival rates of juvenile salmonids through the Federal Columbia River Power System (FCRPS) continues to be a high priority for the U.S. Army Corps of Engineers, Portland District. Many of these fish are from populations listed as threatened or endangered under the Endangered Species Act of 1973. Increased survival rates are necessary to meet performance standards set forth in the 2008 Biological Opinion (BiOp) on FCRPS operations. The BiOp mandates 96% and 93% survival rates be achieved for spring and summer downstream migrating juvenile salmonids, respectively. At John Day Dam, the Portland District is evaluating the provision of surface flow outlets (SFOs) as a means to increase fish-passage efficiency and in turn increase passage survival rates by reducing turbine passage of juvenile salmonids. The goal of the study reported herein is to provide the passage and survival data necessary to evaluate the performance of the prototype SFO and the dam as a whole relative to the standards in the BiOp. The study was conducted by the Pacific Northwest National Laboratory and the University of Washington. The Portland District and regional fisheries managers will use the data to adaptively manage the configuration and operation of John Day Dam to maximize the survival rates of juvenile salmonids.

Objectives

In this report, we present survival estimates, passage efficiencies, and fish behavior data for acoustic-tagged steelhead (STH), yearling Chinook salmon (YC), and subyearling Chinook salmon (SYC) passing through John Day Dam during 2008. We examined the data relative to two spill treatments, 30% versus 40% spill out of total water discharge through the dam, to assess the performance of SFOs, called top-spill weirs (TSWs). The field study period was from April 29 to August 20, 2008. The objectives were as follows:

- Survival Rates
  - Estimate single- and paired-release, route-specific, dam-passage, and concrete-passage survival rates for YC, STH, and SYC passing through John Day Dam for each of two spillway operational treatments.
- Fish Passage
  - Estimate passage proportions among major passage routes, and calculate efficiency and effectiveness metrics for each of two spillway operational treatments for YC, STH, and SYC separately.
  - Estimate travel times (forebay residence and tailrace egress) of YC, STH, and SYC for each of two spill treatments.
- Fish Behavior
  - Characterize fish behaviors, including forebay approach paths, for YC, STH, and SYC and compare approach paths with the final route of passage for each of two spill treatments.
  - Describe vertical and horizontal distributions and residence times of YC, STH, and SYC within the dam forebay.

The study area included 187 river kilometers (rkm) of the Columbia River from Arlington, Oregon (rkm 390), 41.4 km upstream of John Day Dam, to Lady Island (rkm 192) near Camas, Washington. John Day Dam is located at rkm 348.6 and consists of a powerhouse with 16 turbine units, 4 skeleton bays, and a 20-bay spillway. The prototype TSWs were installed at spill bays 15 and 16.

Methods

This study used the Juvenile Salmon Acoustic Telemetry System (JSATS). We surgically implanted acoustic tags and passive integrated transponder tags in 3447 YC and 3450 STH in spring and in 5931 SYC in summer. Median lengths of tagged fish were as follows: YC = 158 mm; STH = 217 mm; SYC = 117 mm.

Tagged YC and STH were released daily over a 29-day spring period (5/1 to 5/29) at Arlington, Oregon (at 0600, 1200, and 1800 hours) and in the John Day Dam tailrace (at 0100, 1300, and 1900 hours). Similarly, acoustic-tagged SYC were released in summer over a 29-day period (June 15 to July) in three release groups at Arlington, Oregon (at 0600, 1200, and 2100 hours) and in the John Day Dam tailrace (at 0100, 1300, and 1900 hours). To receive signals from tagged fish, we deployed shallow and deep JSATS cabled hydrophones on the upstream face of John Day Dam. We also deployed and maintained autonomous node arrays at six river cross sections including 2 km upstream of John Day Dam, 9.4 km downstream of John Day Dam, 2 km upstream of The Dalles Dam spillway, 2 km upstream of the Bonneville Dam Second Powerhouse, Reed Island in the Bonneville Dam tailwater, and Lady Island downstream near Camas, Washington.

Using tagged fish regrouped at the John Day Dam-face array and released in the John Day Dam tailrace, paired release-recapture methods were applied to estimate the concrete-passage survival rate for each fish stock. The detection arrays at The Dalles Dam forebay, the Bonneville Dam forebay, and Reed Island provided eight possible capture histories for each release group. When detection counts associated with sequences of detection probabilities for the three downstream arrays were homogeneous over time, fish composing virtual releases were pooled for the entire season, but this was rare. Most of the time counts for the eight possible capture histories were heterogeneous and the number of fish in individual virtual releases was used to calculate a weighted mean survival rate for each season. Separate concrete-passage survival estimates were made for YC released at Arlington, Oregon, and downstream of Lower Granite Dam in spring. We also made single-release dam-passage survival estimates for STH and YC passing The Dalles Dam in spring and single and paired-release estimates of The Dalles Dam-passage survival rate for SYC in summer. To derive tag-life corrections for the John Day Dam concrete-passage survival estimates and The Dalles Dam-passage survival estimates, we conducted a tag-life study using 50 three-second tags randomly sampled from the same lots of tags that were surgically implanted in fish for the study. The fraction of transmitting tags remaining was plotted against days since tag activation and the Kaplan-Meier estimator of tag survival rate was used to derived tag-life corrections. We did not make tag-life corrections for comparing survival rates among spill conditions or day and night periods. Testable assumptions of the survival models were evaluated using established techniques.

Fish passage and behavior at John Day Dam relative to the TSW and spill treatments were investigated using detections at dam-face and forebay hydrophones and acoustic tracking. Acoustic tracking is a common technique in bioacoustics based on time-of-arrival-differences from different hydrophones. Typically, tracking requires a 3-hydrophone array for two-dimensional (2D) tracking and a 4-hydrophone array for 3D tracking. For this study, 3D tracking was performed.

Results

Survival Rates

For the dam as a whole, paired-release concrete-passage survival rates were highest for YC (0.957) and STH (0.986) and lowest for SYC (0.861) (Table ES.1). Single-release estimates were generally a few hundredths lower than the corresponding paired-release estimate. The highest survival rates were at the juvenile bypass system (JBS; 0.973 to 1.002). The TSW had the second highest route-specific survival rates in spring (0.961 for YC; 0.992 for STH) and summer (0.927 for SYC). The lowest survival rates were observed at the turbine route (Table ES.1). Dam-passage survival rates for each tagged stock did not differ between the two spill treatments (Table ES.2).

Table ES.1. Tag-life-corrected, paired-release estimates of concrete-passage and route-specific survival rates

	Yearling Chinook Salmon		Steelhead		Subyearling Chinook Salmon	
Route	Paired Release	1/2 95% CI	Paired Release	1/2 95% CI	Paired Release	1/2 95% CI
Concrete	0.957	0.013	0.986	0.019	0.861	0.017
Non-TSW	0.966	0.011	0.985	0.023	0.844	0.044
TSW	0.961	0.020	0.992	0.023	0.927	0.016
Turbine	0.855	0.034	0.749	0.062	0.728	0.056
JBS	0.976	0.045	1.002	0.019	0.973	0.057

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

Fish Passage

Various passage efficiencies were similar for the two spill treatments for each of the three tagged stocks (Table ES.2). Interestingly, the point estimates for TSW-passage efficiency were higher for 30% than 40% spill for all three stocks. During 2008, the TSWs passed almost 24% of the total number of acoustic-tagged YC passing through John Day Dam (Table ES.3). Combining the TSW spill bays with non-TSW spill bays resulted in over three-quarters of the YC passing through the spillway. Of the YC passing into the powerhouse, over two-thirds were diverted by the intake screens into the JBS. About 8% of total YC passage was through turbines. For steelhead at John Day Dam during 2008, the TSWs passed almost 50% of the total number of acoustic-tagged STH passing the dam (Table ES.3). Combining the TSW spill bays with non-TSW spill bays resulted in over three-quarters of the STH passing through the spillway. Of the STH passing into the powerhouse, about 89% were diverted by the intake screens into the JBS. About 3% of total STH passage was through turbines. Passage data for acoustic-tagged subyearling Chinook salmon at John Day Dam show that the TSWs passed about 20% of the total number of SYC passing the dam (Table ES.3). Combining the TSW spill bays with non-TSW spill bays resulted in about 69% of the SYC passing through the spillway. Of the SYC passing into the powerhouse, almost half were diverted by the intake screens into the JBS. About 17% of total SYC passage was through turbines.

Table ES.2. Estimates of dam-passage survival rates and passage efficiencies by spill condition.[a] Confidence intervals are provided in corresponding tables in the main body of the report and in all instances overlapped with those of the alternative spill condition. These estimates were not corrected for tag life, because tag-life bias was small and common to both spill conditions.

	Yearling Chinook Salmon		Steelhead		Subyearling Chinook Salmon	
Metric	30%	40%	30%	40%	30%	40%
Dam-Passage Survival	0.955	0.956	0.991	0.972	0.852	0.866
FPE	0.929	0.911	0.974	0.967	0.820	0.844
SE	0.759	0.768	0.758	0.724	0.657	0.711
FGE	0.704	0.615	0.894	0.881	0.476	0.462
TSWE	0.250	0.213	0.538	0.439	0.214	0.208

(a) During spring, spill treatment conditions were met for most of Blocks 1 through 3 but not for large parts of Blocks 4 through 7. During summer, treatment conditions were not met for Blocks 1 through 4, but were met for most of Blocks 5 through 7. Blocks were 4 days long. As a result, post-hoc spill conditions were identified: fish passage when spill was <35% was designated as a 30% spill condition and spill between 35 and 45 was designated as a 40% spill condition.

FGE = fish-guidance efficiency.
FPE = fish-passage efficiency.
SE = spillway-passage efficiency.
TSWE = top spillway weir passage efficiency.

Table ES.3. Summary of passage efficiency and effectiveness data. Confidence intervals are provided in corresponding tables in the main body of the report.

Metric	Yearling Chinook Salmon	Steelhead	Subyearling Chinook Salmon
Fish-Passage Efficiency	0.921	0.972	0.833
Spillway-Passage Efficiency	0.762	0.744	0.686
Fish-Guidance Efficiency	0.669	0.889	0.468
TSW-Passage Efficiency	0.236	0.496	0.206
JBS-Passage Efficiency	0.159	0.227	0.147
Spillway-Passage Effectiveness	2.32	2.25	1.94
TSW-Passage Effectiveness	3.41	7.21	3.14

JBS = juvenile bypass system.
TSW = top-spill weir.

Travel time from the Arlington release location to the John Day Dam forebay was about 1 day for each tagged stock. YC and SYC spent about 2 to 3 hours in the forebay before passing the dam, whereas STH residence time was 3 to 6 hours depending on passage route. Durations between passage time and exit at the egress array were about 1.5 hours for the three stocks. The ~1.5-hour egress time did not differ much between the 30% and 40% spill treatments, except turbine-passed STH had a 2.2-hour egress time during the 40% spill treatment. Travel times from the John Day Dam egress array to the forebay array at

The Dalles Dam were 7 to 11 hours depending on stock. Travel times from The Dalles Dam forebay to the Bonneville Dam forebay were shortest for STH (22 hours), followed by YC (24.4 hours), then SYC (30 hours).

Fish Behavior

To investigate fish behavior, fish detections were classified into "arrival blocks" based on forebay array data and "passage blocks" based on dam-face array data. The blocks corresponded to areas of the dam, moving from south to north: powerhouse turbine units 1–8, units 9–16, skeleton bays 17–20, spill bays 17-20, TSW bays 15–16, and spill bays 1−14. Skeleton bays were included in arrival blocks but not in passage blocks because fish could not pass there. The data generally show that at least half of the tagged fish arriving upstream of the turbine units and skeleton bays moved north to ultimately pass at the spillway, including the TSWs. This pattern was strongest for STH and weakest for SYC. Tagged fish arriving upstream of the spillway, however, did not tend to move south toward the powerhouse.

Specifically, of the YC detected arriving in the entire forebay, about 45% and 16% approached the powerhouse upstream of turbine units 1−16 and the skeleton bays, respectively (Figure ES.1a). Arrivals at the spillway involved about 12% upstream of spill bays 17−20, the area between the skeleton bays and the TSWs, 5% at the TSWs, and 22% at spill bays 1−14. However, almost 60% of the YC that arrived at the powerhouse moved north and passed at the spillway, mostly at spill bays 17-20 and the TSWs. On the contrary, few YC arriving at the spillway moved south and passed at the powerhouse. YC approaching at the spillway usually passed at the spillway.

For acoustic-tagged STH detected arriving in the forebay, about 52% and 12% approached the powerhouse upstream of turbine units 1−16 and the skeleton bays, respectively (Figure ES.1b). Arrivals at the spillway included about 9% at spill bays 17−20, 4% at the TSWs, and 23% at spill bays 1−14. Importantly, almost 66% of the STH that arrived at the powerhouse moved north and passed at the spillway, mostly at the TSWs. Again, few STH arriving at the spillway moved south and passed at the powerhouse. As with YC, STH approaching at the spillway typically passed at spill bays 1−14 or the TSWs. Overall, a noticeable portion of STH moved toward the TSWs regardless of arrival block.

About 60% of the total number of tagged SYC detected in the forebay arrived upstream of the powerhouse turbine units and the skeleton bays (Figure ES.1c). About half of these fish moved north to ultimately pass at the spillway, mostly at spill bays 17−20 and the TSWs. Of the 25% of total SYC arrivals at units 9−16, over half passed there or at units 1−8 and did not apparently move north toward the spillway. The SYC arriving at the spillway tended to pass there.

Detailed horizontal distribution data on fish passage into the dam support the behavioral trends described above for fish movements in the forebay, i.e., horizontal distributions were highly skewed toward the TSWs and spill bays 17−20 for all three tagged stocks. Horizontal distributions were relatively uniform elsewhere at the dam. Fish passage was not proportional to discharge when the powerhouse and spillway were compared. Discharge proportions were higher and passage proportions lower at the powerhouse than they were at the spillway, and fish passage per unit discharge was by far highest at the TSW spill bays.

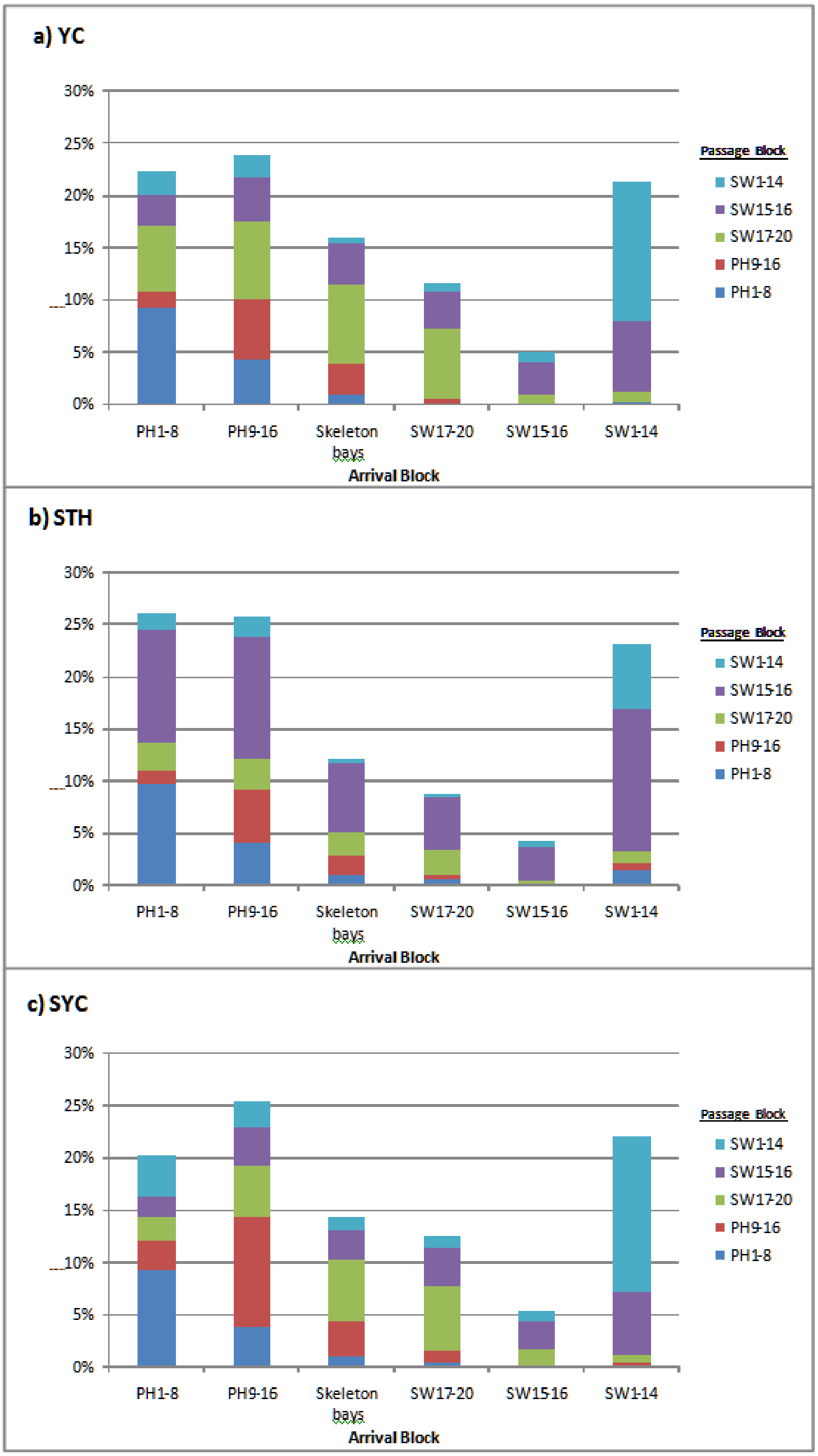

Figure ES.1. Fish behavior patterns – relationships between where fish arrived in the forebay (arrival block) and where they ultimately passed the dam (passage block) by tagged stock: a) YC; b) STH; and c) SYC. The blocks are areas at the dam: powerhouse turbine units 1−8; units 9−16, skeleton bay 17−20; spill bays 17−20, TSW bays 15−16, and spill bays 1−14.

Vertical distribution data were based on 3D tracking of individual acoustic-tagged fish in the John Day Dam forebay. As smolts moved from 75 m to within 10 m of the powerhouse face, travel depths often decreased, but there was a sudden increase to over 20 m at a distance of less than 5 m from the powerhouse. Note that powerhouse piers on which hydrophones were mounted do not extend more than about 1 m upstream of the powerhouse face so that sounding fish within 5 m of the dam face can be tracked moving down toward intake openings. The turbine intake ceilings at John Day Dam are about 20 m deep. At the spillway, detection depths were less than 5 m regardless of distance upstream from the face of the spillway. There was no difference in diel vertical distributions for powerhouse or spillway passed YC. For STH, vertical distribution was shallow for fish passed through the spillway; this pattern was quite evident at the TSW. The last-detection depths at the powerhouse were much deeper. Most SYC in the forebay of the powerhouse and skeleton bays traveled at depths between 5 and 11 m, while median depths of smolts within 5 m of the powerhouse or skeleton bays were between 20 and 25 m. As with YC and STH, the last-detection depths for SYC were relatively shallow at the spillway. Notably, as SYC approached the TSW, they migrated up in the water column; this trend was not evident for approach at non-TSW spill bays. Fish approaching spill gates were not detected diving to pass under conventional tainter gates because hydrophones were mounted on the upstream face of piers about 10 m upstream of the gates. Sounding to pass under tainter gates likely occurs between piers where fish could not be detected.

Conclusions

During the 2008 evaluation of juvenile salmonids at John Day Dam, the JSATS provided reliable data about survival rates, fish passage, and fish behavior.

Tag-life-corrected paired-release estimates of concrete-passage survival rates for YC (0.957 ± 0.013 [1/2 95% confidence level (CI)]) and STH [0.986 ± 0.019 (1/2 95% CI] were high and close to the 96% performance standard set forth in the 2008 BiOp. Similar estimates for SYC, however, were about 86%, which would be 7% below the BiOp standard of 93%. The highest route-specific survival rates were for the JBS and TSW (~97%); fish passing through turbines had the lowest survival rates (73% to 86%).

Fish passage metrics were generally highest for STH and lowest for SYC. Proportionately more SYC than YC or STH passed through the dam via turbines.

The comparison of 30% versus 40% post-hoc spill conditions was inconsequential. Stock-specific survival estimates, passage efficiencies, and fish behaviors were similar between the two spill conditions. The increase in spill discharge from 30% to 40% of total water discharge through the dam basically served to pass incrementally more fish at non-TSW bays and incrementally fewer at the TSWs. Spillway-passage effectiveness was significantly higher at 30% spill than it was at 40% spill for STH smolts (one tailed $P = 0.0293$) and for SYC smolts ($P = 0.0020$).

Spill and TSW operations attracted downstream migrant juvenile salmonids. About half of the tagged fish arriving in the forebay of the powerhouse and skeleton bays moved toward and passed at the spillway including the TSWs. In contrast, few smolts approaching the spillway passed at the powerhouse, and fish approaching the spillway had the shortest median residence time. The longest residence time was for fish approaching the powerhouse and then passing at the spillway or vice versa.

Tagged fish were surface-oriented, being distributed in the upper portion of the water column on approach to the dam. The median depths of smolts last detected within 5 m of the powerhouse ranged from 21 to 24 m depending on the stock of fish, and turbine-passed fish had median depths that were about 5 m deeper than the median depth of JBS-passed fish. Most fish approaching the spillway piers were high in the water column.

The prototype TSWs performed well. Using about 20 kcfs, the TSW bays passed half of the STH, a quarter of the YC, and a fifth of the SYC of the respective total number of fishes passing John Day Dam. As was the intent of the design, the TSW surface flows appeared to attract, or at the least provide a surface outlet opportunity for, fish that had originally arrived at the dam in the powerhouse forebay. Passage at the TSW bays was much higher during the day than it was at night, which is consistent with observations at many other surface flow outlets (Johnson and Dauble 2006; Sweeney et al. 2007).

Acknowledgments

Many people made valuable contributions to this study and deserve acknowledgment. The Pacific States Marine Fisheries Commission Supervisor at the John Day Dam Smolt Monitoring Facility (SMF), Greg Kovalchuk, was very helpful in coordinating fish collections with daily fish sampling at the respective locations. Seasonal staff of the Pacific States Marine Fisheries Commission also helped with tagging fish: Laura Daniel, Steve Goss, Kenneth Kenny, John Mathieus, and Randy Wall. Karah Prather with Cascade Aquatics helped as well.

Many PNNL staff assisted in study project management (Geoff McMichael), surgery training (Rich Brown and Kate Deters), fish collection (Robin Durham), fish transport and release, tag-life monitoring (Rich Brown and Kathleen Carter), Juvenile Salmon Acoustic Telemetry System (JSATS) development (Eric Choi, Brian LaMarche, Daniel Deng, Tao Fu, Thomas Seim, and Thomas Carlson), and database entry and management (Jessica Carter). Dr. Kenneth Ham developed filters for autonomous node data. Dr. David Geist was the Ecology Group Manager at PNNL, and Dr. Dennis Dauble was the line Manager during this study.

Advanced Telemetry Systems (ATS), Inc. manufactured the JSATS acoustic tags. Autonomous and dam-mounted hydrophones were manufactured by Sonic Concepts, Seattle, Washington. Precision Acoustic Systems, also in Seattle, made the quad channel receivers and conducted node acceptance tests for PNNL. Cascade Aquatics, Inc. in Ellensburg, Washington, activated and delivered the acoustic tags. Schlosser Machine Shop fabricated anchors for autonomous nodes and frames for star clusters that were deployed in the spillway forebay.

Acronyms and Abbreviations

A1CR351	John Day Dam forebay entrance array
A2CR339	John Day Dam tailwater egress array
A3CR312	The Dalles Dam forebay entrance array; John Day Dam primary survival-detection array
A4CR236	Bonneville Dam forebay entrance array; John Day Dam secondary survival-detection array; The Dalles Dam primary survival-detection array
A5CR203	1st Bonneville tailwater array; John Day Dam tertiary survival-detection array; The Dalles Dam secondary survival-detection array
A6CR192	2nd Bonneville Dam tailwater survival detection array; The Dalles Dam tertiary survival-detection array
ATS	Advanced Telemetry Systems, Inc.
BiOp	Biological Opinion
°C	degree(s) Celsius or Centigrade
CF	Compact Flash (card)
cfs	cubic feet per second
CI	confidence interval (1/2 95%)
CSV	comma-separated variables
d	day(s)
DART	Data Access in Real Time
dB	decibel(s)
FCRPS	Federal Columbia River Power System
FPE	fish-passage efficiency
FGE	fish-guidance efficiency (in-turbine screens)
ft	foot/ft
g	gram(s)
GPS	global positioning system
h	hour(s)
JBS	juvenile bypass system
JBSE	juvenile bypass system-passage efficiency
JSATS	Juvenile Salmon Acoustic Telemetry System
kcfs	thousand cubic feet per second
km	kilometer
L	liters
LRT	likelihood ratio test
m	meter(s)
min	minute(s)
mL	milliliter

mm	millimeter
MSL	mean sea level
NA	not applicable
NOAA	National Oceanic and Atmospheric Administration
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
rkm	river kilometer
RMS	root mean square
s	second(s)
SAS	Statistical Analysis System
SE	spillway-passage efficiency
SEF	spillway-passage effectiveness
SFO	surface-flow outlet
SMF	Smolt Monitoring Facility (John Day Dam)
STH	steelhead
SW	spillway or spillway block
SYC	subyearling Chinook salmon
TOA	time of arrival
TOAD	time of arrival difference
TSW	top-spill weir
TSWE	top spillway weir passage efficiency
TSWEF	top spillway weir passage effectiveness
μPa	micro-Pascal
USACE	U.S. Army Corps of Engineers
UW	University of Washington
WEL	Wells Dam
YC	yearling Chinook salmon

Contents

Figures

Tables

1.0 Introduction

Improving the survival rate of juvenile salmonids migrating downstream through the Federal Columbia River Power System (FCRPS) continues to be a high priority for the U.S. Army Corps of Engineers (USACE) Portland District. Many of these fish are from populations listed as threatened or endangered under the Endangered Species Act. The increased survival rate is necessary to meet performance standards set forth in the 2008 Biological Opinion (BiOp; NMFS 2008) on operation of the FCRPS (NOAA Fisheries 2008). The BiOp mandates that 96% and 93% survival rates be achieved for spring and summer downstream-migrating juvenile salmonids, respectively. At John Day Dam, the Portland District is evaluating the provision of surface-flow outlets (SFOs) as a means to increase fish-passage efficiency and in turn increase the fish passage survival rate by reducing turbine passage of juvenile salmonids. The goal of the study reported here was to provide fish passage and survival data necessary to evaluate the performance of the prototype SFO and the dam as whole relative to the performance standards in the BiOp. The Portland District and regional fisheries managers will use the data to adaptively manage the configuration and operation of John Day Dam to maximize the survival rate for juvenile salmonids.

This is the report of research for the acoustic telemetry evaluation of juvenile salmonids during 2008 at John Day Dam (Figure 1.1). The study also provides estimates of dam-passage survival rates for The Dalles Dam. The study was conducted by the Pacific Northwest National Laboratory (PNNL) and the University of Washington (UW) for the USACE Portland District.

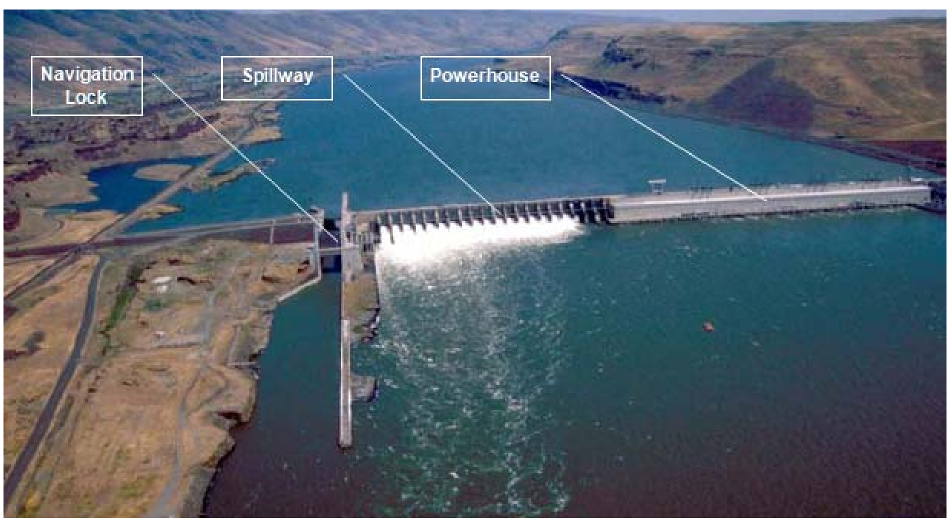

Figure 1.1. John Day Dam on the Columbia River

1.1 Previous Passage and Survival Studies

Radio telemetry was first used at John Day Dam in 1999 to estimate fish survival rates (Counihan et al. 2002a) and passage proportions for turbine, screen bypass, and spillway routes through the dam (Hansel et al. 2000). For three stocks of salmonids that have been studied, estimates of the rate of fish passage survival tend to be higher at the spillway than at the powerhouse, with whole-dam estimates in between (Table 1.1). The differences in survival rates between the powerhouse and spillway were greater for yearling Chinook salmon (YC) and subyearling Chinook salmon (SYC) than for steelhead (STH) (Table 1.1). These data indicate that the BiOp performance standard would not be met under most conditions.

Table 1.1. Radio-telemetry estimates of survival rates for three salmonid stocks passing routes at John Day Dam during 2000, 2002, and 2003. The ranges are for point estimates under different treatments.

Study Year (Passage Route)	Steelhead	Yearling Chinook	Subyearling Chinook	Reference
2000 (Dam)	90.5 to 98.8%	93.7 to 98.6%		Counihan et al. 2002b
2002 (Spillway)	93.2 to 95.8%	99.3 to 100%	98.5 to 100%	Counihan et al. 2006c
2002 (Powerhouse)	89.9 to 93.0%	77.8 to 83.2%	86.6 to 96.6%	Counihan et al. 2006c
2002 (Dam)	91.5 to 94.0%	92.9 to 96.3%	92.8 to 99.2%	Counihan et al. 2006c
2003 (Spillway)		93.4 to 93.9%	90.1 to 95.5%	Counihan et al. 2006d
2002 (Powerhouse)		76.4 to 82.0%	71.9 to 72.2%	Counihan et al. 2006d
2002 (Dam)		92.2 to 94.0%	84.5 to 88.6%	Counihan et al. 2006d

At least five studies have estimated fish-passage efficiency[1] and spill efficiency[2] at John Day Dam (Table 1.2). The radio-telemetry studies indicated that fish-passage efficiency ranged from 88% to 94% for STH, 82% to 92% for YC, and from 70% to 75% for SYC. A hydroacoustic study in 2002 estimated a similar range of fish-passage efficiency for spring stocks but the estimate for SYC (88% to 92%) was higher than the radio-telemetry estimate that year. Estimates of spill efficiency for the three fish stocks were highly variable among years (Table 1.2).

1.2 Surface-Flow Outlet Development

Sweeney et al. (2007) provides a compendium on SFO development in the Pacific Northwest. Although the Portland District's SFO program for juvenile salmonids commenced in 1994 (USACE 1995), SFO development is in its early stages at John Day Dam. To support this effort, baseline biological data on fish distributions were summarized by Giorgi and Stevenson (1995) and Anglea et al. (2001). Generally, yearling migrants approach the dam along the Washington side of the forebay, and SYC approach using migration pathways near both shorelines. Tagged fish have been observed traversing the forebay laterally before passing.

Field work on a prototype surface spill SFO was conducted in 1997 when "over/under" weirs were placed at spill bays 18 and 19 at John Day Dam. BioSonics (1999) found that passage at the prototype bays was higher during spring when the weirs were removed than when weirs were in place. During summer, passage rates between "in" and "out" treatment conditions were comparable. This study, however, was affected by very high spill through adjacent bays during a year of above-average river discharge.

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[1] Fish-passage efficiency is defined as total passage through non-turbine routes divided by total dam passage.
[2] Spillway-passage efficiency is defined as total spillway passage divided by total dam passage.

Table 1.2. Some radio-telemetry and hydroacoustic estimates of fish-passage efficiency and spillway-passage efficiency for John Day Dam. The ranges are for point estimates under different treatments.

Study Year/Type	Steelhead	Yearling Chinook	Subyearling Chinook	Reference
FPE				
1999 RT	90 to 94%	82 to 88%		Hansel et al. 2000
2000 RT	91 to 93%	90 to 92%		Beeman et al. 2003
2002 RT	88 to 91%	84 to 85%	70 to 72%	Beeman et al. 2006
2002 HA	89 to 94%		88 to 92%	Moursund et al. 2003
2003 RT		84 to 86%	71 to 75%	Hansel et al. 2004
Spill Efficiency				
1999 RT	45 to 53%	53 to 66%		Hansel et al. 2000
2000 RT	61 to 79%	75 to 86%		Beeman et al. 2003
2002 RT	54 to 64%	48 to 57%	42 to 58%	Beeman et al. 2006
2002 HA	72 to 78%		58 to 61%	Moursund et al. 2003
2003 RT		47 to 57%	48 to 62%	Hansel et al. 2004

FPE = fish-passage efficiency.
HA = hydroacoustic.
RT = radio-telemetry.

Engineering and model studies examining skeleton bays as potential SFO sites were conducted in the 1990s (Montgomery Watson et al. 2000). At a physical model at the USACE Engineering, Research, and Development Center, observations of a 20,000-cfs SFO in a skeleton bay showed strong forebay flow nets, indicating a potential for fish to discover the SFO flow. However, because of concerns about cost and tailrace egress caused by a large eddy that formed in the spillway stilling basin adjacent to the SFO outfall plume, this effort was tabled.

The Portland District identified SFO development as a major priority in the John Day Configuration and Operation Plan (USACE 2007). Accordingly, new numerical and physical model investigations and engineering design work were undertaken to develop a prototype SFO for John Day Dam. In winter 2007/2008, the Portland District installed prototype SFOs, called top-spill weirs (TSWs), at spill bays 15 and 16. A bulkhead on top of the weir provided hydraulic control, creating a critical entrance flow regime. The discharge was about 10,000 cfs per bay. The weir was designed to minimize the angle of SFO jet impact on the ogee. The intent was to increase the fish-passage efficiency and passage survival rates of downstream-migrating juvenile salmonids at John Day Dam.

1.3 Research Objectives

The overall purpose of the acoustic telemetry study at John Day Dam during 2008 was to estimate fish survival rates and passage efficiencies to assess the performance of a prototype SFO composed of TSWs installed at spill bays 15 and 16. We also estimated dam-passage survival rates and fish passage proportions for each of two spill conditions (30% versus 40% spill out of all water discharged through the dam) and compared the respective estimates. Randomized block experimental designs were developed for spring and summer, and each 4-day block was supposed to have one 2-day treatment randomly selected to be 30% or 40% spill followed by the alternate treatment. The field study period was from April 29 to August 20, 2008. The five study objectives are listed below within three categories: survival rate, fish passage, and fish behavior.

- Survival Rate
  1. Estimate route-specific, dam-passage, and concrete-passage survival rates[1] for YC, STH, and SYC passing through John Day Dam for each of two spill treatments (30% or 40% spill), pooled treatments, and during day and night periods.
- Fish Passage
  2. Estimate passage proportions among major passage routes, and calculate efficiency and effectiveness metrics for each of two spillway treatments, both treatments pooled, and for day and night periods for YC, STH, and SYC.
  3. Estimate travel times (forebay residence and tailrace egress) of YC, STH, and SYC for each of two 2-day long spill treatments and both treatments pooled.
- Fish Behavior
  4. Characterize fish behaviors, including forebay approach paths, for YC, STH, and SYC and compare approach paths with the final route of passage for each of two spill treatments.
  5. Describe vertical and horizontal distributions and residence times of YC, STH, and SYC within the dam forebay during day, night, and pooled time periods.

1.4 Study Area

The area for this research study included 198 river kilometers (rkm) of the lower Columbia River from Arlington, Oregon (rkm 390), 41.4 km upstream of John Day Dam (rkm 348.6), to Lady Island (rkm 192) near Camas, Washington (Figure 1.2). John Day Dam is a single structure located at rkm 348.6; it consists of a powerhouse with 16 turbine units and 4 skeleton bays (bays where turbines were never installed) on the Oregon side and a 20-bay spillway on the Washington side (Figure 1.2).

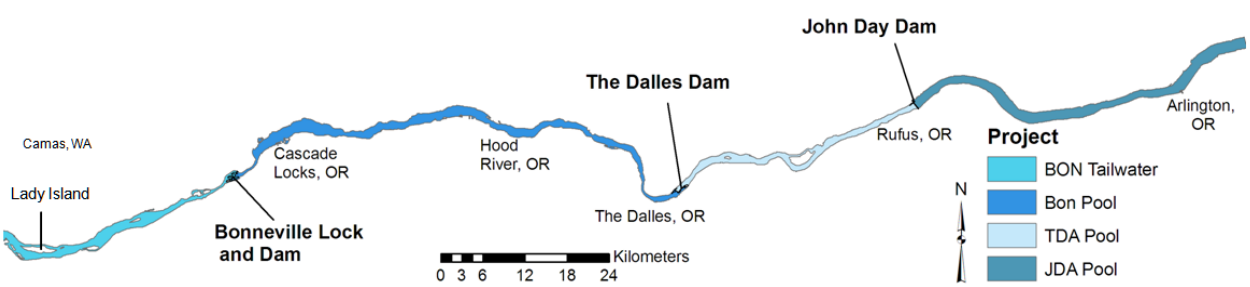

Figure 1.2. Study area on the lower Columbia River from Arlington, Oregon, to Camas, Washington

All fish implanted with acoustic tags were collected and processed in the Smolt Monitoring Facility (SMF), which is located at the downstream end of the juvenile bypass system (JBS; Figure 1.3) at John

[1] See Section 2.1.3 for definitions.

Day Dam. These fish were diverted by extended-length submersible bar screens from the upper part of the powerhouse turbines to the gatewell slots. They passed through one of two gatewell orifices into a bypass channel that runs the length of the powerhouse. The channel volume is reduced by dewatering to a volume small enough to pass through pipes to the SMF, where fish could be sampled or routed to an outfall pipe to the tailrace. Monitoring of tagged smolts was accomplished by deploying underwater listening devices at strategic locations above, on, and below John Day Dam. Throughout this report, we refer to locations on the river that are varying distances apart, so we created Table 1.3 to provide a quick reference to determine distances between locations. Distances upstream of the mouth of the Columbia River are highlighted in light yellow and columns and rows associated with dam locations are highlighted in gray.

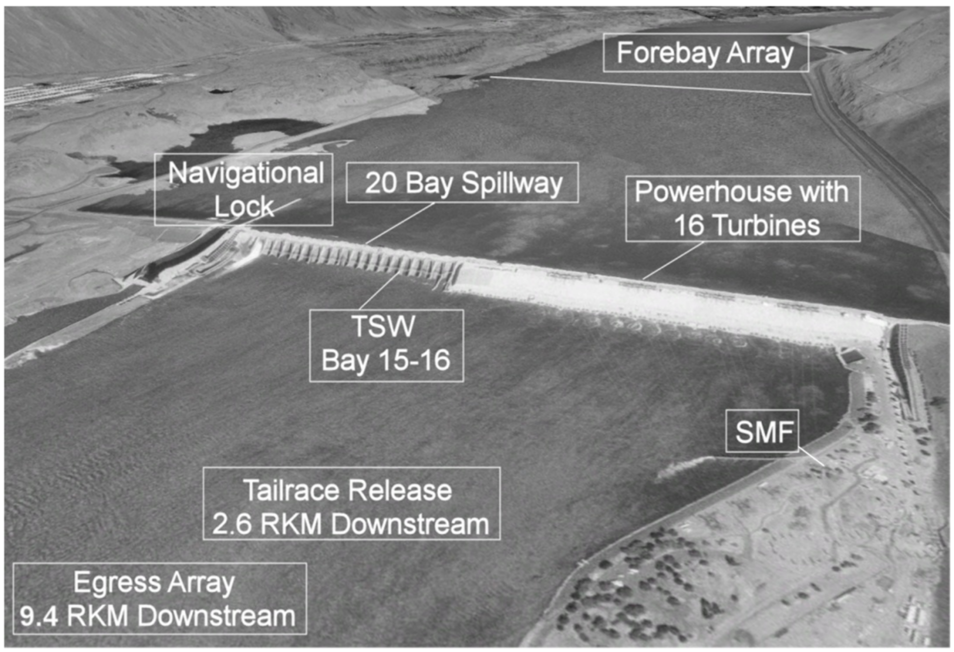

Figure 1.3. Aerial view of John Day Dam

1.5 Report Contents

The ensuing sections of this report present the materials and methods (Section 2.0), results (Section 3.0), and discussion (Section 4.0). References may be found in Section 5.0. Fourteen appendices contain tagging data tables (Appendix A); hydrophone locations (Appendix B); plots of tag life, time of arrival at survival-detection arrays, and tag-life probabilities (Appendix C); survival and detection probabilities without tag-life corrections (Appendix D); tag-life-corrected concrete-passage and route-specific survival rates for John Day Dam (Appendices E through K); tagging, release, capture histories, and dam operations data (Appendix L); Burnham Tests (Appendix M); and time-of-arrival plots to test mixing assumptions (Appendix N).

Table 1.3. Lookup table for determining distances (km) between locations referenced in this study

Location	Study Function	Km Upstream of CR Mouth	LGR	ARL	A1CR351	JDA	JDA TW	A2CR339	A3CR312	TDA	TDA TW	A4CR237	BON	A5CR203	A6CR192
			696	390	351	349	346	339	312	309	306	237	235	203	192
LGR	Release Site – Spr	696	0	306	345	347	350	357	384	387	390	459	461	493	504
ARL	Release – Spr & Sum	390		0	39	41	44	51	78	81	84	153	155	187	198
A1CR350	Survival	351			0	2	5	12	39	42	45	114	116	148	159
JDA	Effects	349				0	3	10	37	40	43	112	114	146	157
JDA TW	Release – Spr & Sum	346					0	7	34	37	40	109	111	143	154
A2CR339	Egress	339						0	27	30	33	102	104	136	147
A3CR312	Survival	312							0	3	6	75	77	109	120
TDA		309								0	3	72	74	106	117
TDA TW	Release Site -- Sum	306									0	69	71	103	114
A4CR237	Survival	237										0	2	103	114
BON	Effects	235											0	32	43
A5CR203	Survival	203												0	11
A5CR192	Survival	192													0

A1CR351 = JDA forebay entrance array; A2CR339 = JDA tailwater egress array; A3CR312 = TDA forebay entrance array and primary survival-detection array for JDA; A4CR237 = BON forebay entrance array and the secondary survival-detection array for JDA; A5CR203 = tertiary survival-detection array for JDA located in the BON tailwater near Reed Island; ARL = Arlington, Oregon; BON = Bonneville Dam; CR = Columbia River, JDA TW = John Day tailwater fish release site; LGR = Lower Granite Dam; SPR = spring; SUM = Summer; TDA TW = The Dalles Dam tailwater release site.

2.0 Materials and Methods

In this section, we describe the materials and methods used for the 2008 acoustic telemetry evaluation at John Day Dam. The primary research tool was the Juvenile Salmon Acoustic Telemetry System (JSATS).

The Portland District has been directing and funding the development of the JSATS to evaluate juvenile salmonid passage performance and survival rate. Currently, two types of JSATS receivers are used: autonomous nodes can be deployed in most environments where external power is not available, and cabled systems can be deployed were an external power source is available. The autonomous nodes are best suited for detecting tagged fish and estimating survival rate, whereas the cabled array has the advantage of precise synchronized time keeping and is well suited for two-dimensional (2D) or 3D tracking and for determining the route of passage. The JSATS technology has several advantages over previously used radio telemetry. The acoustic tag does not require an external antenna, making it less invasive to the fish than a radio transmitter. Acoustic telemetry can detect acoustic signals over a greater range and depth than radio telemetry, thereby increasing the detection area and reducing depth-related bias. When appropriate, an acoustic telemetry system can be deployed for 2D and 3D tracking that can be used to determine route of passage, forebay residence behavior, and aid in estimating route-specific survival rates.

Acoustic telemetry has been used on the lower Columbia River to describe fish passage and approach behavior at Bonneville Dam (Faber et al. 2001) and The Dalles Dam (Cash et al. 2005). The JSATS has been used in the Columbia River Estuary to estimate in-river survival rates since 2004 (McComas et al. 2004, 2005, 2006, 2007, 2008). In 2006, the JSATS receivers were deployed at various locations between John Day Dam and Camas, Washington (a 150-km reach of the river), to estimate turbine passage and tailwater survival rates at John Day Dam, and dam-passage and tailwater-passage survival rates for The Dalles Dam and Bonneville Dam (Ploskey et al. 2007). The first deployment of the JSATS cabled system was in 2007 at the Bonneville spillway to estimate route-specific passage and survival rates (Ploskey et al. 2008).

2.1 Study Context

The study context includes water discharge and temperature conditions, the spill treatments (30% versus 40% spill out of total water discharge through the dam), and definitions of various estimates of survival rates.

2.1.1 Water Discharge and Temperature

Water discharge data by spill bay and turbine unit and elevation data for the forebay and tailwater were acquired in 5-minute increments by the automated data-acquisition system at John Day Dam, and provided to us weekly by John Day Dam operators. The 5-minute discharge data for the entire dam and spillway were averaged by day and plotted together with daily averages for the previous 10-year period to provide some historical perspective for 2008 observations. Average water discharge and forebay water temperature data from 1998 through 2007 were downloaded from the DART (Data Access in Real Time) website (http://www.cbr.washington.edu/dart).

2.1.2 Spill Treatments

We evaluated the effects of 30% and 40% spill treatments on fish passage and survival rates while TSWs were installed at spill bays 15 and 16. The effects on fish-passage efficiency, spill efficiency, spill effectiveness, dam-passage rates, and route-specific survival rates of JSATS-tagged juvenile salmonids were evaluated. Randomized block experimental designs were developed for spring (Figure 2.1) and summer (Figure 2.2). Each 4-day block was supposed to have one 2-day treatment randomly chosen to be 30% or 40% spill followed by the alternate treatment. Treatment changes were made at 0600 hours. The first treatment each season was in place a couple of days before the first study block, and a few fish that arrived before the first treatment but under the same spill conditions were assigned to the first treatment. Similarly, the last treatment each season continued for more than 2 days and late-arriving fish under the same spill conditions were assigned to the last 2-day treatment.

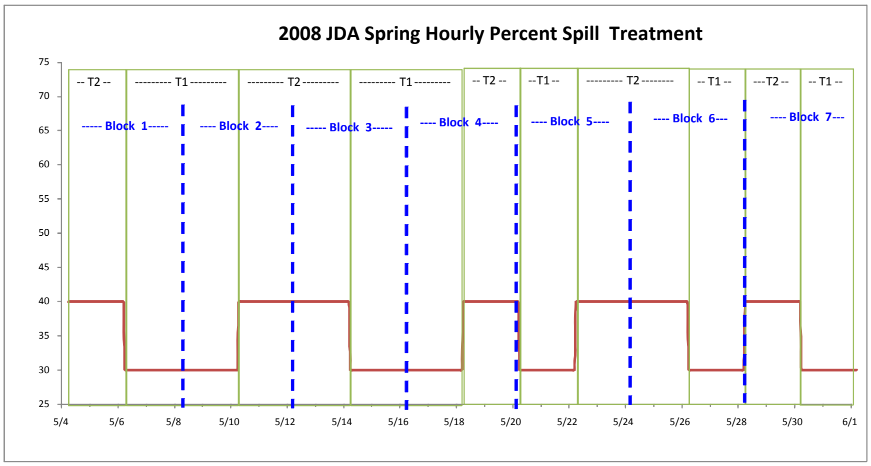

Figure 2.1. Spill treatments for the spring study at John Day Dam from May 4 through May 31, 2008. There were seven treatment blocks with two treatments per block. Treatment 1 (T1) was 30% spill and Treatment 2 (T2) was 40% spill.

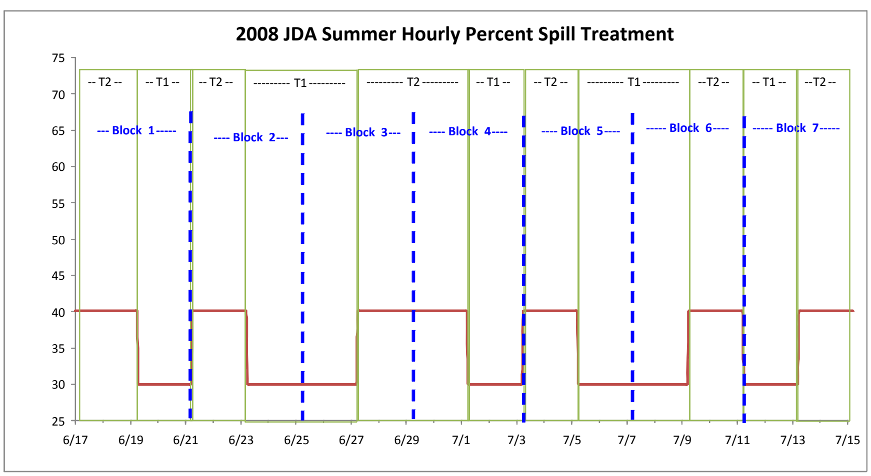

Figure 2.2. Summer spill treatments at John Day Dam from June 17 through July 14, 2008. There were seven treatment blocks with two treatments per block. Treatment 1 (T1) was 30% spill and Treatment 2 (T2) was 40% spill.

2.1.3 Definitions

We define estimates of single-release reach survival rates by the upstream and downstream boundaries of the reach of interest. The following additional definitions are needed to clarify paired-release survival metrics (Peven et al. 2005 provide other definitions):

- ***Forebay*** is the segment of river immediately upstream of a dam where operations at the dam are the primary contributing factor to velocity and direction of water flow. The upstream boundary is where a significant alteration in the allocation of water flow through dam operational changes affects water velocity or direction of flow. Locations of the forebay entrance arrays of autonomous nodes for John Day Dam and The Dalles Dam were 2 km upstream of the dam face. The downstream boundary is the upstream face of the dam, where we installed cabled arrays for tracking fish.
- ***Tailrace*** is the segment of river immediately downstream of the dam where dam operations are the primary factor affecting velocity and direction of flow. The upstream boundary of the tailrace is the downstream face of the dam and the downstream boundary is where operational changes at the dam no longer affect the direction of water flow and mixing from the spillway and powerhouse is complete. Tailrace release locations below John Day Dam and The Dalles Dam were at rkm 346 and 305, respectively, approximately 3 km downstream of each dam.
- ***Reservoir or pool*** is the segment of river impounded by a dam where volume and water-surface elevations are controlled by the dam. A reservoir or pool may extend upstream to the tailrace of another dam. For example, The Dalles Dam pool extends from The Dalles Dam upstream to near the tailrace of John Day Dam, although it also could be referred to as the tailwater of John Day Dam.
- ***Tailwater*** is the segment of river downstream of a dam tailrace, and it is synonymous with reservoir or pool when it lies between two dams.
- The ***project-passage survival rate*** is the probability of fish surviving when passing from the upstream boundary of the reservoir or pool upstream of a dam to the downstream boundary of the tailrace of the dam.
- The ***dam-passage survival rate*** is the probability of fish surviving when passing from the upstream boundary of the forebay to the downstream boundary of the tailrace and includes the forebay, all routes of passage, and the tailrace of a given dam. In this study, the dam-passage survival rate is loosely defined as being from a forebay detection line to the tailrace release location for reference release groups of fish.
- The ***concrete-passage survival rate*** is the probability of fish surviving when passing from the upstream dam face to the downstream boundary of the tailrace and does not include survival in the forebay. (This is how the 2008 BiOp defines the dam-passage survival rate.)
- The ***passage-route survival rate*** is the probability of fish surviving when passing through any individual route (i.e., spillway, turbine, bypass, etc.) to the downstream boundary of the tailrace (release location of a tailrace reference group). In this study, the passage-route survival rate was estimated for fish passing the powerhouse (turbines and JBS), spillway, and TSW spill bays at John Day Dam.

2.2 Fish Collection, Tagging, Transportation, and Release

The following sections describe the collection site, associated record-keeping related to meeting permitting requirements for fish collection and handling, sampling methods, JSATS acoustic micro-transmitter and tag implantation, fish recovery and holding, and transportation and release.

2.2.1 Collection Site

Juvenile Chinook salmon and STH were collected and tagged at the John Day Dam SMF. The SMF is situated on the south side of John Day Dam at the downriver edge of the fish bypass system where bypassed juvenile salmonids and other fishes are routed through a series of flumes and dewatering structures. Smolts can be diverted into the SMF as part of a sample of the JBS population for routine smolt monitoring or directed into the tailrace through an outfall pipe located downstream of the facility. Routinely sampled smolts also were rerouted to the tailrace outfall after they were examined unless they were selected for tagging as part of this study of survival rates.

2.2.2 Federal and State Permitting

Records were kept on all smolts handled and collected (both target and nontarget species) for permit accounting. Collections were conducted in conjunction with routine sampling at the SMF to minimize handling impacts. Surgical candidates collected from routine SMF target sample sizes were accounted for under permits issued to the SMF. Additional fish needed to meet research needs (beyond SMF goals) were accounted for under separate federal and state permits. A federal scientific take permit was authorized for this study by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Hydropower Division's FCRPS Branch and administered by NOAA; permit number 20-08 PNNL-40. The Oregon Department of Fish and Wildlife authorized take for this study under permit number OR2008-4600. The federal and Oregon permits were both authorized under the 2004 FCRPS BiOp. All requirements and guidelines of both permits were met and reports of collection and release were reported to both agencies.

2.2.3 Sampling Methods

Juvenile salmonids were diverted from the bypass system and routed into a 1795-gal holding tank in the SMF. About 150–200 smolts and other fishes were crowded with a panel net into a 20- by 24-in. pre-anesthetic chamber. Water levels in the chamber were lowered to about 8 in. (48 L) at which point fish were anesthetized with 60 mL of a stock tricaine methanesulfonate (MS-222) solution prepared at a concentration of 50 g/L. Once anesthetized, fish were routed into the examination trough. Technicians added MS-222 as needed to maintain sedation, and 5 to 10 mL of PolyAquaTM was added to reduce fish stress. Water temperatures were monitored in the main holding tank and in the examination trough, and water in the trough was refreshed before temperatures there increased more than 2ºC above those observed in the main holding tank.

Once in the examination trough, smolts targeted for surgical procedures were evaluated in accordance with the following specific acceptance and rejection criteria:

Qualifying (Acceptable) Conditions

- sized >95 mm
- visible elastomer tag(s) present or absent
- adipose-fin clipped or unclipped
- trematodes, copepods, leeches
- short operculum
- healed (moderate) injuries (e.g., bird strikes)
- ≤ 3% fungal patch
- minor fin blood
- partial descaling (3–19%)
- STH with eroded pectoral or ventral fins (likely hatchery steelhead).

Disqualifying Conditions

- ≥ 20% descaling
- body punctures (showing blood e.g., predator marks, bird strikes, head wounds, nose/snout injuries)
- obvious signs of bacterial kidney disease
- eye hemorrhage or pop eye
- >3% coverage with fungus
- deformed
- holdovers (fish not "spring" yearling or "summer" subyearling)
- passive integrated transponder (PIT)- or radio-tagged or other post-surgical fishes
- notable operculum damage (except short operculum)
- columnaris, furuncles
- injured caudal peduncles
- injured caudal fins
- fin hemorrhage.

Nontarget species and fish that did not meet the above criteria were released to the river through the SMF holding system after a 30-minute recovery period. Accepted fish were counted and released into transfer buckets containing fresh river water before being moved to one of six 80-gal pre-surgery holding tanks, where they were held for 18 to 30 hours before surgery. The pre-surgery holding duration depended on the time of collection and the time of tagging on the next day.

During spring and summer tagging seasons, 91 total fish were rejected for tagging. Fish that were rejected during the tagging process were placed in a recovery tank to allow for the anesthesia to be displaced from their system before releasing them. The total number of fish rejected and reason for their rejection are listed below in Table 2.1.

Table 2.1. Number of fish rejected by criteria during spring and summer tagging at John Day Dam

Rejection Criteria	Number Rejected
Descaling	5
Fungus	8
BKD	1
Skeletal deformities	0
Parasites	1
Emaciation	0
Cuts/lacerations	32
Hemorrhaging	13
Popeye	0
Fin rot	0
Head deformities	0
Lesions	4
Moribund	0
Other	9
Operculum damage	18
Total fish collected	12,876
Number of fish rejected	91
Percent total fish rejected	0.71%

2.2.4 JSATS Acoustic Micro-Transmitter and Tag Implantation

The size of JSATS acoustic micro-transmitters surgically implanted in fish differed between spring and summer. In spring, the mean weight of tags was 0.485 g in air and 0.324 g in water, and tags were nominally 12.46 mm long, 5.30 mm wide, and 3.70 mm high. In summer, the mean weight of tags was 0.425 g in air and 0.29 g in water. Summer tags averaged 12.04 mm long, 5.27 mm wide, and 3.74 mm high (Figure 2.3). The acoustic tags used in this study had a ping rate of 1 pulse every 3 seconds to provide an expected tag life of at least 23 days.

A team of eight people was part of the tagging process to reduce the handling time between netting and post-surgery recovery. The team followed the latest guidelines for surgical implantation of acoustic transmitters in juvenile salmonids. Procedure development is an ongoing process initiated by the USACE for contractors conducting survival studies. Numerous steps were taken to minimize the handling impacts of collection and surgical procedures. Most smolts used for tagging were part of the routine collection for SMF monitoring and additional fish did not have to be collected to meet the tagging quota on most days.

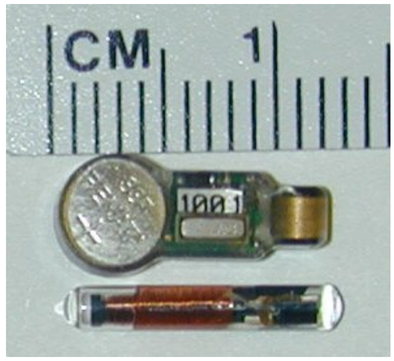

Figure 2.3. JSATS 0.425-g acoustic micro-transmitter and PIT tag surgically implanted in subyearling Chinook salmon

The number of personnel on hand was the biggest contributor to ensuring that all tagged fish were handled as efficiently and un-intrusively as possible to minimize handling times. One individual was responsible for anesthetizing fish and delivering them to be weighed and measured. Two people were responsible for weighing, measuring, and recording data; three to four people performed surgeries to implant tags in the fish, and one or two people were responsible for moving tagged fish into the post-surgery tanks.

Fish were netted in small groups from the 80-gal holding tanks and placed in a 5-gal “knockdown” bucket with water and 20 mL of a 40-g/L stock solution of MS-222. Once a fish lost equilibrium, it was transferred to a processing table in a small container of river water. Each fish was measured (fork length ±1 mm), the species type and whether its adipose fin was intact or clipped were recorded on a GTCO CalComp Drawing Board VI digitizer board. Fish were weighed (±0.01 g) on an Ohaus Navigator scale and returned to the small transfer container along with an assigned PIT tag and an activated acoustic tag. Length, weight, species type, tag codes, and fin clip were all added automatically into the tagging database by PIT Tag Information System (PTAGIS) P3 software to minimize human error. The transfer container, fish, and tags were assigned a recovery bucket number and passed to a surgeon for tag implantation.

An established protocol was used in the tagging process to help minimize the handling impact on tagged fish. All surgical instruments were sterilized daily in an autoclave and each surgeon used four complete sets of instruments during each day’s tagging. When a set was not being used, it was placed in a 70% ethanol solution for approximately 10 minutes. The instruments were then transferred to a distilled water bath for 10 minutes, to remove residual ethanol and any remaining particles, before being used again. To reduce the disruption of the mucus membrane at the incision, Poly-Aqua was used to help replace the membrane that was removed from the fish’s epidermal layers. Anesthesia buckets were kept within ±1ºC of river temperature. Anesthesia solutions were either replaced or cooled with ice when temperatures exceeded protocols. Recovery buckets were also kept within ±1ºC of river water temperature.

During surgery (Figure 2.4), each fish was placed ventral side up and a gravity-fed anesthesia supply line was placed into its mouth. The dilution of this “maintenance” line was 40 mg/L. A 6–8-mm incision, using a #15 stainless steel surgical blade or a Micro-Sharp stab scalpel with a 5-mm blade (depending on the surgeon’s preference), was made ventrally, 3 mm from and parallel to the mid-ventral line and equidistant from the pelvic girdle and pectoral fin. The PIT tag was inserted first, followed by the acoustic tag. Both tags were inserted toward the anterior portion of the fish. Two interrupted sutures of 5-0 monofilament with an RB-1 needle were used to close the incision. With the incision closed, fish were then taken to an aerated recovery bucket containing river water.

Figure 2.4. Surgery being conducted in the Smolt Monitoring Facility at John Day Dam

2.2.5 Recovery and Holding

Tagged fish were placed in 5-gal aerated recovery buckets and closely monitored until fish had reestablished equilibrium. Each bucket held two to seven fish depending on the size of the fish and the number to be released at each site. The buckets were then carried to a larger holding tank where they were supplied with a continuous feed of river water (Figure 2.5). Fish were held and monitored for 18 to 30 hours prior to being released. The large holding tanks were insulated to keep the water temperature within acceptable limits.

2.2.6 Fish Transportation and Release

To transport tagged fish, a 3/4-ton truck was outfitted with one 180-gal Bonar insulated tote and one 70-gal Bonar insulated tote. The 180-gal tote could hold ten 5-gal fish buckets, and the 70-gal tote could hold four 5-gal fish buckets. The totes had snug-fitting lids and some extra space inside so that ice could be added for cooling on hot days. A network of valves and plastic tubing was attached to an oxygen tank for delivering oxygen to the totes from a 2200-psi oxygen tank during transport. The Bonar totes were filled with fresh river water before fish buckets were removed from the post-surgery holding tanks and placed in the totes. Air lines were then placed into the totes. A YSI meter was used to measure the dissolved oxygen and the temperature of water in the totes before and after transport to make sure that these properties stayed within acceptable limits.

The JSATS tagged fish from each of the three stocks (STH, YC, and SYC) were released 41 rkm upstream of John Day Dam near Arlington, Oregon (rkm 390), and John Day Dam reference fish were released in the John Day Dam tailwater at rkm 346. In summer only, SYC smolts also were released in the tailrace below The Dalles Dam to provide reference groups for estimating paired-release dam-passage survival rate for The Dalles Dam and to supplement the number of treatment fish available to pass the Bonneville Dam and support two survival rate studies there. All fish were released from a boat at three locations along a line transect across the river at each site, unless river conditions were too rough to safely release fish by boat. For boat releases, fish buckets were moved from the Bonar transport totes into the stern of the boat. Fish buckets were opened to check and record all mortalities. Dead fish were scanned with a BioMark portable transceiver PIT-tag scanner to identify the implanted PIT-tag code in each dead fish. The associated acoustic tag codes were identified later. In preparation for fish release, the boat operator maneuvered the boat to the release waypoint using an on-board global positioning system (GPS) and put the motor in neutral. Each bucket was submerged in the water so that fish could swim out on their own volition. The release site and time were recorded to the nearest minute on data sheets.

Figure 2.5. Post-surgery holding tank with recovery buckets

When conditions were too rough to release fish from a boat, alternate locations were used. Upstream of John Day Dam, fish were released from the grain elevator platform in Arlington, Oregon, by lowering the fish buckets into the water with a rope. Below John Day Dam, fish were released into the SMF outfall. The numbers of fish tagged and released in spring and summer are listed in Appendix A.

A 2008 tag-effects study (Dr. Richard Brown, PNNL, Personal Communication) released YC in the JBS outfall at Lower Granite Dam (also listed in Appendix A), and those fish also had the potential to be detected on receivers deployed for this study, as described in the next section.

2.3 Detection of Tagged Fish

Two types of JSATS arrays, cabled and autonomous, were deployed to detect fish tagged with JSATS acoustic transmitters as they passed downstream through the study reach between Arlington, Oregon, at rkm 351, and Camas, Washington, at rkm 192 (Table 2.2). The John Day Dam forebay array was used to create a virtual release for fish as they enter the forebay 2 km upstream of John Day Dam. The John Day Dam dam-face array was used to create a virtual release for fish known to have passed John Day Dam and to estimate route of passage at the dam using 3D tracking and last-detection data. The time of last detection by the dam-face array minus the time of first detection on the forebay array provide an estimate of forebay residence time. The time of first detection by the John Day Dam tailwater egress array minus the time of last detection on the dam-face array provided an estimate of relative egress time. The Dalles Dam forebay array was the primary array for estimating the survival rate for tagged smolts passing through John Day Dam and for defining the virtual release of fish to estimate the survival rate for smolts passing through The Dalles Dam. The Bonneville Dam forebay array was used as the secondary array for estimating the dam-passage survival rate at John Day Dam and as the primary survival-detection array for virtual and reference releases of fish at The Dalles Dam. The Bonneville Dam forebay array was also used to create a virtual release for Bonneville Dam survival studies (at Bonneville Dam Powerhouse 2 [B2] and the Bonneville Dam spillway); although those study results are not discussed in this report. The first Bonneville Dam tailwater array was used as the tertiary survival-detection array for estimating the survival rate of tagged smolts passing through John Day Dam and as the secondary survival-detection array for estimating The Dalles Dam-passage survival rate. The second Bonneville Dam tailwater array near Lady Island was used as a tertiary survival-detection array for estimating the product of survival and detection probabilities for estimating The Dalles Dam-passage survival rate. The GPS positions of individual dam-face hydrophones and autonomous nodes are presented in Appendix B.

Table 2.2. Description, location, name, and survival model function of arrays deployed in 2008. Array names were a concatenation of "A" for autonomous or "D" for dam face with a sequential number for each type (from upstream to downstream) with "CR" for Columbia River, and the nearest whole rkm.

Array Description	Location	Array Name	Array Function
JDA Forebay	2 km upstream JDA	A1CR351	Regroup fish for virtual releases
JDA Dam Face	JDA	D1CR349	Regroup fish for route-specific virtual releases
JDA Tailwater	2.6 km downstream JDA	A2CR339	Detect tagged fish to estimate egress rate
TDA Forebay	2 km upstream TDA	A3CR312	JDA primary; regroup fish for virtual releases
BON Forebay	1.5 km upstream BON	A4CR237	JDA secondary; regroup fish for virtual releases; TDA primary;
B2 Dam Face	BON PH2	D2CR235	B2 route-specific passage assignments
BON Spill Dam Face	BON spillway	D3CR234	Spillway route-specific passage assignments
BON Tailwater 1	Reed Island	A5CR203	JDA tertiary; TDA secondary; BON primary;
BON Tailwater 2	Lady Island	A6CR192	TDA tertiary; BON secondary;

B2 = Bonneville Dam Powerhouse 2.
BON = Bonneville Dam.
JDA = John Day Dam.
TDA = The Dalles Dam.

2.3.1 Cabled Dam-Face Array

The cabled dam-face receiver was designed by PNNL for the USACE Portland District using an off-the-shelf user-build system goal. Each cabled receiver consists of a computer, data-acquisition software, digital signal-processing cards with field-programmable logic gate array (DSP+FPGA), GPS card, four-channel signal-conditioning receiver with gain control, hydrophones, and cables (Figure 2.6). The software that controls data acquisition and signal processing is the property of the USACE and is made available by the USACE as needed.

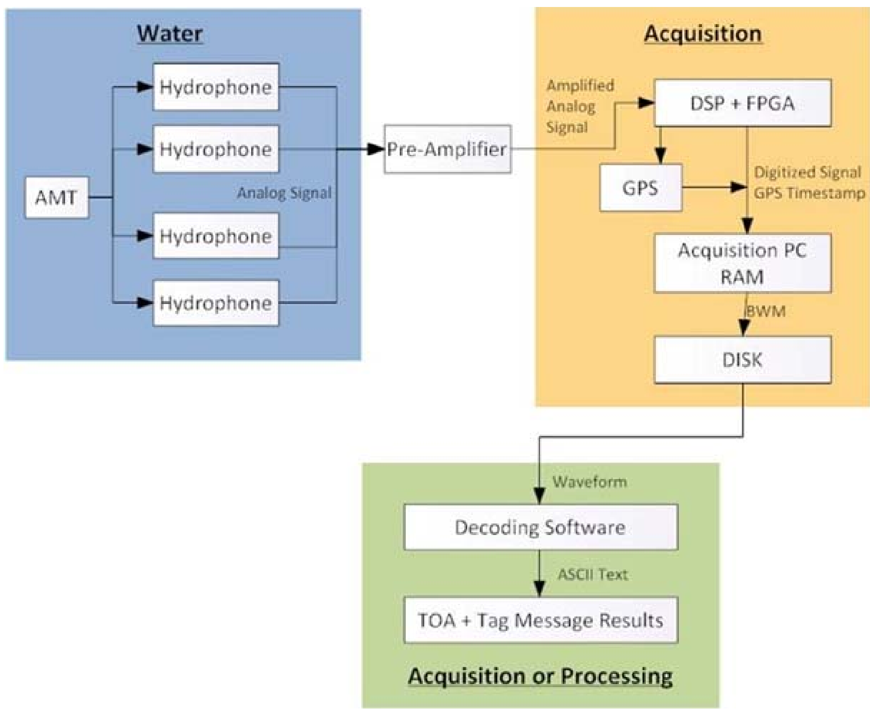

Figure 2.6. Schematic of the JSATS Dam-Face Receiver System showing the main components and the direction of signal acquisition and processing. Abbreviations are as follows: AMT = acoustic micro-transmitter implanted in fish; DSP = digital signal processing card; FPGA = field programmable logic gate array; GPS = global positioning system; PC = personal computer; RAM = random access memory; BWM = binary waveform; TOA = time of arrival.

A modular JSATS dam-face cabled array was deployed along the upstream face of John Day Dam on each main pier and in the forebay (Figure 2.7) to detect smolt tagged with an acoustic micro-transmitter as they approached and passed the dam. The dam-face cabled array consisted of 23 cabled receivers each supporting four hydrophones. The receivers were housed in trailers on the dam forebay deck. The four hydrophones per cabled receiver were deployed on trolleys in pipes attached to the main piers at the powerhouse and spillway (Figure 2.7) in a known fixed geometry. Trolley pipes at the powerhouse were 4 in. in diameter, and made of powder-coated schedule 40, 4-in.-internal-diameter steel pipes that were slotted down one side for deployment of the trolley. A cone was attached to the top of the pipe to assist with insertion of trolleys (Figure 2.8). Pipes at the powerhouse were 120 ft long and extended from deck level at elevation 281 ft above mean sea level (MSL) down to a mid-intake depth at elevation 164 ft above MSL. Two hydrophones were deployed at each main pier. One hydrophone was deployed at a shallow elevation (at 255.5 ft above MSL) and the other was deployed at a deep elevation (at 166.5 ft above MSL) to provide acceptable geometries for tracking an acoustic-tagged fish in three dimensions and then assigning it a route of passage through the dam.

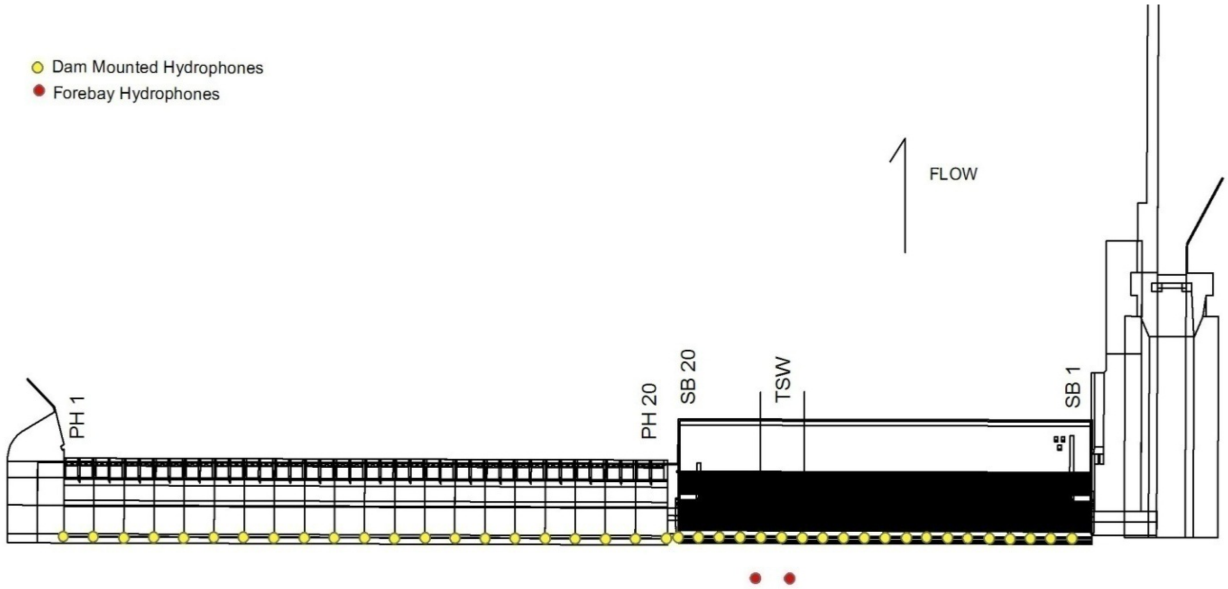

Figure 2.7. Location of JSATS hydrophones on the dam face and in the forebay of John Day Dam

Figure 2.8. Trolley pipe mounted on a main pier of the John Day Dam powerhouse

At the spillway, hydrophones were mounted on trolleys that were deployed in 40-ft-long 8-in.-diameter slotted pipes installed previously for radio-telemetry studies. Cones were added to the tops of the pipes to aid with installation of trolleys from the deck. At each spillway pier, one hydrophone was deployed at a shallow elevation (259.5 ft above MSL) and the other at a deep elevation (232.5 ft above MSL). Each steel trolley slid down inside the pipe and was guided by an extension arm that protruded from the slot. The arm positioned the anechoic baffled hydrophone perpendicular to the face of the dam (Figure 2.9). Hydrophones were also deployed on clump mounts in the forebay upstream of spill bays 15 and 17 to provide additional detection and greater 3D resolution of tagged smolt as they passed at the TSWs.

Figure 2.9. A 4-in.-diameter trolley with hydrophone (left) for slotted pipes on powerhouse piers and an 8-in.-diameter trolley with hydrophone (right) for slotted pipes on spillway piers. Each trolley had a steel arm to support a hydrophone that was surrounded by a plastic cone lined with anechoic material to prevent sound reception from a downstream direction.

2.3.2 Autonomous Nodes and Arrays

Autonomous acoustic telemetry receivers were deployed in arrays at specific sites in the lower Columbia River study area (Figure 2.10). An array is defined as a group of autonomous nodes deployed across the entire width of a river cross section to detect passing fish that have been surgically implanted with acoustic tags. Most arrays had autonomous nodes that were deployed within 400 ft of each other and less than 300 ft from shore. The hydrophone, pair of electronic circuit boards, compact flash (CF) card, and battery connectors were located in the node top (Figure 2.10).

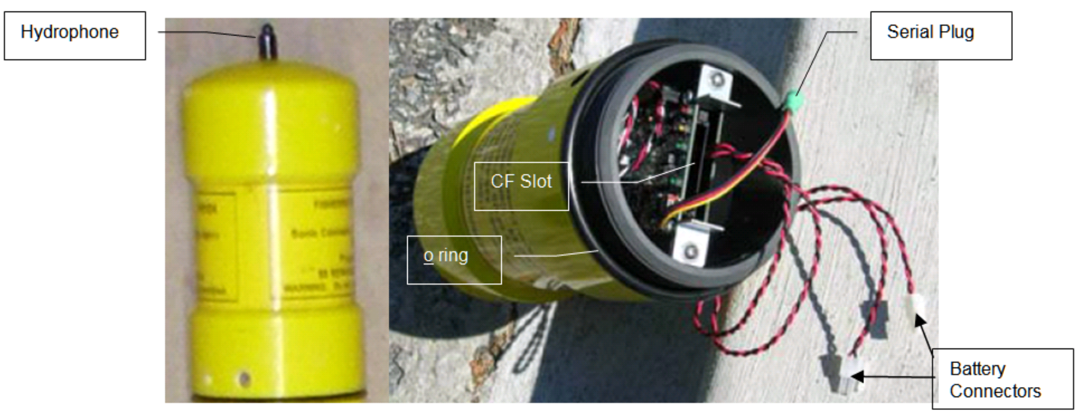

Figure 2.10. Side (left) and bottom (right) view of an autonomous node top

Five arrays of autonomous nodes were deployed for this study (Figure 2.11). Arrays were named by concatenating several letters and numbers. For example, the first array was A1CR351, which is the concatenation of "A" (for autonomous node), a sequential array number (counting from upstream to downstream), "CR" (for Columbia River), and 351, which is the nearest river kilometer to that array site. This array was located 2 km upstream of John Day Dam, and it was used to detect and regroup acoustic-tagged fish as they entered the John Day Dam forebay and, thereby, define virtual releases of fish for estimating the forebay survival rate. The last time of detection on the dam-face array described in

Section 2.4.1 minus the time of first detection on the forebay entrance array provided estimates of forebay residence time. A tailwater egress array (A2CR339) was located at rkm 339.2 about 7.8 km below John Day Dam. The first time of detection on the egress array minus the last time of detection on the dam-face array provided a relative estimate of tailrace egress time. The Dalles Dam forebay entrance array (A3CR312) was located 2 km upstream of The Dalles Dam spillway. This array was the primary array for estimating the survival rate of fish passing at John Day Dam and was used to detect and define virtual releases for estimating the rate of The Dalles Dam-passage survival rate. The Bonneville Dam forebay array (A4CR237) was located about 2 km upstream of B2. This array was the secondary array for estimating the survival rate of fish passing John Day Dam. The tertiary array for estimating the product of detection and survival rates for John Day Dam (A5CR203) was located near Reed Island in the Bonneville Dam tailwater. See Appendix B for the nominal GPS coordinates of autonomous nodes deployed in this study.

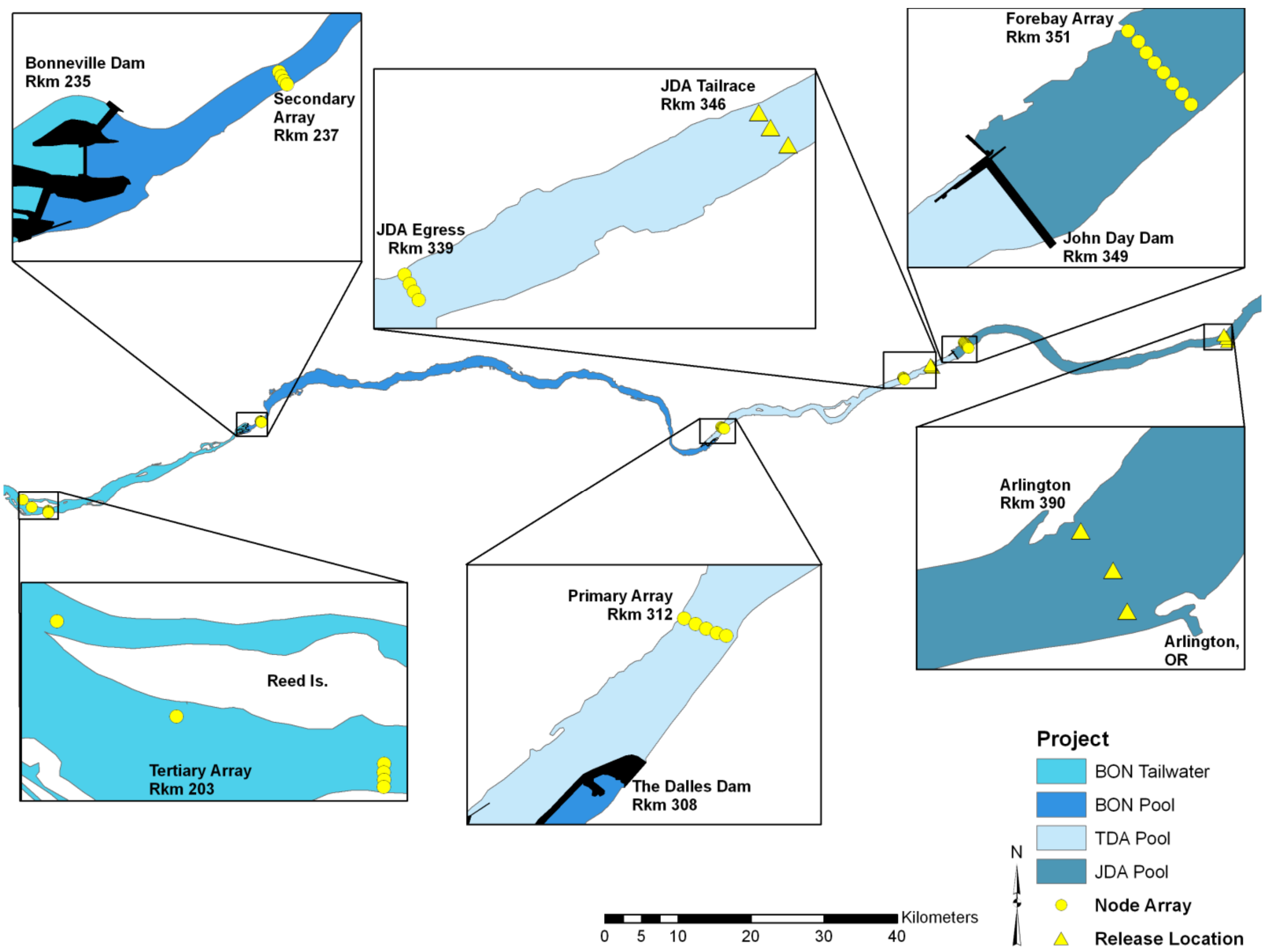

Figure 2.11. Locations of autonomous node arrays and fish release locations in the Lower Columbia River in 2008

2.3.3 Node Retrieval, Servicing, and Redeployment

We usually retrieved nodes by boat and downloaded data every week. The first step in servicing a node was to trigger its acoustic release. Staff entered a release-specific code into a topside command transceiver, and it transmitted an electrical signal to an underwater transducer, which in turn converted the electrical signal into underwater sound detectable by a specific release mechanism. Upon receipt of a recognized sound by an acoustic modem at the upper end of the acoustic release, the mechanism usually would open and free the positively buoyant package from the anchor so that it would surface and could be retrieved by staff in the boat. The next step was to dry the node with a towel, open it, eject the CF card, and download the data from the card to a laptop computer. Each file was checked to verify that data were collected during the entire deployment, records were continuous, and records included time stamps and tag detections. The CF card was replaced every time nodes were retrieved and batteries were changed at about 28-day intervals. When the data were corrupt, the node top was replaced with a new one and the faulty top was sent to Sonic Concepts for repair. Damage to the relatively delicate hydrophone tip was the most common problem. Nodes were deployed and serviced from April 25 until August 20, 2008.

2.3.4 Autonomous Node Deployment

Autonomous nodes were rigged with the configuration shown in Figure 2.12. A 5-ft section of rope with three 6-lb buoyancy floats was attached to a strap half way between the node tip and the bottom of the battery housing. An InterOcean Systems Mode 111 acoustic release was attached to the other end of the 5-ft line. A 1-, 3-, or 6-ft length of wire rope was attached to the bottom of the acoustic release, depending on water depth, and the other end of that cable was shackled to a 75-lb steel anchor. The shorter 1-ft length of wire rope was used in water less than 40 ft deep; the 3-ft length was used in water over 40 ft deep; and 6-ft lengths were used in deep locations were sandy substrates had the potential to gum up release mechanisms.

2.4 Data Processing and Validation

Signals were decoded and filtered and tag life was studied as part of data processing and validation efforts.

2.4.1 Signal Decoding and Filtering

Data collected by the JSATS cabled hydrophones were encoded candidate messages saved in binary time-domain waveform files. Figure 2.13 shows the waveforms of an actual example acquired at the John Day Dam spillway on June 18, 2008. The waveform files were then processed by a decoding utility (Waveform Utilities developed by USACE and PNNL) that identifies valid tag signals and computes the tag code and time of arrival using Binary Phase Shift keying. Binary Phase Shift keying is a digital-modulation technique that transmits messages by altering the phase of the carrier wave. Several filtering algorithms were then applied to the raw results from the decoding utilities to exclude spurious data and false positives.

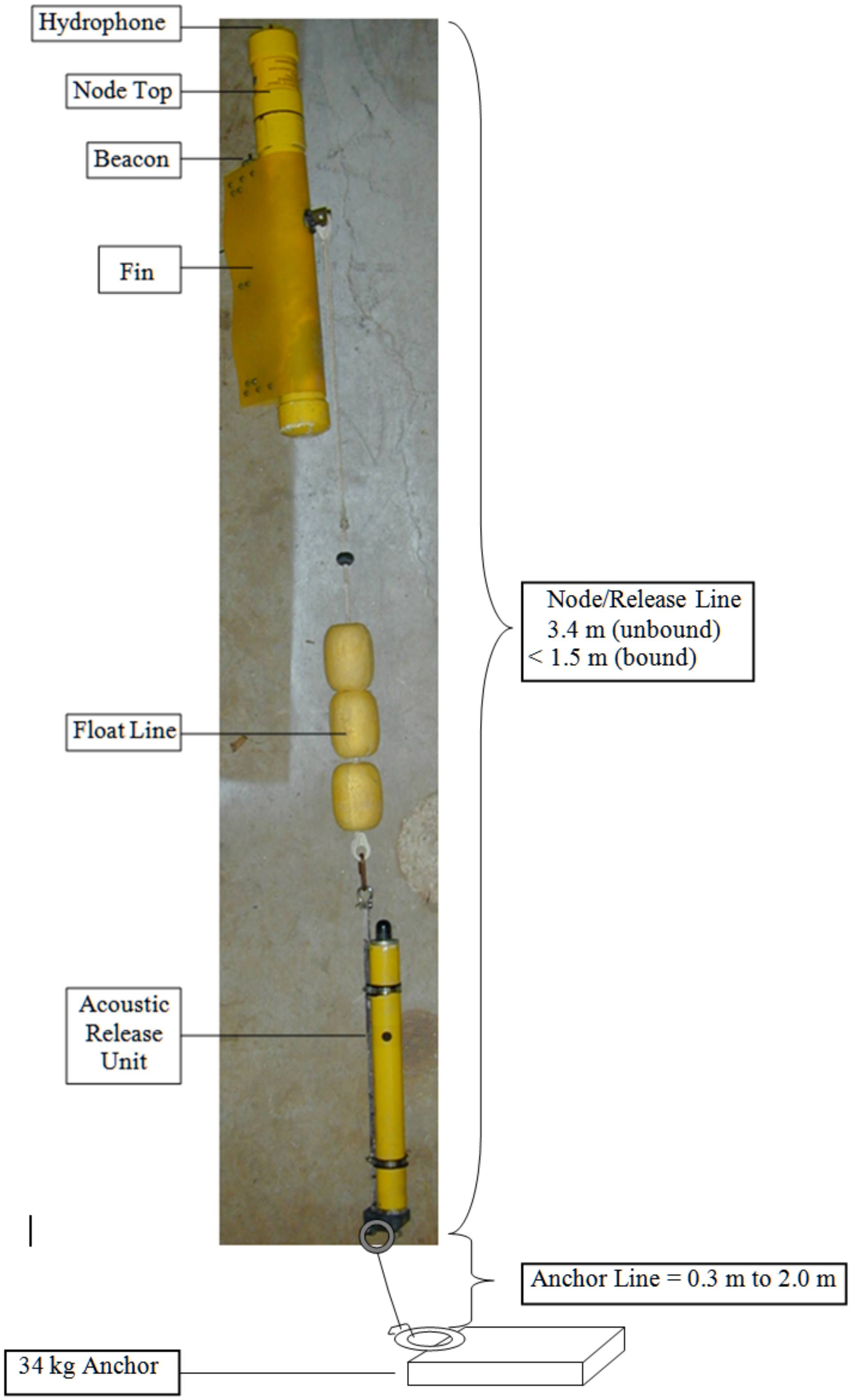

Figure 2.12. Autonomous node rigging in 2008

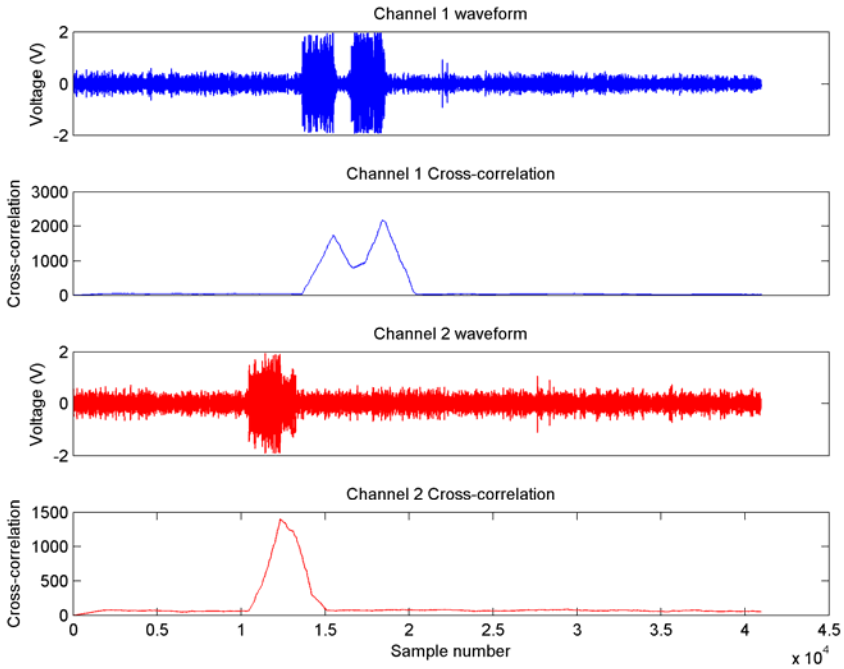

Figure 2.13. Example of time-domain waveforms and corresponding cross-correlations acquired at the John Day Dam spillway. The message portion was 1860 samples (744 µs long). Note that multipath components were present in both channels. Decodes from the multipath components were filtered out in post-processing.

Tag-detection data from JSATS autonomous nodes were processed by two independent groups as a quality-control measure as in previous studies (Ploskey et al. 2007; Ploskey et al. 2008) using standardized methods. One method processed data using programs written in Python, and the other involved processing data with programs written in the Statistical Analysis System (SAS). No significant difference was found in estimates of the detection and survival rates based upon detection histories generated by the two processing methods. Regardless of processing method, tag, release, and detection data were merged into a single data set, and the same rules were applied to identify valid detections and to generate detection histories for every tag.

Steps for filtering raw autonomous node data to produce a clean detection data set included the following:

1. Decodes of the same tag within 0.156 seconds of the previous decode were assumed to be multipath and deleted.
2. Invalid detection events were deleted. A detection event was started when the time interval between any four identical decodes was ≤ 47.8 seconds (3-s tags), ≤ 79 s (5-s tags), or ≤ 157 s (10-s tags). Once started, the event continued until the time lapse between any two successive decodes exceeded the same time durations.
3. Decodes within valid detection events, as described in Filter 2 above, were deleted if the time interval from the original decode in the series did not closely match an even multiple of one of the modes of the estimated pulse-repetition interval.

4. Remaining detection events for tag codes that were not used during the study year were flagged as orphans in hope of explaining the presence of those codes at a later date. Flagged detections were not used in any analysis unless they were explained. Resources for resolving issues included the list of codes of tags implanted in fish, lists of codes of beacons deployed on autonomous nodes or in forebays, and coordination with other researchers in the basin.
5. We flagged remaining detections that occurred before a tag was released, at sites upstream of the listed release location, or on upstream arrays after a series of detections on downstream arrays. Analysts attempted to explain and resolve the flagged problems by examining all available information in the tagging, release, autonomous array, and cabled array data sets. Flagged detections were not used in any analysis unless the spatial or temporal discrepancies were adequately explained and resolved. Discrepancies might be explained by fish being released at the wrong site or incorrect data and time settings on an autonomous node.

Steps for filtering cabled array data to produce a clean detection data set included the following:

1. Decodes of a tag code within 0.156 seconds of a previous decode of the same code were assumed to be multipath and deleted.
2. Invalid detection events were deleted. A detection event was started when the time interval between any four identical decodes was ≤ 47.8 seconds (3-s tags), ≤ 79 seconds (5-s tags), or ≤ 157 seconds (10-s tags). Once started, the event continued until the time lapse between any two successive decodes exceeded the same time durations.
3. Decodes within valid detection events, as described in Filter 2 above, were deleted if the time interval from the original decode in the series did not closely match an even multiple of one of the modes of the estimated pulse-repetition interval.
4. Remaining detection events for tag codes that were not used during the study year were flagged as orphans in hope of explaining the presence of those codes at a later date. Flagged detections were not used in any analysis unless they were explained. Resources for resolving issues included the list of codes of tags implanted in fish, lists of codes of beacons deployed on autonomous nodes or in forebays, and coordination with other researchers in the basin.
5. We flagged remaining detections that occurred before a tag was released, at sites upstream of the listed release location, or on upstream arrays after a series of detections on downstream arrays. Analysts attempted to explain and resolve the flagged problems by examining all available information in the tagging, release, autonomous array, and cabled array data sets. Flagged detections were not used in any analysis unless the spatial or temporal discrepancies were explained and resolved. Discrepancies might be explained by fish being released at the wrong site or incorrect data and time settings on an autonomous node.

The final results from the steps above included a complete detection history for each tag: detection time (TOA), detection hydrophone location, and the signal-to-noise ratio.

2.4.2 Tag-Life Study

Acoustic tags were used to characterize tag life from systematically sampling tags used in the YC and STH survival rate studies. As part of the 2008 Tag Effects Study, Dr. Richard Brown and colleagues implanted tags subsampled from all tags used in this study into juvenile Chinook salmon from Priest

Rapids Hatchery and monitored transmissions from those tags until every tag quit transmitting. When a tagged fish died, the tag was re-implanted in another fish until the tag died. A JSATS mobile node was used to listen for tags daily and tag-life history data were compiled to produce tag-life curves, which indicate the percent of each tag type transmitting as a function of days since activation. In addition, 44 Advanced Telemetry Systems, Inc. (ATS) 3-s tags, 40 ATS 5-s tags, and 27 10-s tags. There also 94 5-s tags were recovered when fish were removed from the river at SMFs using a sort-by-code diversion. The fraction of tags transmitting and the cumulative frequency of arrivals of tagged fish at survival-detection arrays as a function of time since tag activation were used to derive tag-life corrections. We did not fit curves to the fraction of tags still transmitting after tag activation and instead used the raw data as a Kaplan-Meier estimator of tag survival rate.

2.5 Statistical Methods

In this section of the report, the statistical methods used and descriptions of the testing conducted are characterized and defined.

2.5.1 Defining Releases for Estimating Survival Rates

The release locations and virtual release locations used in calculating survival rate estimates for tagged fish are described here, along with the JSATS detection arrays used in calculating fish survival rates.

2.5.1.1 Fish Released at John Day Dam in Spring and Summer

The PNNL team released YC and STH in spring and SYC in summer into the river near Arlington, Oregon, at rkm 390. Some of these tagged fish were detected by the forebay entrance array (A1CR351) and detections were pooled over several days to define virtual releases for estimating forebay- and dam-passage survival rates. Some of the fish also were detected on the dam-face array (D1CR349) and pooled over several days to define virtual releases for estimating concrete-passage and route-specific survival rates. The concrete-passage survival rate at John Day Dam was estimated using The Dalles Dam forebay array (A3CR312, primary), Bonneville Dam forebay array (A4CR237, secondary), and the Bonneville Dam tailwater array (A5CR203, tertiary) (Figure 2.14).

Some of the YC and STH released at sites designated as R1 and R2 (Figure 2.14) also were detected on The Dalles Dam forebay entrance array (A3CR312) and pooled over several days to define virtual releases for making single-release estimates of The Dalles Dam-passage survival rate. Paired-release estimates could not be made in 2008 because no YC or STH were released in The Dalles Dam tailrace.

2.5.1.2 Yearling Chinook Salmon Released in the Lower Granite Tailrace in Spring

Yearling Chinook were released at Lower Granite Dam through the juvenile bypass outfall into the Snake River at rkm 173, which is 696 rkm upstream of the mouth of the Columbia River. Some Lower Granite Dam fish were detected by the dam-face array (D1CR349) and used to define virtual releases for estimating the rate of concrete-passage survival based on subsequent detections on The Dalles Dam forebay entrance array (A3CR312, primary), the Bonneville Dam forebay entrance array (A4CR237, secondary), and Bonneville Dam tailwater array (A5CR203, tertiary) (Figure 2.15).

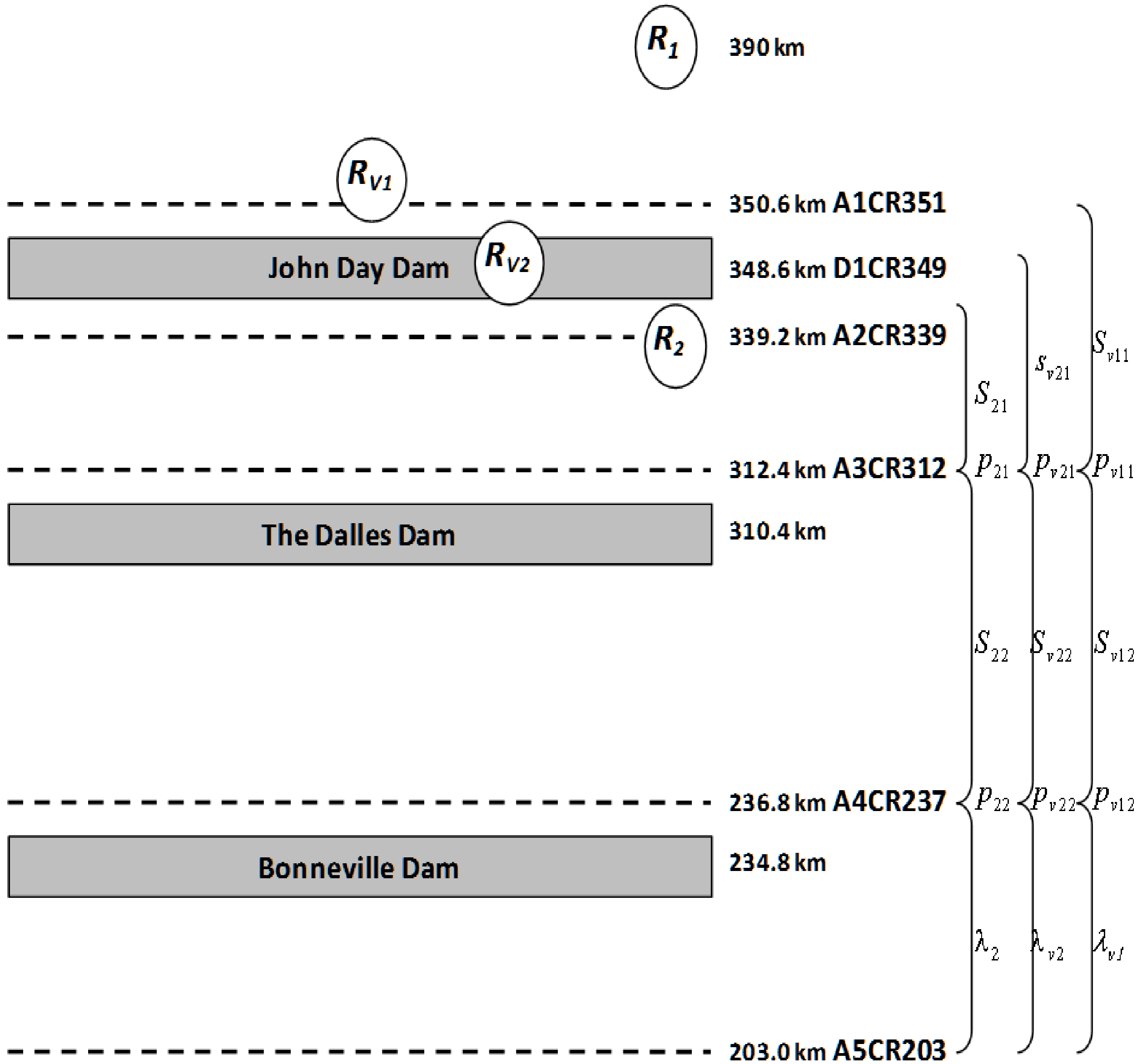

Figure 2.14. Schematic of the paired-release design (R_1 and R_2) and virtual releases (R_{v1}, R_{V2}) for estimating dam- and concrete-passage survival rates at John Day Dam

2.5.1.3 Paired-Release Estimates of TDA Dam-Passage Survival Rate for SYC

In summer, SYC were released in The Dalles Dam tailrace at rkm 306 (R3), and these releases were paired with virtual releases defined by detections of smolts from the John Day Dam pool and tailrace releases on The Dalles Dam forebay entrance array (Figure 2.16). We made single- and paired-release estimates of The Dalles Dam-passage survival rate using detection histories from the Bonneville Dam forebay array (A4CR237, primary), and two Bonneville Dam tailwater arrays (A5CR203 = secondary and A6CR192 = tertiary).

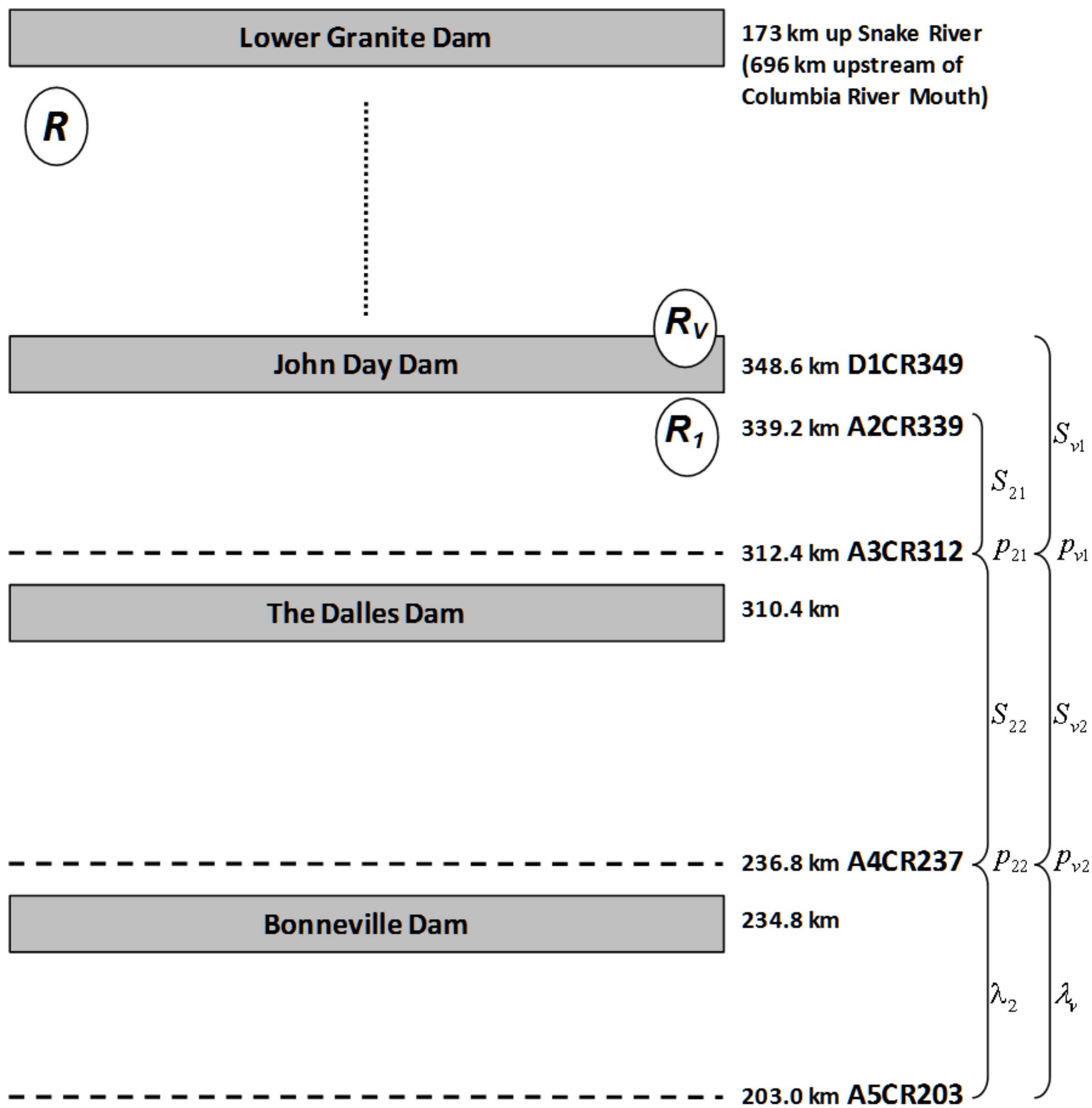

Figure 2.15. Schematic of the paired-release design (R_V and R_1) for estimating dam- and concrete-passage survival rates at John Day Dam for YC released downstream of Lower Granite Dam

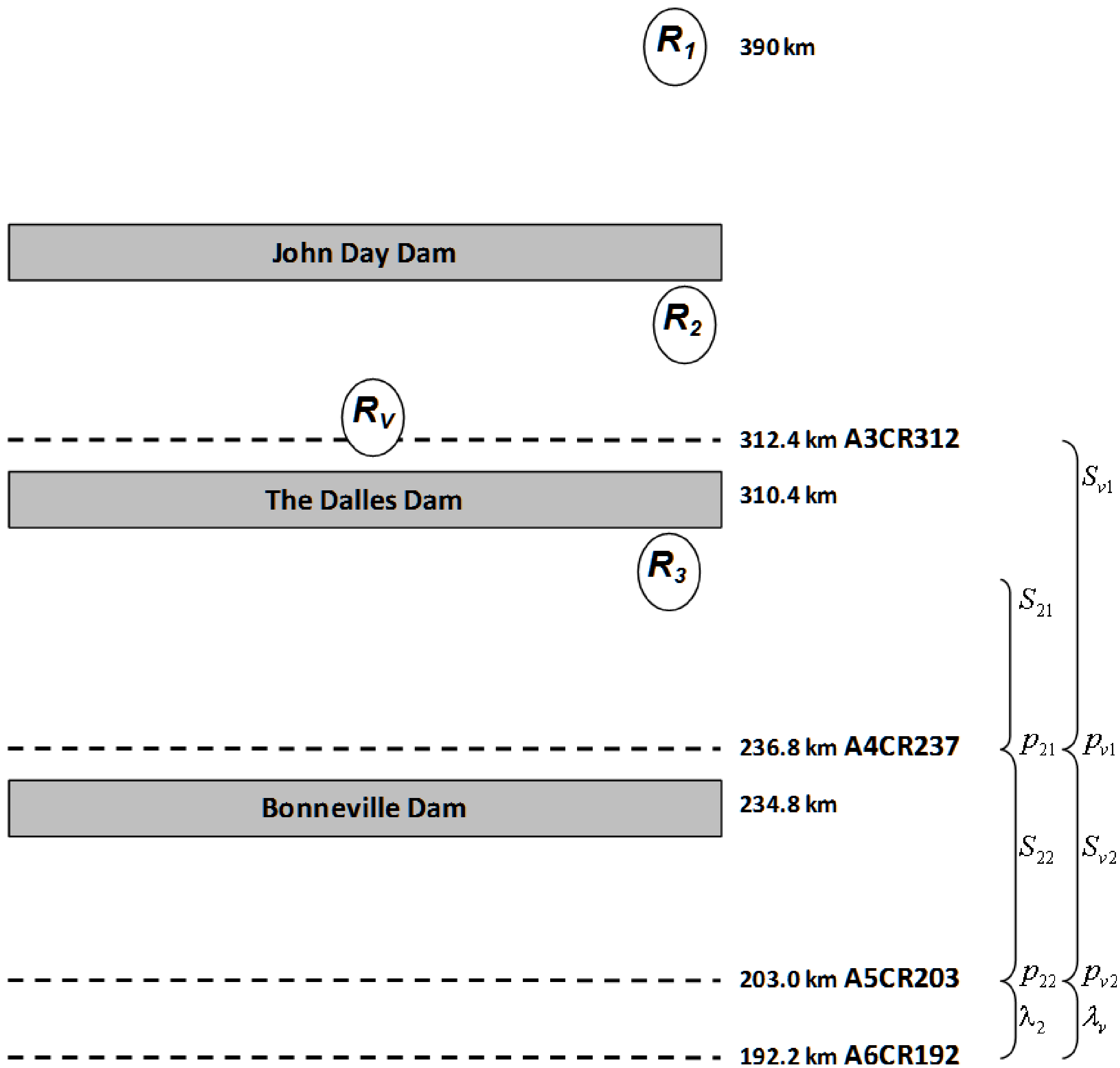

Figure 2.16. Schematic of the paired-release design for estimating fish passage survival rates at The Dalles Dam for subyearling Chinook. Tagged fish were regrouped for a virtual release in The Dalles Dam forebay (R_V) paired with a fish release in The Dalles Dam tailwaters (R_3).

2.5.2 Estimation of Survival Rate

Using tagged fish regrouped at the John Day Dam-face array (R_{V2}) and released in the John Day Dam (R_2) tailrace, paired release-recapture methods were used to estimate the rate of concrete-passage survival for each fish stock. The detection arrays at A3CR312, A4CR237, and A5CR203 provided $2^3 = 8$ possible capture histories for each release group. Virtual releases were pooled for the entire season when detection probabilities for the three downstream arrays were homogeneous over time. When detection probabilities as a function of release date were heterogeneous, as indicated by a significant Chi square test, we calculated a weighted-mean survival rate for the season. The number of fish in each virtual release was used to weight individual estimates of survival rate. In estimating the dam-passage survival rate at John Day Dam, the fully parameterized paired release-recapture model can be written as follows:

$$
\begin{aligned}
L = & \binom{R_{V2}}{\underset{\sim}{n}} \left(S_{11}p_{11}S_{12}p_{12}\right)^{n_{111}} \left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\lambda_1\right)^{n_{011}} \\
& \cdot\left(S_{11}p_{11}S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{101}} \left(S_{11}\left(1-p_{11}\right)S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{011}} \\
& \cdot\left(S_{11}p_{11}S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{110}} \left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{010}} \\
& \cdot\left(S_{11}p_{11}\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{100}} \\
& \cdot\left(\left(1-S_{11}\right)+S_{11}\left(1-p_{11}\right)\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{000}} \\
& \cdot\binom{R_{2}}{\underset{\sim}{m}} \left(S_{21}p_{21}S_{22}p_{22}\lambda_2\right)^{m_{111}} \left(S_{21}\left(1-p_{21}\right)S_{22}p_{22}\lambda_2\right)^{m_{011}} \\
& \cdot\left(S_{21}p_{21}S_{22}\left(1-p_{22}\right)\lambda_2\right)^{m_{101}} \left(S_{21}\left(1-p_{21}\right)S_{22}\left(1-p_{22}\right)\lambda_2\right)^{m_{011}} \\
& \cdot\left(S_{21}p_{21}S_{22}p_{22}\left(1-\lambda_2\right)\right)^{m_{110}} \left(S_{21}\left(1-p_{21}\right)S_{22}p_{22}\left(1-\lambda_2\right)\right)^{m_{010}} \\
& \cdot\left(S_{21}p_{21}\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{100}} \\
& \cdot\left(\left(1-S_{21}\right)+S_{21}\left(1-p_{21}\right)\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{000}},
\end{aligned}
\tag{2.1}
$$

where $\underset{\sim}{n}$ and $\underset{\sim}{m}$ are the vector of counts associated with the downstream capture histories of releases R_{V2} and R_2, respectively. For example, n_{101} is the number of R_{V2} fish detected at A3CR312, not detected at A4CR237, and subsequently detected at A5CR203.

The concrete-passage rate was estimated as the following ratio

$$
\hat{S}_{\text{JDA}} = \frac{\hat{S}_{11}}{\hat{S}_{21}}
\tag{2.2}
$$

with the following associated variance estimator

$$
\widehat{\text{Var}}\left(\hat{S}_{\text{JDA}}\right) = \hat{S}_{\text{JDA}}^2 \left[\frac{\widehat{\text{Var}}\left(\hat{S}_{11}\right)}{\hat{S}_{11}^2} + \frac{\widehat{\text{Var}}\left(\hat{S}_{21}\right)}{\hat{S}_{21}^2}\right]
\tag{2.3}
$$

For historical release-recapture studies like this, modeling could be performed to simplify the likelihood for common survival or detection probabilities downriver between the two release groups. However, modeling was not conducted because of the need to apply a different tag-life correction to the tags detected at each array for each release, and the fact that release sizes and detection probabilities were sufficient to meet precision requirements. Tag-life corrections were applied to the individual release Cormack (1964), Jolly (1965), and Seber (1965) (CJS) survival estimates.

Tag-life corrections were applied to single-release estimates of survival rate for treatment releases of fish passing through John Day Dam and The Dalles Dam and to associated reference releases. In the case of potential tag failure, additional parameters had to be added to the basic survival rate model based on methods of Townsend et al. (2006). Table 2.3 presents the expected probabilities of occurrence for each of the possible capture histories under tag failure where:

- L_{11} = probability a tag from release R_1 survives the first reach
- L_{12} = probability a tag from release R_1 survives both reach 1 and reach 2
- L_{13} = probability a tag from release R_1 survives reaches 1 through 3
- L_{21} = probability a tag from release R_2 survives the first reach
- L_{22} = probability a tag from release R_2 survives both reach 1 and reach 2
- L_{23} = probability a tag from release R_1 survives reaches 1 through 3.

Table 2.3. Detection histories and expected probabilities of occurrences for releases R_1 and R_2 in the presence of tag failure

Release	Detection History	Expected Probabilities
R_1	111	$S_{11}p_{11}S_{12}p_{12}\lambda_1 L_{13}$
	011	$S_{11}(1-p_{11})S_{12}p_{12}\lambda_1 L_{13}$
	101	$S_{11}p_{11}S_{12}(1-p_{12})\lambda_1 L_{13}$
	001	$S_{11}(1-p_{11})S_{12}(1-p_{12})\lambda_1 L_{13}$
	110	$S_{11}p_{11}S_{12}p_{12}(L_{12}-L_{13}\lambda_1)$
	010	$S_{11}(1-p_{11})S_{12}p_{12}(L_{12}-L_{13}\lambda_1)$
	100	$S_{11}p_{11}\left[(L_{11}-L_{12}S_{12})+S_{12}(1-p_{12})(L_{12}-L_{13}\lambda_1)\right]$
	000	$(1-L_{11}S_{11})+S_{11}(1-p_{11})\left[(L_{11}-L_{12}S_{12})+S_{12}(1-p_{12})(L_{12}-L_{13}\lambda_1)\right]$
R_2	111	$S_{21}p_{21}S_{22}p_{22}\lambda_2 L_{23}$
	011	$S_{21}(1-p_{21})S_{22}p_{22}\lambda_2 L_{23}$
	101	$S_{21}p_{21}S_{22}(1-p_{22})\lambda_2 L_{23}$
	001	$S_{21}(1-p_{21})S_{22}(1-p_{22})\lambda_2 L_{23}$
	110	$S_{21}p_{21}S_{22}p_{22}(L_{22}-L_{23}\lambda_2)$
	010	$S_{21}(1-p_{21})S_{22}p_{22}(L_{22}-L_{23}\lambda_2)$
	100	$S_{21}p_{21}\left[(L_{21}-L_{22}S_{22})+S_{22}(1-p_{22})(L_{22}-L_{23}\lambda_2)\right]$
	000	$(1-L_{21}S_{21})+S_{21}(1-p_{21})\left[(L_{21}-L_{22}S_{22})+S_{22}(1-p_{22})(L_{22}-L_{23}\lambda_2)\right]$

The joint likelihood can be expressed as

$$L = L\left(S_{11}, p_{11}, S_{12}, p_{12}, \lambda_1 \middle| R_1, \underset{\sim}{n}, \underset{\sim}{L}_1\right) \cdot L\left(S_{21}, p_{21}, S_{22}, p_{22}, \lambda_2 \middle| R_2, \underset{\sim}{m}, \underset{\sim}{L}_2\right) \tag{2.4}$$

The estimates of survival rate from likelihood model (Equation 2.4) should be more reliable because it takes into account possible tag failure and tag-life probabilities less than one.

The estimates of the survival rates and capture parameters in the likelihood model (Equation 2.4) were calculated treating the estimates of tag life (i.e., $\hat{L}_{11}$, $\hat{L}_{12}$, $\hat{L}_{21}$, and $\hat{L}_{22}$) as known constants. However, to calculate a realistic variance estimator for the survival-rate parameters, the error in the estimation of the tag-life probabilities had to be incorporated into an overall variance calculation.

The variance of the estimates of survival rates can be calculated using the total variance formula

$$\operatorname{Var}\left(\hat{S}_{PR}\right) = \operatorname{Var}_{\hat{\underset{\sim}{L}}}\left[E\left(\hat{S}_{PR} \middle| \hat{\underset{\sim}{L}}\right)\right] + E_{\hat{\underset{\sim}{L}}}\left[\operatorname{Var}\left(\hat{S}_{PR} \middle| \hat{\underset{\sim}{L}}\right)\right] \tag{2.5}$$

The above variance can therefore be estimated in stages using the expression

$$\operatorname{Var}\left(\hat{S}_{PR}\right) = s^2_{\hat{S}_{PR}|\hat{\underset{\sim}{L}}} + \operatorname{Var}\left(\hat{S}_{PR} \middle| \hat{\underset{\sim}{L}}\right) \qquad \text{(2.6}$$

The second term in Equation (2.6) was derived from the maximum likelihood model (Equation 2.4) conditioning on the tag-life probabilities (i.e., $\hat{\underset{\sim}{L}}$). The first variance component in Equation (2.6) was calculated using bootstrap resampling techniques (Efron and Tibshirani 1993). Alternative estimates of $\hat{\underset{\sim}{L}}$ were computed by bootstrapping both the observed tag-life data and travel-time data. For each estimated vector of tag-life parameters, survival rate was estimated using the likelihood model (Equation 2.4). One thousand bootstrap estimates of the tag-life parameters were calculated along with the corresponding conditional maximum likelihood estimates of survival rate. The first variance component in Equation (2.6) was then estimated by the quantity

$$s^2_{\hat{S}_{PR}|\hat{\underset{\sim}{L}}} = \frac{\sum_{b=1}^{1000}\left(\hat{S}_b - \hat{\bar{S}}\right)^2}{(1000-1)} \tag{2.7}$$

where $\hat{S}_b$ = the bth bootstrap estimate of survival rate $(b = 1,\ldots,1000)$,

$$\hat{\bar{S}} = \frac{\sum_{b=1}^{1000}\hat{S}_b}{1000} \tag{2.8}$$

Use of Equations (2.5) and (2.6) also permitted us to estimate the contribution of sampling error in tag-life parameters to the overall variance in survival-rate estimates.

2.5.3 Tests of Assumptions

Each release group (i.e., R_{v2} and R_2) provides the data to estimate reach survival rate based on the single release-recapture model (Skalski et al. 1998). The assumptions of the single release-recapture model are as follows:

1. Individuals marked for the study are a representative sample from the population of interest.
2. Survival and capture probabilities are not affected by tagging or sampling. That is, tagged animals have the same probabilities as untagged animals.
3. All sampling events are "instantaneous." That is, sampling occurs over a negligible distance relative to the length of the intervals between sampling events.
4. The fate of each tagged individual is independent of the fate of all others.
5. All tagged individuals alive at a sampling location have the same probability of surviving until the end of that event.
6. All tagged individuals alive at a sampling location have the same probability of being detected at that event.
7. All tags are correctly identified and the status of the smolt (i.e., alive or dead) is correctly assessed.

The first assumption concerns making inferences from the sample to the target population. For example, if inferences are sought to Chinook salmon smolts, then the sample of tagged fish should be drawn from that class of fish. Otherwise, nonstatistical inferences are necessary, justifying the similarity between the target population and the representative of acoustic-tagged fish. These assumptions could also be violated if smolts selected for acoustic tagging differ from the target population in a way that biases survivals (either lower or higher).

Assumption 2 again relates to making inferences to the population of interest (i.e., untagged fish). If tagging has a detrimental effect on fish survival, then survival-rate estimates from the single release-recapture design will tend to be negatively biased (i.e., underestimated).

The third assumption specifies that mortality is negligible immediately in the vicinity of the sampling stations, so that the estimated mortality is related to the river reaches in question and not during the sampling event. In the case of outmigrating smolts, the time they spend in the vicinity of a hydrophone array is brief relative to the size of the river reaches in question. This assumption is for the sake of mathematical convenience and should be fulfilled by the nature of the outmigration dynamics and deployment of the hydrophone array.

The assumption of independence (4) implies that the survival or death of one smolt has no effect on the fates of others. In the larger river system with tens of thousands of smolts, this is likely true. Furthermore, this assumption is common to all tag analyses with little or no evidence collected to suggest it is not generally true. Nevertheless, violations of assumption 4 have little effect on the point estimate but might bias the variance estimate with precision being less than calculated.

Assumption 5 specifies that a smolt's prior detection history has no effect on its subsequent survival. This could be violated if some smolts were self-trained to repeatedly go through turbine or spill routes or, alternatively, avoid routes because of prior experience. This occurrence is unlikely and can be assessed from the detection histories of the individual smolts. The lack of handling following initial release of acoustic-tagged smolts further minimizes the risk that subsequent detections influence survival. Similarly, assumption 6 could be violated if downstream detections are influenced by upstream passage routes taken by the smolts. Violation of this assumption is minimized by placing hydrophone arrays across the breadth of the river or below the mixing zones for smolts following different passages at the dam.

Assumption 7 implies that the smolts do not lose their tags and are not subsequently misidentified as dead or not captured, nor are dead fish falsely recorded as alive at detection locations. The use of surgically implanted tags should minimize the change of tag loss. Tag loss and tag failure would tend to result in a negative bias (i.e., underestimation) of smolt survival rates. The possibility of tag failure will depend on travel time relative to battery life. Dead fish drifting downstream could also result in a false-positive detections and upwardly bias estimates of survival rates. For this reason, tailrace hydrophone arrays are not proposed for this set of analyses.

To estimate survival rates from the paired releases, two additional assumptions for valid survival-rate estimates are necessary. These assumptions are

8. Survival in the lower river segment of the first reach is conditionally independent of survival in the upper river segment.
9. Releases R_{V2} and R_2 experience the same survival probabilities in the lower river segment of the first reach they share in common.

Assumption 8 implies that there is no synergistic relationship between survival processes in the two river segments within the first reach. In other words, smolts that survive the first river segment are no more or less susceptible to mortality in the second river segment than smolts released in the second river segment. Assumption 9 is satisfied by the in-river mixing of the release groups but can also be satisfied if the survival processes are stable over the course of smolt passage by the releases. A stable survival process might well be expected for one to a few days under similar flow and spill conditions. Furthermore, unlike paired-release methods of the earlier Mid-Columbia survival studies, the assumption of equal capture probabilities is unnecessary for estimation.

2.5.3.1 Tests Within a Release

For the single release-recapture model to be valid, certain data patterns should be evident from the capture histories. Both releases R_{V2} and R_2 permit tests of goodness-of-fit to the release-recapture model. A series of tests of assumptions was performed to determine the validity of the model (i.e., goodness-of-fit). The data from release R_{V2} were summarized by an m-array matrix of the form provided below:

Release Site	Recovery Site A3CR312(2)	A4CR237 (3)	A5CR203 (4)
JDA Dam Face (1)	m_{12}	m_{13}	m_{14}
JDA Tailwater (2)		m_{23}	m_{24}
TDA Tailwater (3)			m_{34}

JDA = John Day Dam.

The value of m_{ij} are the number of smolts detected at site i that are next detected at site j.

Burnham et al. (1987:65, 71-74) present a series of tests of assumptions called Test 2 that examine whether upstream detections affect downstream survival and/or detection. For release R_{V2}, a contingency table test can be performed using a table constructed as follows:

Test 2.2

m_{13}	m_{14}
m_{23}	m_{24}

χ_1^2 (2.9)

Burnham et al. (1987:65, 71-74) also present a series of tests of assumptions called Test 3 that examine whether upstream capture histories affect downstream survival and/or capture. For release R_{V2}, a contingency table can be constructed of the form:

Capture History at A5CR203	Capture History to A4CR237: 101	111
1		
0		

χ_1^2 (2.10)

This contingency table tests whether detection at A3CR312 has a subsequent effect on the capture history at A5CR203.

2.5.3.2 Tests of Mixing

For the estimates of dam-passage, concrete-passage, and route-specific survival rates to be valid, the detection data need to conform to the assumptions of statistical model. One assumption is the downstream mixing of release groups. A chi-square R × C contingency tables was used to evaluate the assumption of homogeneous arrival distributions for releases R_{V2} and R_2 at A3CR312 for JDA paired-release estimates. The chi-square contingency table tests of homogeneity are of the following form:

		Release	
		R_{V2}	R_2
Arrival Date	1		
	2		
	⋮	⋮	⋮
	D		

(2.11)

Instead of running specific chi-square tests on the TOA data, which are notoriously sensitive to slight departures in distributions, we plotted the cumulative hour of arrival of fish in each release pair (e.g., R_{V2} and R_2), fish stock, and dam (John Day Dam and The Dalles Dam) at the primary survival-detection array and looked for systematic deviations between the two arrival distributions over time. These plots and the plots of arrival times before and after midnight were used to assess the efficacy of the mixing assumption for the 2008 survival models.

To test whether releases with a paired-release (e.g., R_{V2} and R_2) have similar downstream survival and capture histories for Arlington, Oregon and below, likelihood ratio tests (LRTs) were performed to compare models. Sequential LRTs were used to help determine the most parsimonious model for the estimation of p_{11}, p_{21}, S_{12}, S_{22}, p_{12}, p_{22}, λ_1, and λ_2 (Figure 2.14).

2.5.4 Probabilities of Detection

Detection probabilities are an integral part of the survival estimation. For any particular passage route the following variables are defined (Figure 2.17):

- n_{10} = number of tagged smolts detected at the first array but not the second
- n_{01} = number of tagged smolts detected at the second array but not the first
- n_{11} = number of tagged smolts detected at both the first and second arrays.

From these counts of smolts with various route-specific detection histories, absolute passage abundance $(\hat{N})$ of tagged smolts can be estimated as

$$\hat{N} = \frac{(n_{10} + n_{11} + 1)(n_{01} + n_{11} + 1)}{(n_{11} + 1)} - 1 \tag{2.12}$$

or

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(n_{11} + 1)} - 1 \tag{2.13}$$

where $n_1 = n_{10} + n_{11}$ and $n_2 = n_{01} + n_{11}$ with associated variance estimate (Seber 1982:60)

$$\widehat{\text{Var}}(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - n_{11})(n_2 - n_{11})}{(n_{11} + 1)^2 (n_{11} + 2)} \tag{2.14}$$

The estimated probability of detection (p_1) in the first array is calculated as

$$\hat{p}_1 = \frac{n_{11}}{n_2} \tag{2.15}$$

and the probability of detection (p_2) in the second array as

$$\hat{p}_2 = \frac{n_{11}}{n_1} \tag{2.16}$$

The overall probability of a smolt being detected in the double-array system is given by

$$\hat{P} = 1 - (1 - \hat{p}_1)(1 - \hat{p}_2) = \frac{n_{11}(n_1 + n_2 + n_{11})}{n_1 n_2} . \tag{2.17}$$

Passage abundance was estimated for the powerhouse $\hat{N}_{PH}$, spillway $\hat{N}_{SP}$, and TSW $(\hat{N}_{TSW})$. For the fish entering the JBS, the PIT-tag detection system was used to provide a complete tally of that passage abundance $(\hat{N}_{JBS})$, assuming 100% detection efficiency.

The proportion of the acoustic-tagged smolts passing through the powerhouse $\hat{P}_{PH}$ was estimated as follows:

$$\hat{P}_{\text{PH}} = \frac{\hat{N}_{\text{PH}}}{\hat{N}_{\text{PH}} + \hat{N}_{\text{SP}} + \hat{N}_{\text{TSW}} + N_{\text{JBS}}} . \tag{2.18}$$

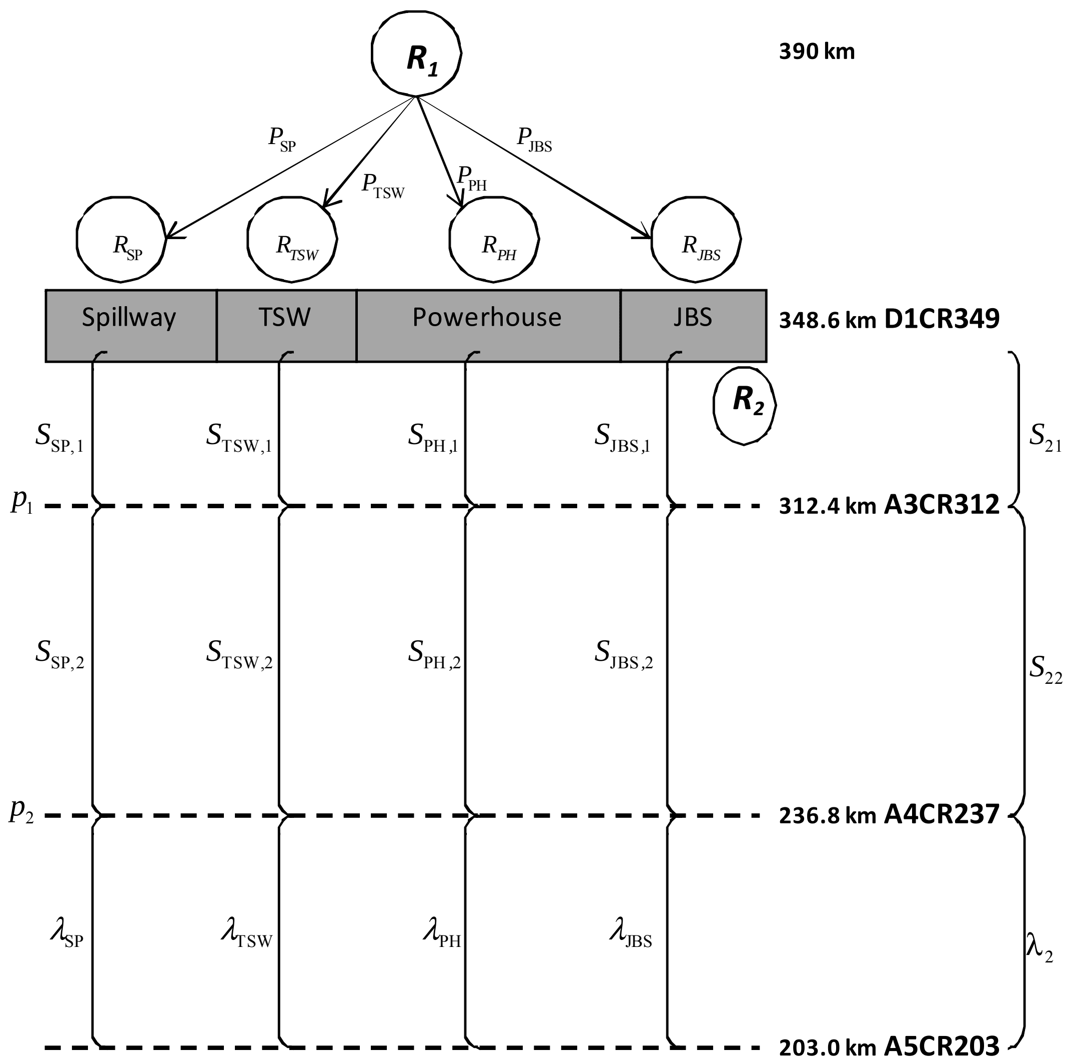

Figure 2.17. Schematic of route-specific passage and downstream recoveries for virtual releases at the spillway $\left(R_{\text{SP}}\right)$, TSW $\left(R_{\text{TSW}}\right)$, powerhouse $\left(R_{\text{PH}}\right)$, and JBS $\left(R_{\text{JBS}}\right)$

Using the delta method (Seber 1982:7-9), the variance of $\hat{P}_{PH}$ is approximated by

$$\widehat{\text{Var}}\left(\hat{P}_{\text{PH}}\right)=\frac{\hat{P}_{\text{PH}}\left(1-\hat{P}_{\text{PH}}\right)}{\hat{N}}+\hat{P}_{\text{PH}}^{2}\left(1-\hat{P}_{\text{PH}}\right)^{2}\cdot\left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right)}{\hat{N}_{\text{PH}}^{2}}+\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\left(\hat{N}_{\text{SP}}+\hat{N}_{\text{TSW}}+N_{\text{JBS}}\right)^{2}}\right], \tag{2.19}$$

where $\hat{N}=\hat{N}_{\text{PH}}+\hat{N}_{\text{SP}}+\hat{N}_{\text{TSW}}+N_{\text{JBS}}$. Values of $\hat{P}_{SP}$, $\hat{P}_{TSW}$, and $\hat{P}_{JBS}$ were estimated analogously to Equation (2.18) and associated variances estimated analogously to Equation (2.19). Note for N_{JBS} that $Var(N_{JBS})=0$.

2.5.5 Route-Specific Relative Survival Rates

The 2D hydrophone array in the John Day Dam forebay was used to identify fish known to have passed through the spillway, powerhouse, and TSWs (spill bays 15–16).

Smolts known to have passed through the various routes at John Day Dam (Figure 2.17) were detected by listening devices on downstream arrays to obtain their capture histories. To estimate survival, it is first necessary to quantify the number of smolts passing by various routes, as follows:

- R_{PH} = number of smolts known to have passed through the powerhouse
- n_{PH} = number of smolts among R_{PH} detected downriver
- R_{SP} = number of smolts known to have passed through the spillway
- n_{SP} = number of smolts among R_{SP} detected downriver
- R_{TSW} = number of smolts known to have passed through the TSW
- n_{TSW} = number of smolts among R_{TSW} detected downriver
- R_{JBS} = number of smolts known to have passed through the JBS
- n_{JBS} = number of smolts among R_{JBS} detected downriver.

Using the relative recoveries of smolts through the various routes compared to the powerhouse, the relative route-specific survival probabilities can be estimated, e.g., the spill bay,

$$RS_{\mathrm{SP/PH}} = \frac{\left(\dfrac{n_{\mathrm{SP}}}{R_{\mathrm{SP}}}\right)}{\left(\dfrac{n_{\mathrm{PH}}}{R_{\mathrm{PH}}}\right)} . \tag{2.20}$$

The variance of $RS_{\mathrm{SP/PH}}$ is estimated by

$$\widehat{\mathrm{Var}}\left(\widehat{RS}_{\mathrm{SP/PH}}\right) = \widehat{RS}^{2}_{\mathrm{SP/PH}}\left[\frac{1}{n_{\mathrm{PH}}} - \frac{1}{R_{\mathrm{PH}}} + \frac{1}{n_{\mathrm{SP}}} - \frac{1}{R_{\mathrm{SP}}}\right] . \tag{2.21}$$

The estimators of relative survival rates for the other three routes are analogous to Equation (2.20) and their variances analogous to Equation (2.21).

2.5.6 Route-Specific Passage Survival Rates

Using the smolts known to have passed through a specific route at the dam, absolute survival rates from the dam entrance to the tailrace release location were estimated using a paired release-recapture model analogous to Equation (2.2). The virtual release through a route was paired with the common tailrace release (R_2) (Figure 2.14). All routes shared the same downstream control group.

It should be noted that pairing a virtual release with the tailrace group is pairing fish that have resided in river and previously tagged with newly tagged and released fish. Any post-release handling mortality among the R_2 smolts will positively bias the estimates of route-specific survival rates.

Route-specific survival rates for the powerhouse-passed fish were estimated by the quotient

$$\hat{S}_{\text{PH}} = \frac{\hat{S}_{\text{PH},1}}{\hat{S}_{21}} \tag{2.22}$$

with associated variance estimator

$$\widehat{\text{Var}}\left(\hat{S}_{\text{PH}}\right) = \hat{S}_{\text{PH}}^2 \left[\frac{\widehat{\text{Var}}\left(\hat{S}_{\text{PH},1}\right)}{\hat{S}_{\text{PH},1}^2} + \frac{\widehat{\text{Var}}\left(\hat{S}_{21}\right)}{\hat{S}_{21}^2} \right] \tag{2.23}$$

Route-specific passage survival rates through the spillway, TSW, or JBS were calculated analogously to Equation (2.22) with associated variance estimators analogous to Equation (2.23).

2.5.7 Concrete-Passage Survival Rates

Two approaches to estimating concrete-passage survival through John Day Dam were used. The first approach uses the estimated passage proportions (Equation [2.18]) and route-specific estimates of survival rates (Equation [2.22]), where

$$\hat{S}_{\text{Concrete}} = \hat{P}_{\text{PH}} \cdot \hat{S}_{\text{PH}} + \hat{P}_{\text{SP}} \cdot \hat{S}_{\text{SP}} + \hat{P}_{\text{TSW}} \cdot \hat{S}_{\text{TSW}} + \hat{P}_{\text{JBS}} \cdot \hat{S}_{\text{JBS}} \tag{2.24}$$

This first method reconstructs the dam-passage survival rate by summing the survival contributions through each route. The second approach uses a paired release (Figure 2.14) based on fish known to have arrived at the dam (i.e., a virtual release) with the tailrace release R_2. A paired release-recapture model analogous to Equation (2.2) was used to estimate the overall concrete-passage survival rate based on fish known to have arrived at the dam face and the common tailrace release R_2 (Figure 2.14).

Both of the above approaches are susceptible to positive bias due to the pairing of in-river, previously tagged fish with newly tagged and released smolts. If the passage proportions and route-specific survival rates are estimated properly, both estimation approaches should produce similar, albeit possibly biased, estimates of the total concrete-passage survival rate.

2.5.8 Lower Granite Dam Tagged Fish – John Day Dam Concrete-Passage Survival Rate

Using tagged fish released at Lower Granite Dam (R) and regrouped at the John Day Dam-face array (R_V) and paired with John Day Dam (R_1) tailrace released fish, paired release-recapture methods were used to estimate concrete-passage survival rates. The detection arrays at A3CR312, A4CR237, and A5CR203 provided $2^3 = 8$ possible capture histories for each release group. A sample-size weighted-mean estimate of survival rate usually was estimated for the season because detection probabilities on the three downstream arrays rarely were homogeneous through time. When detection probabilities were homogeneous through time, as indicated by a nonsignificant chi-square test, virtual and tailrace release trials were pooled to estimate survival for the season.

In estimating the John Day Dam-passage survival rate for fish released at Lower Granite Dam, a fully parameterized paired release-recapture model can be written as follows:

$$
\begin{aligned}
L = & \binom{R_V}{\underset{\sim}{n}} \left(S_{11} p_{11} S_{12} p_{12}\right)^{n_{111}} \left(S_{11}\left(1-p_{11}\right) S_{12} p_{12} \lambda_1\right)^{n_{011}} \\
& \cdot \left(S_{11} p_{11} S_{12}\left(1-p_{12}\right) \lambda_1\right)^{n_{101}} \left(S_{11}\left(1-p_{11}\right) S_{12}\left(1-p_{12}\right) \lambda_1\right)^{n_{011}} \\
& \cdot \left(S_{11} p_{11} S_{12} p_{12}\left(1-\lambda_1\right)\right)^{n_{110}} \left(S_{11}\left(1-p_{11}\right) S_{12} p_{12}\left(1-\lambda_1\right)\right)^{n_{010}} \\
& \cdot \left(S_{11} p_{11}\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{100}} \\
& \cdot \left(\left(1-S_{11}\right)+S_{11}\left(1-p_{11}\right)\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{000}} \\
& \cdot \binom{R_1}{\underset{\sim}{m}} \left(S_{21} p_{21} S_{22} p_{22} \lambda_2\right)^{m_{111}} \left(S_{21}\left(1-p_{21}\right) S_{22} p_{22} \lambda_2\right)^{m_{011}} \\
& \cdot \left(S_{21} p_{21} S_{22}\left(1-p_{22}\right) \lambda_2\right)^{m_{101}} \left(S_{21}\left(1-p_{21}\right) S_{22}\left(1-p_{22}\right) \lambda_2\right)^{m_{011}} \\
& \cdot \left(S_{21} p_{21} S_{22} p_{22}\left(1-\lambda_2\right)\right)^{m_{110}} \left(S_{21}\left(1-p_{21}\right) S_{22} p_{22}\left(1-\lambda_2\right)\right)^{m_{010}} \\
& \cdot \left(S_{21} p_{21}\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{100}} \\
& \cdot \left(\left(1-S_{21}\right)+S_{21}\left(1-p_{21}\right)\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{000}},
\end{aligned}
\tag{2.28}
$$

where $\underset{\sim}{n}$ and $\underset{\sim}{m}$ are the vector of counts associated with the downstream capture histories of releases R_V and R_1, respectively. For example, n_{101} is the number of R_V fish detected at A3CR312, not detected at A4CR237, and subsequently detected at A5CR203.

The concrete-passage survival rate was estimated as the ratio

$$
\hat{S}_{LGR} = \frac{\hat{S}_{11}}{\hat{S}_{21}}
\tag{2.29}
$$

with associated variance estimator

$$\widehat{\text{Var}}\left(\hat{S}_{LGR}\right)=\hat{S}_{LGR}^{2}\left[\frac{\widehat{\text{Var}}\left(\hat{S}_{11}\right)}{\hat{S}_{11}^{2}}+\frac{\widehat{\text{Var}}\left(\hat{S}_{21}\right)}{\hat{S}_{21}^{2}}\right]. \tag{2.30}$$

Model selection procedures were used to find the most parsimonious model to describe the paired release-recapture data as described in Section 2.5.2 immediately after Equation (2.3).

2.5.9 Dam-Passage Survival Rate for The Dalles Dam

In spring, tagged fish were regrouped at The Dalles Dam forebay entrance array (A3CR312) to define virtual releases R_v and the dam-passage survival rate was estimated using a single release-recapture method. There were no releases of YC or STH in The Dalles Dam tailrace in spring so paired release estimates were not possible. In summer, tagged fish were regrouped at the same location (R_v) and virtually released and paired with fish released from The Dalles Dam tailrace (R_3) to obtain dam-passage survival rates using the paired release-recapture method. The detection arrays at A4CR237, A5CR203, and A6CR192 provided $2^3 = 8$ possible capture histories for each release group. A sample-size weighted-mean estimate of survival usually was estimated for the season because detection probabilities on the three downstream arrays rarely were homogeneous through time. When detection probabilities were homogeneous through time, trials were pooled throughout the season. In estimating The Dalles Dam-passage survival rate for fish virtually released in The Dalles Dam forebay, the fully parameterized paired release-recapture model can be written as follows:

$$\begin{aligned}
L=&\binom{R_V}{\underset{\sim}{n}}\left(S_{11}p_{11}S_{12}p_{12}\right)^{n_{111}}\left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\lambda_1\right)^{n_{011}}\\
&\cdot\left(S_{11}p_{11}S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{101}}\left(S_{11}\left(1-p_{11}\right)S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{011}}\\
&\cdot\left(S_{11}p_{11}S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{110}}\left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{010}}\\
&\cdot\left(S_{11}p_{11}\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{100}}\\
&\cdot\left(\left(1-S_{11}\right)+S_{11}\left(1-p_{11}\right)\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{000}}\\
&\cdot\binom{R_3}{\underset{\sim}{m}}\left(S_{21}p_{21}S_{22}p_{22}\lambda_2\right)^{m_{111}}\left(S_{21}\left(1-p_{21}\right)S_{22}p_{22}\lambda_2\right)^{m_{011}}\\
&\cdot\left(S_{21}p_{21}S_{22}\left(1-p_{22}\right)\lambda_2\right)^{m_{101}}\left(S_{21}\left(1-p_{21}\right)S_{22}\left(1-p_{22}\right)\lambda_2\right)^{m_{011}}\\
&\cdot\left(S_{21}p_{21}S_{22}p_{22}\left(1-\lambda_2\right)\right)^{m_{110}}\left(S_{21}\left(1-p_{21}\right)S_{22}p_{22}\left(1-\lambda_2\right)\right)^{m_{010}}\\
&\cdot\left(S_{21}p_{21}\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{100}}\\
&\cdot\left(\left(1-S_{21}\right)+S_{21}\left(1-p_{21}\right)\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{000}},
\end{aligned} \tag{2.31}$$

where $\underset{\sim}{n}$ and $\underset{\sim}{m}$ are the vector of counts associated with the downstream capture histories of releases R_V and R_3, respectively. For example, n_{101} is the number of R_V fish detected at A4CR237, not detected at A5CR203, and subsequently detected at A6CR192.

The dam-passage survival rate was estimated as the ratio

$$\hat{S}_{\text{TDA}} = \frac{\hat{S}_{11}}{\hat{S}_{21}} \tag{2.32}$$

with associated variance estimator

$$\widehat{\text{Var}}\left(\hat{S}_{\text{TDA}}\right) = \hat{S}_{\text{TDA}}^{2}\left[\frac{\widehat{\text{Var}}\left(\hat{S}_{11}\right)}{\hat{S}_{11}^{2}} + \frac{\widehat{\text{Var}}\left(\hat{S}_{21}\right)}{\hat{S}_{21}^{2}}\right]. \tag{2.33}$$

2.6 Statistical Methods – Fish Passage

Fish passage was characterized by estimating various passage efficiencies (e.g., spillway-passage efficiency and TSW-passage efficiency). Spatial and temporal trends in passage and residence and egress times were also estimated, as described below.

2.6.1 Fish Passage Characterization

Fish-passage efficiency (FPE) is defined as the proportion of fish that pass through the dam through nonturbine routes (i.e., spill, TSW, or JBS). In this study, FPE was estimated by the sum of the proportions nonturbine passage proportions:

$$\widehat{\text{FPE}} = \hat{P}_{\text{SP}} + \hat{P}_{\text{TSW}} + \hat{P}_{\text{JBS}} \tag{2.34}$$

with associated variance estimator

$$\widehat{\text{Var}}\left(\widehat{\text{FPE}}\right) = \frac{\widehat{\text{FPE}}\left(1-\widehat{\text{FPE}}\right)}{\hat{N}} + \widehat{\text{FPE}}^{2}\left(1-\widehat{\text{FPE}}\right)^{2} \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right)}{\hat{N}_{\text{PH}}^{2}} + \frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\left(\hat{N}_{\text{SP}} + \hat{N}_{\text{TSW}} + \hat{N}_{\text{JBS}}\right)^{2}}\right]. \tag{2.35}$$

Spillway-passage efficiency (SE) is defined as the proportion of fish that pass through the spillway (i.e., TSW and non-TSW spill bays). In the case of this study, SE refers to fish that pass through the spillway, or TSW. SE was estimated by the sum

$$\widehat{\text{SE}} = \hat{P}_{\text{SP}} + \hat{P}_{\text{TSW}} \tag{2.36}$$

with associated variance estimator

$$\operatorname{Var}\left(\widehat{\mathrm{SE}}\right)=\frac{\widehat{\mathrm{SE}}\left(1-\widehat{\mathrm{SE}}\right)}{\hat{N}}+\widehat{\mathrm{SE}}^{2}\left(1-\widehat{\mathrm{SE}}\right)^{2}
\cdot\left[\frac{\widehat{\operatorname{Var}}\left(\hat{N}_{\mathrm{SP}}\right)+\left(\hat{N}_{\mathrm{TSW}}\right)}{\left(\hat{N}_{\mathrm{SP}}+\hat{N}_{\mathrm{TSW}}\right)^{2}}+\frac{\widehat{\operatorname{Var}}\left(\hat{N}_{\mathrm{PH}}\right)+\widehat{\operatorname{Var}}\left(\hat{N}_{\mathrm{JBS}}\right)}{\left(\hat{N}_{\mathrm{PH}}+\hat{N}_{\mathrm{JBS}}\right)^{2}}\right]. \tag{2.37}$$

Spillway-passage effectiveness (SEF) is defined as the ratio of spillway-passage efficiency divided by the proportion of water passing the spillway relative to the total water discharge through the dam. In the case of this study, SEF was estimated as

$$\widehat{\mathrm{SEF}}=\frac{\hat{P}_{\mathrm{SP}}+\hat{P}_{\mathrm{TSW}}}{\left(\frac{f_{\mathrm{SP}}}{F}\right)}=\widehat{\mathrm{SE}}\left(\frac{F}{f_{\mathrm{SP}}}\right) \tag{2.38}$$

where F = total water volume discharge at the dam and f = total water volume discharge through the spillway and TSW. The variance of $\widehat{\mathrm{SEF}}$ was calculated as

$$\widehat{\operatorname{Var}}\left(\widehat{\mathrm{SEF}}\right)=\widehat{\operatorname{Var}}\left(\widehat{\mathrm{SE}}\right)\left(\frac{F}{f}\right)^{2}. \tag{2.39}$$

Top spillway weir passage efficiency (TSWE) is defined as the proportion of smolts passing the dam through the TSW spill bays. For this study, the efficiency of TSW passage was expressed by

$$\widehat{\mathrm{TSWE}}=\hat{P}_{\mathrm{TSW}} \tag{2.40}$$

with associated variance estimator

$$\widehat{\operatorname{Var}}\left(\widehat{\mathrm{TSWE}}\right)=\frac{\hat{P}_{\mathrm{TSW}}\left(1-\hat{P}_{\mathrm{TSW}}\right)}{\hat{N}}+\hat{P}_{\mathrm{TSW}}{}^{2}\left(1-\hat{P}_{\mathrm{TSW}}\right)^{2}
\cdot\left[\frac{\widehat{\operatorname{Var}}\left(\hat{N}_{\mathrm{TSW}}\right)}{\hat{N}_{\mathrm{TSW}}^{2}}+\frac{\widehat{\operatorname{Var}}\left(\hat{N}_{\mathrm{SP}}\right)+\widehat{\operatorname{Var}}\left(\hat{N}_{\mathrm{PH}}\right)+\widehat{\operatorname{Var}}\left(\hat{N}_{\mathrm{JBS}}\right)}{\left(\hat{N}_{SP}+\hat{N}_{\mathrm{PH}}+\hat{N}_{\mathrm{JBS}}\right)^{2}}\right]. \tag{2.41}$$

The TSW passage effectiveness (TSWEF) is defined as TSW passage efficiency divided by the proportion of water discharge through the dam that passed through TSW spill bays. For this study, the effectiveness of TSW was expressed as the quotient

$$\widehat{\mathrm{TSWEF}}=\frac{\hat{P}_{\mathrm{TSW}}}{\left(\frac{f_{\mathrm{TSW}}}{F}\right)}=\widehat{\mathrm{TSWE}}\left(\frac{F}{f_{\mathrm{TSW}}}\right) \tag{2.42}$$

where f_{TSW} = total water volume discharge through the TSW.

The variance of the $\widehat{\text{TSWEF}}$ was estimated by the quantity

$$\widehat{\text{Var}}\left(\widehat{\text{TSWEF}}\right)=\widehat{\text{Var}}\left(\widehat{\text{TSWE}}\right)\cdot\left(\frac{F}{f_{\text{TSW}}}\right)^2 . \tag{2.43}$$

Fish-guidance efficiency (FGE) is the proportion of smolts entering turbines that were subsequently guided by in-turbine screens to the JBS. It was estimated by the proportion

$$\widehat{\text{FGE}}=\hat{P}_{\text{JBS}} \tag{2.44}$$

with the associated variance estimator

$$\widehat{\text{Var}}\left(\widehat{\text{FGE}}\right)=\frac{\widehat{\text{FGE}}\left(1-\widehat{\text{FGE}}\right)}{\hat{N}}+\widehat{\text{FGE}}^2\left(1-\widehat{\text{FGE}}\right)^2 \cdot\left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\hat{N}_{\text{JBS}}^2}+\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right)}{\left(\hat{N}_{SP}+\hat{N}_{\text{PH}}+\hat{N}_{\text{TSW}}\right)^2}\right]. \tag{2.45}$$

The passage efficiency of the JBS (JBSE) is the proportion of fish passing the dam through the JBS:

$$\text{JBSE}=\hat{P}_{\text{JBS}} \tag{2.46}$$

with the associated variance estimator

$$\widehat{\text{Var}}\left(\widehat{\text{JBSE}}\right)=\frac{\hat{P}_{\text{JBS}}\left(1-\hat{P}_{\text{JBS}}\right)}{\hat{N}}+\hat{P}_{\text{JBS}}^2\left(1-\hat{P}_{\text{JBS}}\right)^2 \cdot\left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\hat{N}_{\text{JBS}}^2}+\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right)}{\left(\hat{N}_{\text{PH}}+\hat{N}_{SP}+\hat{N}_{\text{TSW}}\right)^2}\right]. \tag{2.47}$$

2.6.2 Spatial Trends

Based on detections on the dam-face array and 3D tracking, we were able to estimate the horizontal distribution of passage of each stock of fish at John Day Dam according to the individual turbine and spill bay of passage. The same 3D tracking data set allowed us to evaluate the vertical distribution of smolts within 75 m of the dam.

For a broader picture of fish behavior in the forebay, we compared the distribution of smolts detected on the forebay entrance array 2 km upstream of John Day Dam with the distribution of smolt passage at the dam. Smolt detections on the forebay array were assigned to horizontal blocks corresponding to locations upstream of dam structures, as follows (from south to north): PH1–8 = powerhouse units 1–8, PH9–16 = powerhouse units 9–16, skeleton bays, SW17–20 = spill bays 17–20, SW15–16 = spill bays 15–16 (each with a TSW), and SW1–14 = spill bays 1–14. Passage locations also were grouped into blocks of routes with the same names used to describe smolt arrivals, except that skeleton bays were dropped because they could not pass fish. This approach allowed us to examine how smolts behaviorally responded to the dam by avoiding or selecting blocks of passage routes. Similar arrival and passage distributions would suggest that smolt responses to forebay conditions and operations were limited, whereas substantial shifts in those distributions would indicate that smolts were responding to forebay conditions or operations by selecting preferred blocks of routes.

2.6.3 Residence and Egress Times and Travel Rates

As mentioned above, the John Day Dam forebay array was used to create a virtual release for fish as they enter the forebay 2 km upstream of John Day Dam. The John Day Dam-face array was used to create a virtual release for fish known to have passed John Day Dam and to estimate the route of passage at the dam using 3D tracking and last-detection data. The time of last detection by the dam-face array minus the time of first detection on the forebay array provide an estimate of forebay residence time. The time of first detection by the John Day Dam tailwater egress array minus the time of last detection on the dam-face array provided an estimate of relative egress time.

2.7 Statistical Methods – Fish Tracking

Fish behavior was assessed by 3D tracking of JSATS-tagged fish in the immediate forebay of John Day Dam.

2.7.1 Tracking Algorithms

Acoustic tracking is a common technique in bioacoustics based on TOA differences (TOADs) among different hydrophones. Usually, the process requires a three-hydrophone array for 2D tracking and a four-hydrophone array for 3D tracking. For this study, only 3D tracking was performed.

Consider a transmitting source (tag) in the range of a four-hydrophone array. The boldface letters indicate matrices or vectors. The source (**S**) and receiver (**r**) position vectors are defined as follows:

$$\begin{aligned} \mathbf{S} &= (s_x, s_y, s_z)^{\mathrm{T}} \\ \mathbf{r}_i &= (x_i, y_i, z_i)^{\mathrm{T}} \qquad i = 0,1,2,3 \end{aligned} \tag{2.48}$$

The distance between transmitting source and receivers gives

$$(s_x - x_i)^2 + (s_y - y_i)^2 + (s_z - z_i)^2 = c^2 (t_i + T_0)^2, \qquad i = 0,1,2,3 \tag{2.49}$$

where c is the speed of sound, T_0 is the time of travel from the source to the reference receiver (receiver 0), and t_i is the TOAD between receiver *i* and the reference receiver. With t_i measured by the common clock, the source position vector and T_0 are the four unknowns to be solved by the four distance equations.

There are several mathematical ways to obtain the exact solutions to the equations above (Watkins and Schevill 1972; Fang 1990; Spiesberger and Fristrup 1990; Juell and Westerberg 1993; Wahlberg et al. 2001). Wahlberg et al. (2001) applied a synthesis of the methods used by Watkins and Schevill (1972) and Spiesberger and Fristrup (1990). It has the advantage of giving the same mathematical form for 2D and 3D array systems, and for both minimum number of receivers arrays and over-determined arrays. Assuming that the first receiver is located at the origin of the coordinate system and subtracting Equation (2.49) for $i = 0$ from Equation (2.49) for $i = 1$, 2 and 3, we obtain

$$2\mathbf{R}^T\mathbf{S} + 2c^2\mathbf{t}T_0 = \mathbf{b} \tag{2.50}$$

where

$$\mathbf{R} = \begin{bmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \\ z_1 & z_2 & z_3 \end{bmatrix},\quad \mathbf{t} = \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix},\quad \mathbf{b} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}, \text{ and } b_i = \|\mathbf{r}_i\|^2 - c^2 t_i^2 \tag{2.51}$$

From Equation (2.4),

$$\mathbf{S} = \mathbf{R}^{-T}(\frac{1}{2}\mathbf{b} - c^2\mathbf{t}T_0) \tag{2.52}$$

substituting Equation (2.5) to the relationship $\mathbf{S}^T\mathbf{S} = c^2{T_0}^2$ gives

$$T_0 = \frac{-p \pm \sqrt{p^2 - aq}}{a} \tag{2.53}$$

where

$$a = c^4\mathbf{t}^T\mathbf{R}^{-1}\mathbf{R}^{-T}\mathbf{t} - c^2,\quad p = -\frac{1}{2}c^2\mathbf{t}^T\mathbf{R}^{-1}\mathbf{R}^{-T}\mathbf{b}, \text{ and } q = \frac{1}{4}\mathbf{b}^T\mathbf{R}^{-1}\mathbf{R}^{-T}\mathbf{b} \tag{2.54}$$

After T_0 is determined, source position (**S**) is then obtained by Equation (2.52).

Note that there are two possible solutions for T_0. If they are both complex, then there is no exact solution for the given configuration and TOADs. A negative T_0 is nonphysical. When there are two real non-negative solutions, then both provide two possible locations for the source. In the John Day Dam 2008 study, all hydrophones were installed at the dam face and were oriented upstream to detect sound emanating from upstream sources only, so estimated source location downstream of the dam face could not be real.

However, an exact solution may not be available due to the nonlinearity of the four distance equations and the errors in sound speed, time measurements, and hydrophone location uncertainties. Therefore, we estimate the location of the sound source iteratively by minimizing the position errors. The most common methods are iterative Taylor-series methods or variant Newton-Gaussian methods, which linearize the equation using Taylor expansion and search for an approximate numerical solution iteratively by minimizing the least-square error (Foy 1976). Several other approaches have been developed: maximum likelihood algorithms (Chan 1994; Chan et al. 2006) that start from maximum likelihood functions instead of linearizing the equations first and derive a close-form approximation; the spherical interpolation approach (Torieri 1984); and linear-correction (Cheung et al. 2004). The codes for these approximation methods were developed but not applied to the John Day Dam 2008 study because of the high success rates of exact solvers.

After the source location was obtained from 3D tracking, a set of artificial TOADs (t'_1, t'_2, t'_3) and T'_0 was computed directly using the 3D-tracked source location for the given hydrophone locations and the speed of sound. The total time error was then defined as

$$\Delta T = \sqrt{(t'_1 - t_1)^2 + (t'_2 - t_2)^2 + (t'_3 - t_3)^2 + (T'_0 - T_0)^2} \, . \tag{2.55}$$

The detailed steps for 3D tracking are as follows:

- Pool together all detections of the same signal from different hydrophones. If more than four hydrophones detect the same tag signal, select the four with the best geometry configuration for 3D tracking (Wahlberg et al 2001; Ehrenberg and Steig 2002). Compute the TOAD directly from detection time because all hydrophones are synchronized to a universal GPS clock with accuracy within 0.4 µs.
- Apply tracking solvers to estimate 3D locations and output solutions that are physical and within the pre-specified ΔT (10 µs for the John Day Dam 2008 study).
- Apply order 3 median filtering (Lim 1990) to remove spurious locations and smoothing fish tracks.
- Assign a route of passage based on the y component of the last tracked location.
- Assign another set of passage routes based on the detections on the last two hydrophones on different piers. For example, if the two hydrophones were at Pier 1 (numbering starting from the Oregon side) and Pier 2, then the passage route would be assigned to the first turbine unit.
- Compare the two sets of passage routes. If the difference for a fish is more than one bay, check its trajectory and detection history manually.

2.7.2 Tracking Error Analysis

To assess the accuracy of the deployed hydrophone arrays and validate tracking solvers, several tests were conducted with beacon tags fixed at various locations or drifting upstream of Turbine 9 intakes and spill bay 11. Two hydrophones were installed at each pier nose at two elevations throughout the dam and all of the systems had similar functional and geometric designs, so only one turbine unit and one spill bay were selected for model validation and error analysis. The locations of the acoustic tags were obtained through a Real Time Kinematic GPS system, which provided benchmark measurements for comparison with the 3D-tracked locations. The accuracy was assessed in terms of median and root mean square (RMS) values of the differences between GPS measurements and the locations computed from 3D tracking:

$$
\begin{aligned}
\Delta x_i &= \left| x_i^{3D} - x_i^{GPS} \right|, \qquad i = 1,\ldots N \\
\Delta y_i &= \left| y_i^{3D} - y_i^{GPS} \right|, \qquad i = 1,\ldots N \\
\Delta z_i &= \left| z_i^{3D} - z_i^{GPS} \right|, \qquad i = 1,\ldots N \\
\Delta d_i &= \sqrt{\Delta x_i^{\,2} + \Delta y_i^{\,2} + \Delta z_i^{\,2}}, \qquad i = 1,\ldots N \\
RMS_x &= \sqrt{\frac{1}{N}\sum_{i=1}^{N} \Delta x_i^{\,2}} \\
RMS_y &= \sqrt{\frac{1}{N}\sum_{i=1}^{N} \Delta y_i^{\,2}} \\
RMS_z &= \sqrt{\frac{1}{N}\sum_{i=1}^{N} \Delta z_i^{\,2}} \\
RMS_d &= \sqrt{\frac{1}{N}\sum_{i=1}^{N} \Delta d_i^{\,2}}
\end{aligned}
\qquad (2.56)
$$

where, N was the number of estimated positions and x, y, z were the three components in the dam-face coordinate system. The dam-face coordinate system was defined as follows: the x-axis was perpendicular to the dam and looking straight into forebay. The y-axis was along the dam face from the Oregon to the Washington side. The z-axis was vertical, pointing upward.

The acoustic transmitters used for the error study had the same source power as JSATS acoustic tags i.e., 155 dB relative to 1 µPa at 1 m. The 2008 JSATS acoustic transmitters were attached at different water depths to a rope that was held steady by an anchor at the bottom of the forebay. For the fixed location tests, seven transmitters were suspended at 1, 2, 3, 5, 10, 15, and 20 m below the water surface, respectively; and were held at various locations from 5 m to 100 m in the forebay (Figures 2.18 and 2.19). For the drogue drifts, six tags were held at 1, 2, 3, 5, 10, and 15 m below the water surface, respectively, and started drifting about 100 m away from the dam. The GPS measurement point was about 1 m above the water surface. Because of the windy conditions and underwater currents, the rope holding the beacons was not always straight or steady. There could be large uncertainties in the locations for the tags in deep water, so only beacons at 2, 3, and 5 m below the water surface were used for the accuracy assessment. Detailed results for the 2-m tags are shown in Tables 2.4 and 2.5 and in Figures 2.20 and 2.21.

The X component was the distance to the dam face. At the spillway, the median errors ranged from 0.06 to 0.83 m for distances up to 75 m, and ranged from 0.67 to 2.38 m at 100 m. The RMS errors fell between 0.1 and 2.12 m for distances up to 75 m, and between 1.18 and 5.24 at 100 m. At the powerhouse, the median errors were within 0.82 to 2.00 m and the RMS errors were within 0.90 to 3.93 m throughout the test. However, for distances less than 30 m, both median and RMS errors were within 1.72 m.

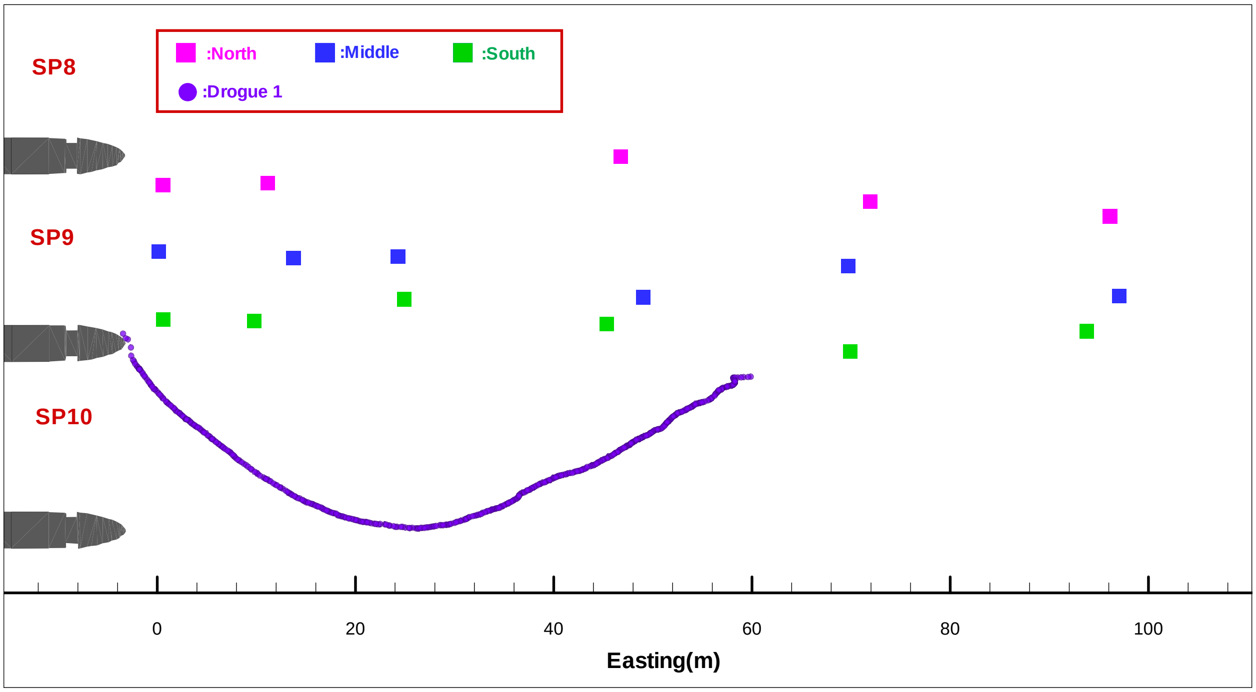

Figure 2.18. Test locations at the John Day Dam spillway for 3D-tracking error analysis

The Y component was used for the assignment of the route of fish passage and had the highest accuracy among the three components. At the spillway, median errors ranged from 0.06 to 0.27 m and RMS errors ranged from 0.05 to 0.58 m. When the distance was less than 50 m, the maximum median errors and RMS errors were within 0.2 to 0.26 m. At the powerhouse, the median errors ranged from 0.03 to 0.48 m throughout the test. The RMS errors were within 0.5 m for distances up to 75 m and within 0.84 m for distances up to 100 m except for the 3-m beacon at 50-m distance in the middle section and 100-m distance in the south section.

The Z component was in the vertical plane. At the spillway, median errors ranged from 0.24 to 1.33 m for all distances. The RMS errors ranged from 0.24 to 2.78 m for distances up to 75 m and were within 0.99 to 4.61 m except the for 3-m-deep beacon tag 100 m toward the south. At the powerhouse, the median errors were within 0.1 to 2.1 m for distances up to 30 m and 1.48 to 8.78 m for distances from 50 to 100 m. The RMS errors fell between 0.18 and 3.99 m for distances up to 30 m and between 2.41 and 8.63 m for distances from 50 to 100 m. However at the 5-m distance, the median errors fell to 0.03 to 0.45 m and RMS errors reduced to 0.04 to 0.65 m except for the 2-m beacon at a 5-m distance in the south section.

Both median and RMS errors were computed from 3D-tracked positions that were slightly smoothed by order 3 median filtering without removing outliers. If outliers were removed or additional smoothing (such as Kalman filtering) algorithms were applied, the RMS errors would be reduced significantly. In addition, windy conditions and underwater currents also could cause differences between GPS-estimated positions and true beacon-tag locations, resulting in an increase in RMS errors.

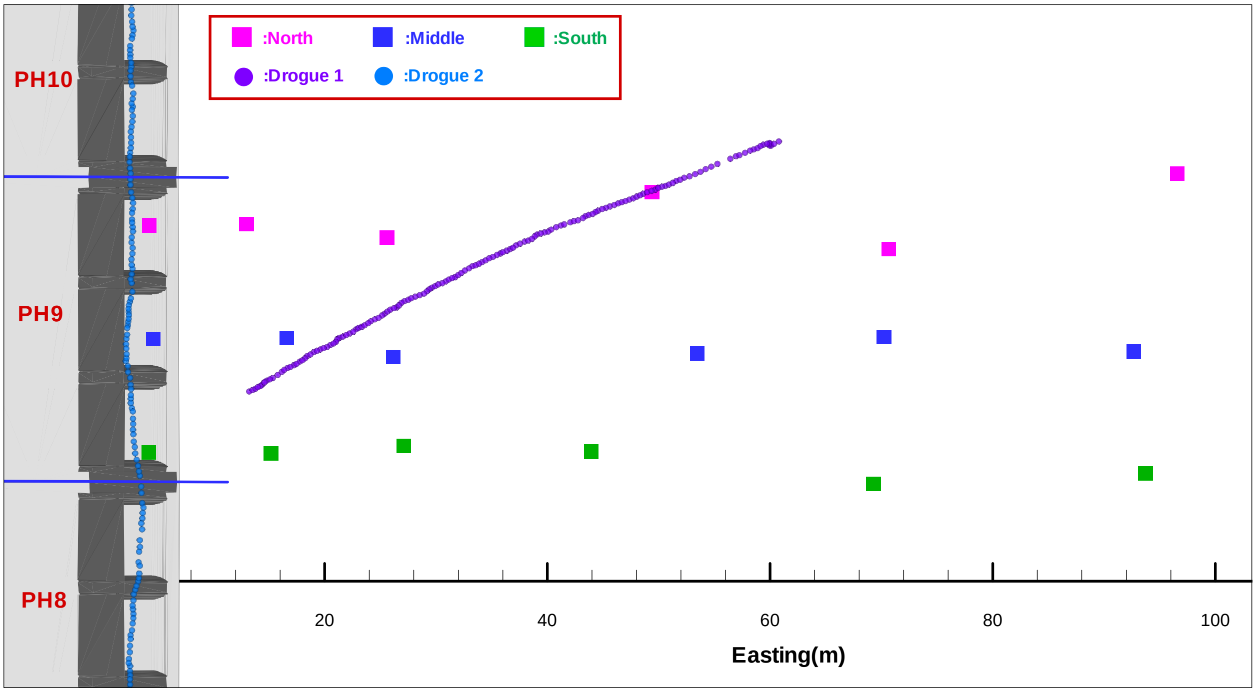

Figure 2.19. Test locations at John Day Dam powerhouse for 3D-tracking error analysis

Table 2.4. Median and route mean square errors in the position estimates of acoustic tags located 2 m below the water surface upstream of the John Day Dam spillway

Location	Distance (m)	Median (Δx_i)	Median (Δy_i)	Median (Δz_i)	Median (Δd_i)	RMS_x	RMS_y	RMS_z	RMS_d
North	5	0.06	0.06	0.39	0.40	0.10	0.08	0.39	0.41
	15	0.06	0.07	0.35	0.37	0.12	0.11	0.33	0.37
	50	0.22	0.07	0.57	0.64	0.38	0.12	2.13	2.16
	75	0.40	0.11	0.46	0.68	0.66	0.16	1.35	1.51
	100	0.52	0.13	0.42	0.78	1.31	0.25	0.99	1.66
Middle	5	0.34	0.05	0.31	0.69	0.97	0.08	0.93	1.35
	15	0.06	0.05	0.41	0.44	0.37	0.09	2.11	2.15
	30	0.21	0.02	0.87	0.94	0.37	0.16	1.82	1.86
	50	0.34	0.11	0.53	0.71	0.98	0.17	2.19	2.41
	75	0.51	0.11	0.58	0.99	0.86	0.16	1.80	2.00
	100	1.18	0.17	0.59	1.64	1.92	0.27	2.17	2.90
South	5	0.07	0.06	0.40	0.42	0.13	0.08	0.43	0.45
	15	0.06	0.04	0.40	0.40	0.32	0.07	0.40	0.52
	30	0.11	0.05	0.53	0.56	0.21	0.09	0.54	0.59
	50	0.18	0.04	0.56	0.60	0.35	0.11	0.66	0.75
	75	0.55	0.18	0.57	0.95	0.79	0.24	1.78	1.96
	100	1.13	0.22	0.59	1.67	2.16	0.56	2.25	3.17

Table 2.5. Median and route mean square errors in the position estimates of acoustic tags located 2 m below the water surface upstream of the John Day Dam powerhouse

Location	Distance (m)	Median (Δx_i)	Median (Δy_i)	Median (Δz_i)	Median (Δd_i)	RMS_x	RMS_y	RMS_z	RMS_d
North	5	0.85	0.15	0.14	0.96	1.05	0.17	0.65	1.25
	15	0.87	0.08	0.73	1.16	1.23	0.22	1.50	1.95
	30	0.99	0.04	1.80	2.07	1.33	0.22	2.45	2.80
	50	1.00	0.06	3.97	4.11	1.36	0.66	3.91	4.19
	75	1.16	0.06	5.66	5.81	1.54	0.29	4.66	4.92
	100	9.78	0.38	4.03	12.00	21.28	8.15	4.57	23.24
Middle	5	1.17	0.03	0.14	1.18	1.65	0.16	0.48	1.73
	15	1.25	0.02	1.13	1.69	1.32	0.18	1.43	1.96
	30	1.09	0.02	1.92	2.22	1.14	0.14	2.05	2.35
	50	1.00	0.07	4.34	4.48	1.09	0.65	3.97	4.17
	75	1.10	0.10	4.26	4.66	1.46	0.34	4.54	4.78
	100	1.05	0.13	3.45	3.77	3.52	0.88	4.15	5.52
South	5	0.92	0.12	0.45	1.17	1.31	0.31	1.50	2.01
	15	1.33	0.09	0.91	1.61	1.30	0.18	1.57	2.05
	30	0.85	0.11	1.97	2.16	1.02	0.30	2.12	2.38
	50	0.92	0.10	1.48	1.75	0.90	0.17	2.41	2.58
	75	1.07	0.11	1.40	2.03	1.49	0.41	3.61	3.93
	100	1.07	0.14	3.56	3.82	1.76	0.32	4.22	4.58

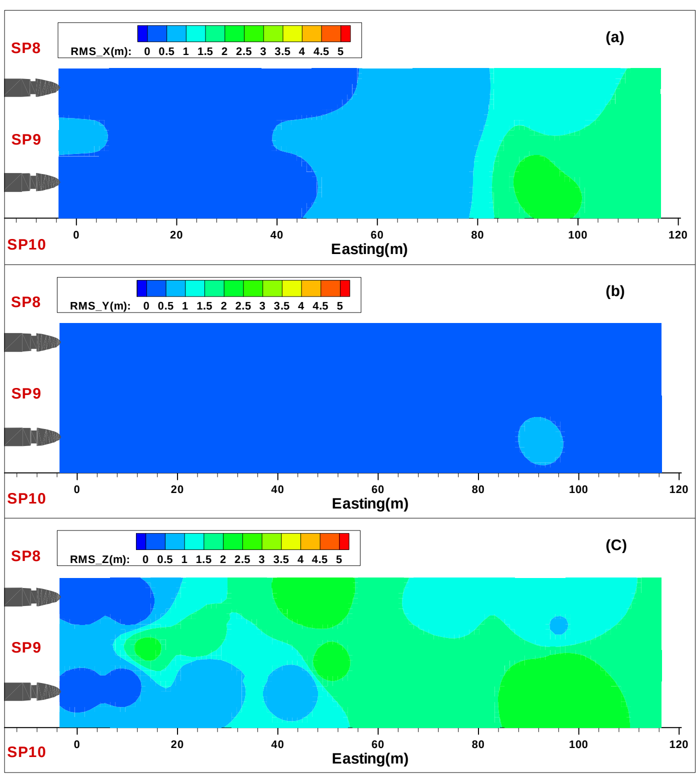

Figure 2.20. Contour plots of route mean square errors in the position estimation of acoustic tags located 2 m below the water surface upstream of the John Day Dam spillway (a) x, (b) y, (c) z

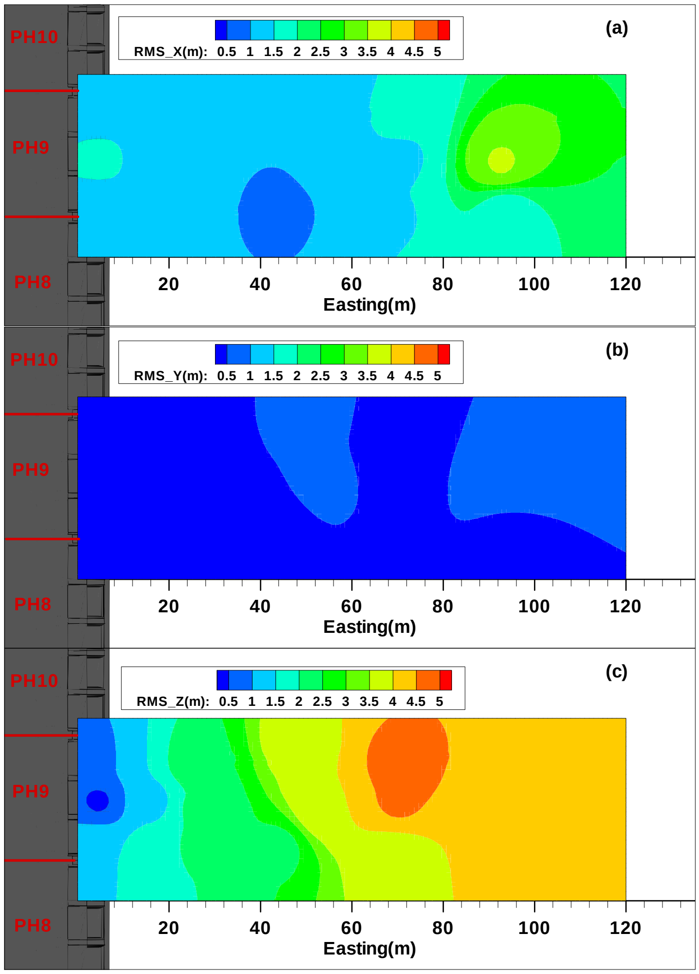

Figure 2.21. Contour plots of route mean square errors in the position estimation of acoustic tags located 2 m below the water surface upstream of the John Day Dam powerhouse (a) x, (b) y, (c) z

3.0 Results

The study results related to environmental conditions, validation of JSATS performance, various survival estimates, fish passage, and fish behavior are presented in the following sections.

3.1 Environmental Conditions

This section contains a description of environmental conditions during the 2008 study, including river discharge and temperature relative to the 10-year average, the length frequencies of tagged and untagged fish that were collected at the John Day Dam SMF, and results of the tag-life study.

3.1.1 Dam Discharge and Temperature

For the entire study period, from the first release of tagged fish to the retrieval of the last node (April 29 to August 20, 2008), total daily discharge through the dam ranged from 81 to 353 kcfs with a mean of 212 kcfs. Overall during this period, 31.6% of total discharge was spilled, including 9.5% TSW discharge. During the first half of the spring portion of the study, tagged fish were released when discharge was at or below the 10-year average (1998 to 2007; Figure 3.1). Discharge was higher than the 10-year average during the second half of the spring season. Discharge exceeded the 10-year average during the release of tagged fish in summer (Figure 3.1). Forebay water temperatures were below the 10-year average in both spring and summer (Figure 3.2).

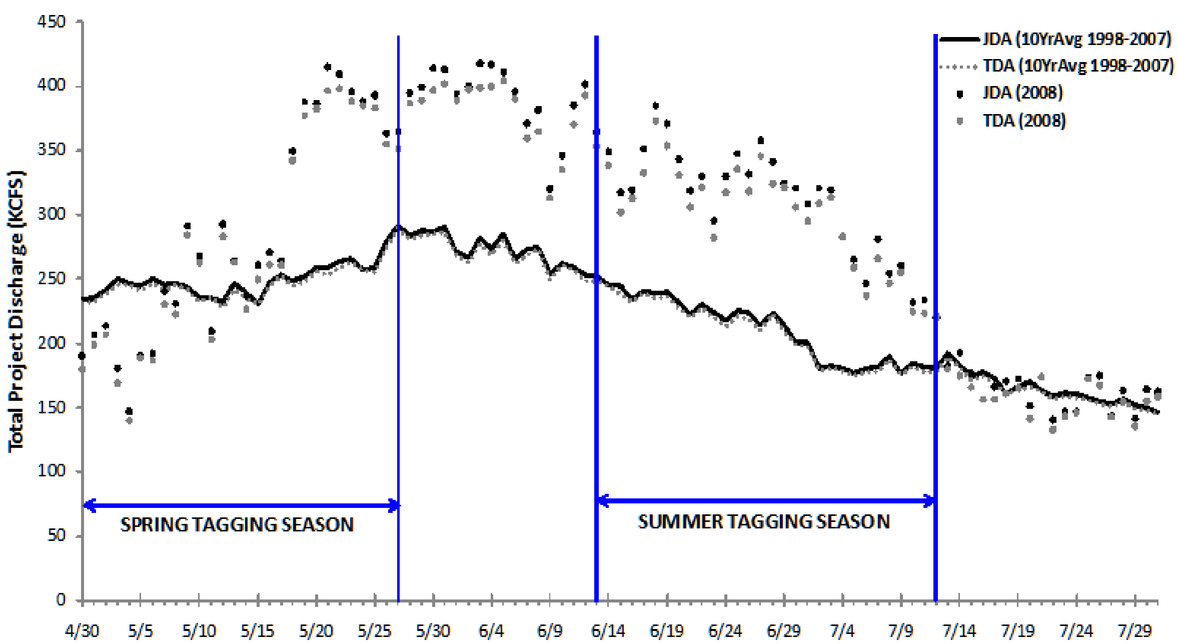

Figure 3.1. Average daily water discharge (kcfs) from John Day Dam and The Dalles Dam during the 2008 study and for the preceding 10-year period. Fish releases lagged the tagging date by 1 day, and travel past all survival-detection arrays lagged the tagging date by 2.5 to 5 days depending on release location and travel time.

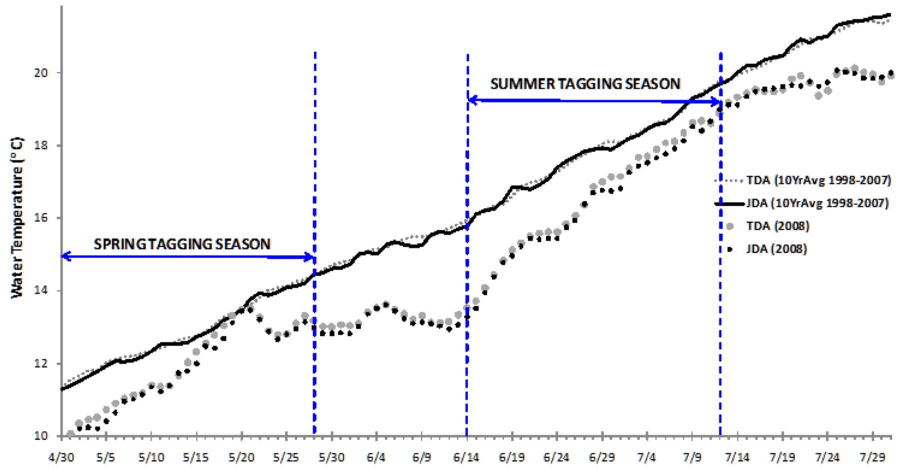

Figure 3.2. John Day Dam and The Dalles Dam average daily forebay water temperatures (ºC) during the 2008 study and for the preceding 10-year period

3.1.2 Realized Spill Treatment Conditions

Treatment conditions were met for most of Blocks 1 through 3 during spring, but percent spill varied from prescribed treatment conditions for large parts of Blocks 4 through 7 (Figure 3.3). During summer, treatment conditions were not met for Blocks 1 through 5, but were met for most of Blocks 6 and 7 (Figure 3.4). Treatment conditions were not always met due to power-load issues and prevailing flow conditions. Except for Block 3 in summer, the dam operators were better able to meet prescribed conditions during 30% spill treatments than they did during 40% spill treatments.

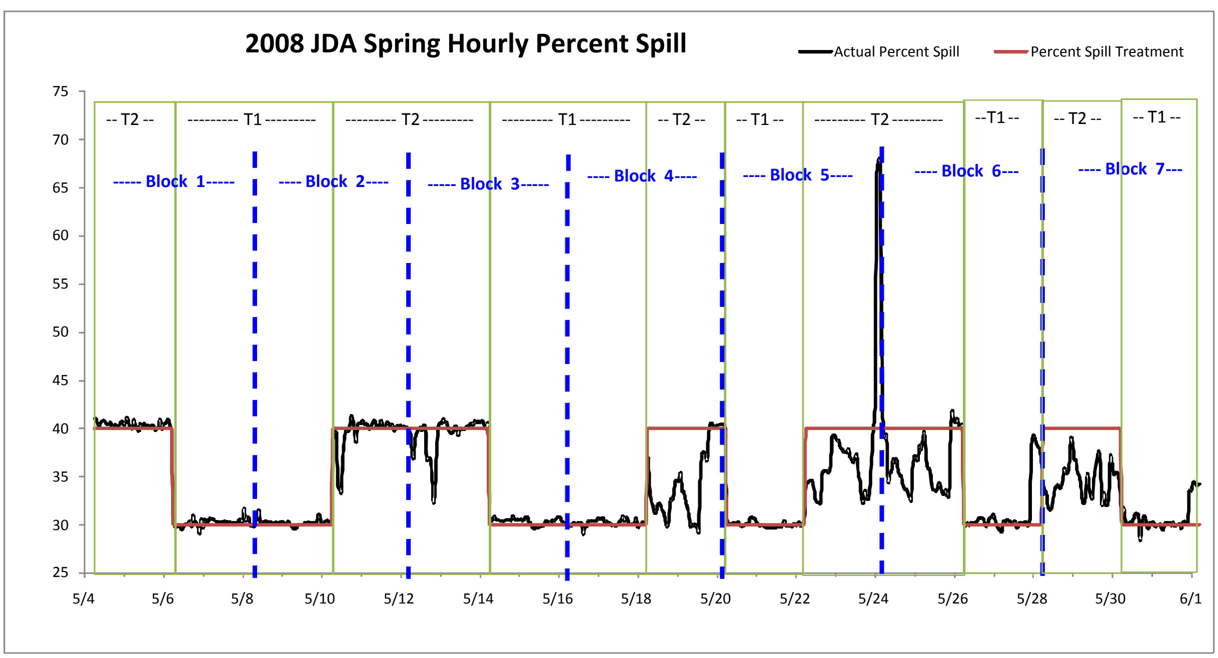

Figure 3.3. Spill treatments for the spring study at John Day Dam from May 4 through May 31, 2008. There were seven treatment blocks with two treatments per block. Treatment 1 (T1) was 30% spill and Treatment 2 (T2) was 40% spill.

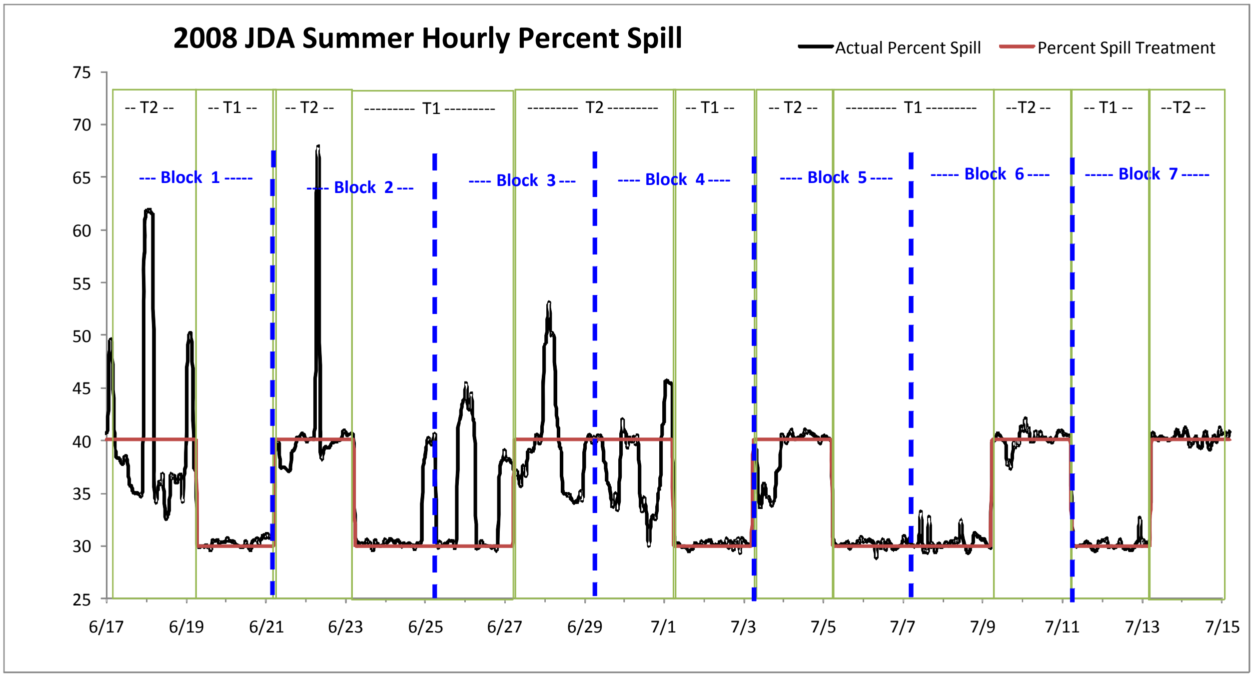

Figure 3.4. Spill treatments in summer at John Day Dam from June 14 through July 16, 2008. There were seven treatment blocks with two treatments per block. Treatment 1 (T1) was 30% spill and Treatment 2 (T2) was 40% spill.

3.1.3 Run Timing

The run timings of downstream migrating STH, YC, and SYC, as indicated by the smolt passage index from the John Day Dam Smolt Monitoring Program (SMP), were compared with the numbers of fish tagged at the John Day Dam SMF in 2008. The fish collection and tagging periods for spring and summer were from April 30 to May 28 and June 14 to July 12, 2008, respectively.

The goal was to tag the middle 80% of the run (10th to 90th percentile) for each species. In spring, the tagging of STH and YC corresponded well with the run timing (Figure 3.5 and 3.6, respectively). With tagged fish being released about 24 hours after tagging and taking about 30 hours after release to reach John Day Dam, the arrival times of the run-of-river and tagged fish were very close to the targeted 80% middle of the run. In summer, tagging of SYC was somewhat early relative to the middle 80% of the run (Figure 3.7). We relied on the 10-year smolt index average as an indicator of run timing to determine the start date for tagging fish (Tables 3.1 to 3.3).

In summary (Table 3.4), we started tagging YC when about 8.2% of the run had passed the dam and finished when about 76.5% had passed. We started tagging STH when about 2.4% of the run had passed at John Day Dam and tagged the last STH when about 85% of the run had passed the dam. In summer, we started tagging SYC when 10% of the run had passed the dam and tagged the last fish when about 65.6% of the run had passed the dam.

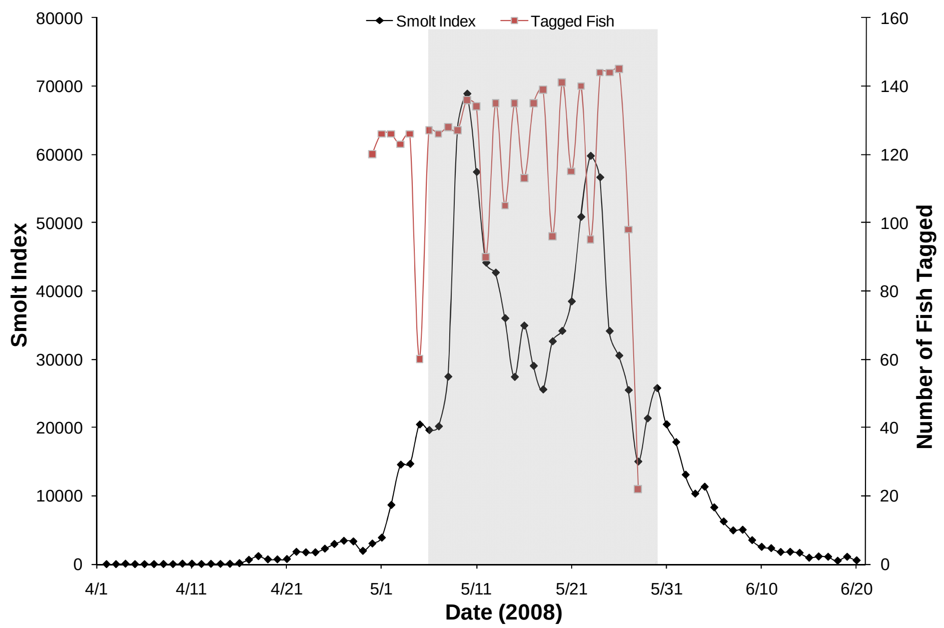

Figure 3.5. Smolt Monitoring Program passage index for April 2–June 20, 2008, and fish tagged per day for steelhead based upon data from the John Day Dam Smolt Monitoring Facility. Ten to 90 percent of the run passed John Day Dam within the region of the gray box. Data were obtained from the DART website (Data Access in Real Time; www.cbr.washington/dart/dart.html).

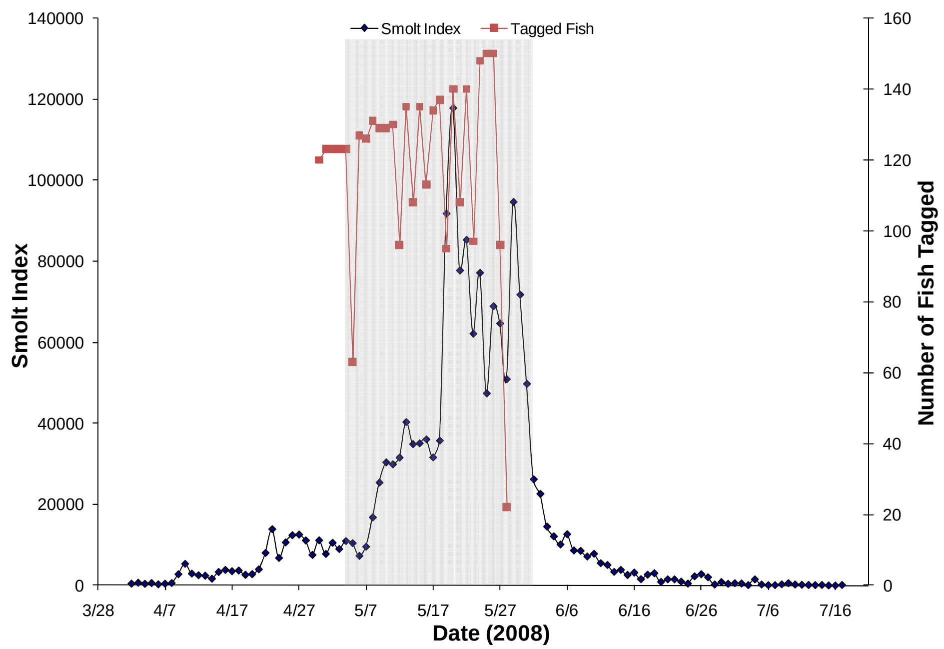

Figure 3.6. Smolt Monitoring Program passage index for April 2–July 16, 2008, and fish tagged per day for yearling Chinook salmon based upon data from the John Day Dam Smolt Monitoring Facility. Ten to 90 percent of the run passed John Day Dam within the region of the gray box. Data were obtained from the DART website (Data Access in Real Time; www.cbr.washington/dart/dart.html).

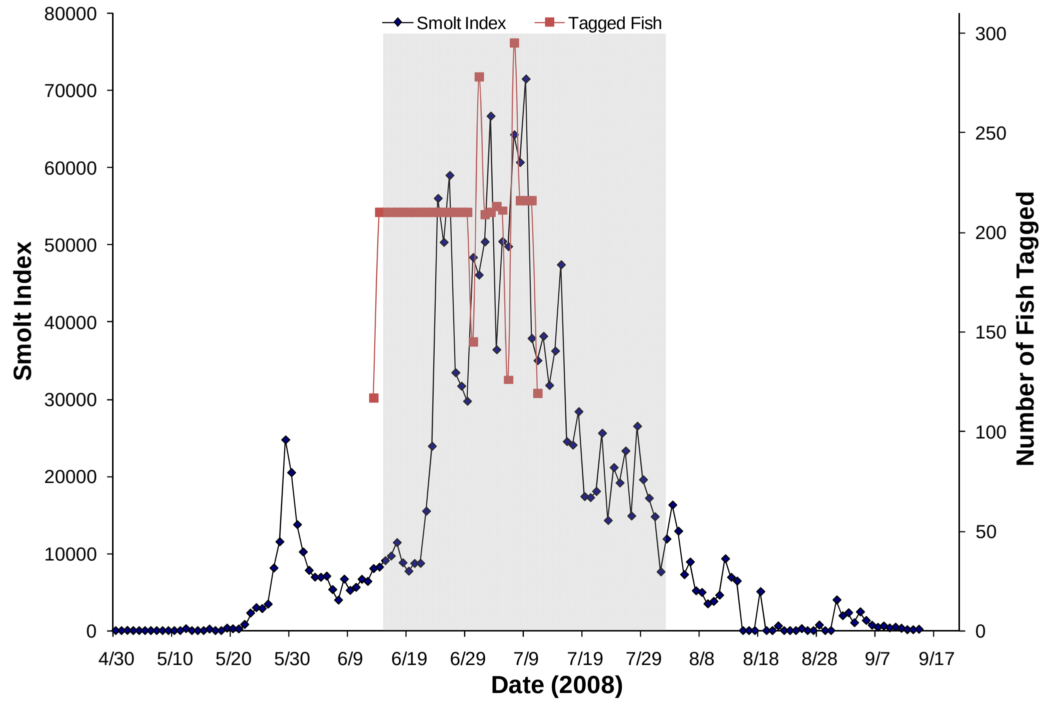

Figure 3.7. Smolt Monitoring Program passage index for June 1–July 31, 2008, and fish tagged per day for subyearling Chinook salmon based upon data from the John Day Dam Smolt Monitoring Facility. Ten to 90 percent of the run passed John Day Dam within the region of the gray box. Data were obtained from the DART website (Data Access in Real Time; www.cbr.washington/dart/dart.html).

Table 3.1. Ten-year average of percent of the run of yearling Chinook salmon passing at the John Day Dam SMF at percentiles of the passage index

Year	First	1%	5%	10%	50%	90%	95%	Last	Middle 80% Days
1998	4/2	4/4	4/18	4/25	5/12	5/22	5/30	8/28	28
1999	4/1	4/10	4/18	4/22	5/13	5/31	6/6	8/30	40
2000	4/4	4/10	4/16	4/21	5/09	5/28	6/5	9/18	38
2001	3/30	4/21	5/01	5/06	5/27	6/20	6/27	9/17	46
2002	3/19	4/18	4/25	5/01	5/17	6/01	6/05	8/30	32
2003	4/01	4/14	4/27	5/03	5/19	6/02	6/04	9/15	31
2004	4/02	4/09	4/20	4/28	5/16	5/30	6/06	9/15	33
2005	4/02	4/05	4/18	4/25	5/12	5/22	5/30	9/15	28
2006	4/4	4/14	4/22	4/25	5/11	5/24	5/27	9/14	30
2007	4/3	4/16	4/26	5/02	5/13	5/25	5/30	9/13	24
10-y avg.	3/31	4/12	4/22	4/27	5/14	5/29	6/04	9/10	33
2008	4/02	4/12	4/26	5/04	5/22	6/01	6/06	9/15	29

Table 3.2. Ten-year average of percent of the run of steelhead passing at the John Day Dam SMF at percentiles of the passage index

Year	First	1%	5%	10%	50%	90%	95%	Last	Middle 80% Days
1998	3/31	4/22	4/26	4/29	5/13	6/1	6/3	9/9	34
1999	4/1	4/2	4/22	4/28	5/26	6/6	6/11	9/9	40
2000	4/4	4/12	4/15	4/16	5/4	5/26	6/2	9/18	41
2001	3/30	4/16	4/25	4/30	5/12	6/2	6/20	9/17	34
2002	3/20	4/14	4/19	4/22	5/16	6/7	6/12	9/16	47
2003	4/1	4/11	4/26	5/2	5/29	6/4	6/6	9/15	34
2004	4/2	4/12	4/25	5/3	5/21	5/31	6/5	9/15	29
2005	4/2	4/17	44/30	5/2	5/18	5/25	5/28	9/15	24
2006	4/4	4/17	4/24	4/27	5/11	5/29	6/1	9/12	33
2007	4/3	4/17	5/1	5/4	5/12	5/26	6/2	9/13	23
10-y avg.	3/31	4/14	4/23	4/28	5/16	5/31	6/5	9/13	34
2008	4/2	4/25	5/4	5/7	5/18	5/31	6/4	9/15	25

Table 3.3. Ten-year average of percent of the run of subyearling Chinook salmon passing at the John Day Dam SMF at percentiles of the passage index

Year	First	1%	5%	10%	50%	90%	95%	Last	Middle 80% Days
1998	4/9	6/2	6/7	6/11	6/30	7/29	8/8	10/29	49
1999	4/2	6/3	6/10	6/18	6/29	7/25	8/5	10/26	38
2000	4/7	6/1	6/5	6/6	6/29	8/3	8/9	9/18	59
2001	4/22	6/10	6/22	6/27	7/30	8/22	8/29	9/17	57
2002	3/22	6/3	6/11	6/20	6/30	7/21	8/4	9/16	32
2003	4/2	5/30	6/3	6/6	6/27	7/30	8/7	9/15	55
2004	4/7	5/30	6/8	6/14	6/28	7/23	7/30	9/15	40
2005	4/4	5/25	6/9	6/19	7/5	7/27	8/1	9/15	39
2006	4/11	5/25	6/5	6/12	7/2	7/17	7/22	9/14	36
2007	4/6	5/28	6/13	6/25	7/8	7/17	7/27	9/13	23
10-y avg.	4/6	5/31	6/9	6/15	7/3	7/27	8/4	9/23	43
2008	5/3	5/28	6/1	6/14	7/7	7/30	8/5	9/15	47

Table 3.4. Percent of the run passing at the John Day Dam SMF on the first and last day of tagging and dates that 10, 25, 50, 75, and 90 percent of the run passed at the John Day Dam SMF

		Percent of Run Passage by Date					
Stock	First Tagging	10%	25%	50%	75%	90%	Last Tagging
Steelhead	4/30 (2.4%)	5/6	5/10	5/17	5/24	5/30	5/28 (85.0%)
Yearling Chinook	4/30 (8.2%)	5/4	5/14	5/21	5/28	6/1	5/28 (76.5%)
Subyearling Chinook	6/14 (10%)	6/14	6/27	7/07	7/17	7/30	7/12 (65.6%)

3.1.4 Length Frequency

The lengths of tagged and untagged fish of each stock were grouped into 5-mm-length classes and plotted to compare length frequencies. The median length of tagged STH (217 mm) was 11 mm longer than that of untagged STH (206 mm; Figure 3.8). The median length of 3447 tagged YC was 8 mm longer than that of untagged YC (Figure 3.9), and the difference was greater for unclipped YC (21 mm) than it was for clipped YC (7 mm). The median length of 5931 tagged SYC (115 mm) was 6 mm longer than that of untagged SYC (109 mm) in routine SMF samples (Figure 3.10). The lower end of the distribution of length frequencies of 5931 tagged SYC was truncated at 95 mm relative to the length frequency distribution of run-of-river SYC handled at the John Day Dam SMF in summer due to a minimum size limit of 95 mm for using JSATS tags (Figure 3.10). Only about 9% of SYC in routine samples could not be tagged because they were too small. Of the SYC tagged, less than 1% were 99 mm or less; the majority of tagged SYC (76%) were in the 105- to 125-mm-length classes.

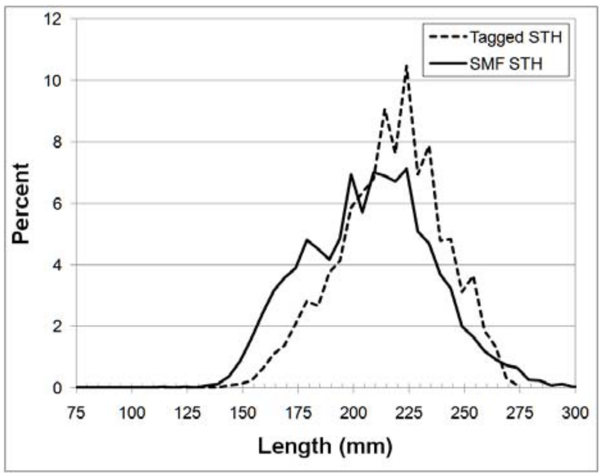

Figure 3.8. Length frequency of steelhead tagged and all steelhead collected at the John Day Dam SMF in spring 2008

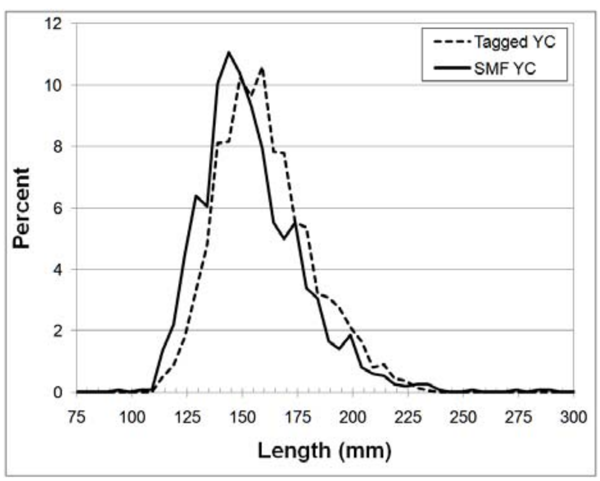

Figure 3.9. Length frequency of yearling Chinook salmon tagged and all yearling Chinook salmon collected at the John Day Dam SMF in spring 2008

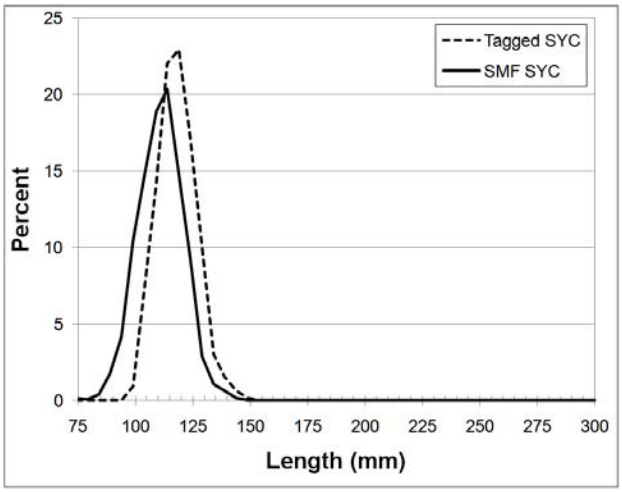

Figure 3.10. Length frequency of all subyearling Chinook salmon tagged and all subyearling Chinook salmon collected (by the John Day Dam SMF) by percent for summer

3.2 JSATS Performance

JSATS performance was evaluated in terms of the detection of dead fish, detection probabilities at dam-face arrays, detection probabilities and fish distribution at autonomous nodes, and probabilities of implanted tags still working by the time they passed the survival-detection arrays.

3.2.1 Detection of Dead Fish

A small subsample of the tagged fish was sacrificed and released dead at the release locations to make sure that if a fish died while passing through a dam it would not be detected on a downstream array and included as alive in the survival estimate. In spring, 14 YC and 15 STH were released with the reference group below John Day Dam. Another five STH and six YC also were released with the treatment fish near Arlington. No dead fish were detected on any of the autonomous or dam-face arrays. In summer, 6 SYC tagged with acoustic tags were sacrificed and released near Arlington, 14 were released with the reference group below John Day Dam, and 2 were released with the release group below The Dalles Dam. None of these tagged fish was detected on the autonomous or dam-face arrays.

3.2.2 Detection Probabilities at Dam-Face Arrays

Detection probabilities for each of three tagged fish populations were over 99% for both independent dam-face arrays, and the combined detection probability was essentially 100% (Table 3.5). Most tagged fish were detected by both arrays.

3.2.3 Detection Probabilities and Fish Distributions at Autonomous Nodes

Detection probabilities for survival-detection arrays composed of autonomous nodes were over 99% for arrays deployed upstream of Bonneville Dam each season, but probabilities fell 8% to 10% for the first survival-detection array below Bonneville Dam and another 10% to 20% for the second array below Bonneville Dam (Figure 3.11). The first array below Bonneville Dam served as the tertiary array for John

Day Dam survival estimates and as the secondary for The Dalles Dam survival estimates. The second array below Bonneville Dam served as the tertiary array for The Dalles Dam survival estimates.

Table 3.5. Detection probabilities for the dam-face arrays (N11 = detected on both arrays; N10 = detected on array 1 but not array 2; N01 = detected on array 2 but not array 1)

Species	Number Released	N11	N10	N01	Detection Probability Array 1	Detection Probability Array 2	Combined Probability
YC	2445	2341	26	15	0.99363	0.98902	0.99993
STH	2448	2305	14	7	0.99697	0.99396	0.99999
SYC	2483	2351	3	5	0.99788	0.99873	0.99999

STH = steelhead.
SYC = subyearling Chinook salmon.
YC = yearling Chinook salmon.

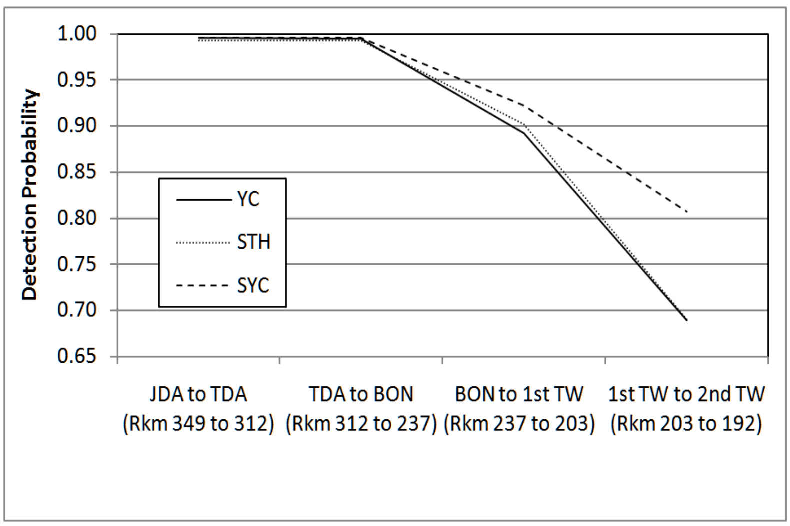

Figure 3.11. Detection probabilities by reach for the autonomous arrays

Most YC, STH, and SYC were detected approaching John Day Dam on the north side of the forebay channel (Figure 3.12). This was also apparent for YC and STH, but not for SYC, approaching Bonneville Dam. The lateral distribution of detections was less skewed at The Dalles Dam forebay entrance array (Figure 3.12). The center node in The Dalles Dam forebay was less effective than the two nodes on either side. The depth of the middle The Dalles Dam forebay node was 92 ft compared to deployment depths of 59 ft and 67 ft for the adjacent nodes. On the Bonneville Dam tailwater arrays, a higher percentage of tagged fish of each stock was detected on nodes deployed in the main channel than in side channels behind islands (Figure 3.12).

Figure 3.12. Percentage of acoustic tag detections by fish stock (columns) on autonomous nodes deployed in arrays in the John Day Dam forebay (1st row), The Dalles Dam forebay (2nd row), Bonneville Dam forebay (3rd row), Bonneville Dam tailwater near Reed Island (4th row), and Bonneville Dam tailwater near Lady Island and Camas, Washington (5th row). In general, the Washington shore is on the left side of each panel and the Oregon shore is on the right as if the reader were looking upstream. Gray bars represent nodes deployed in side channels outside of the main channel.

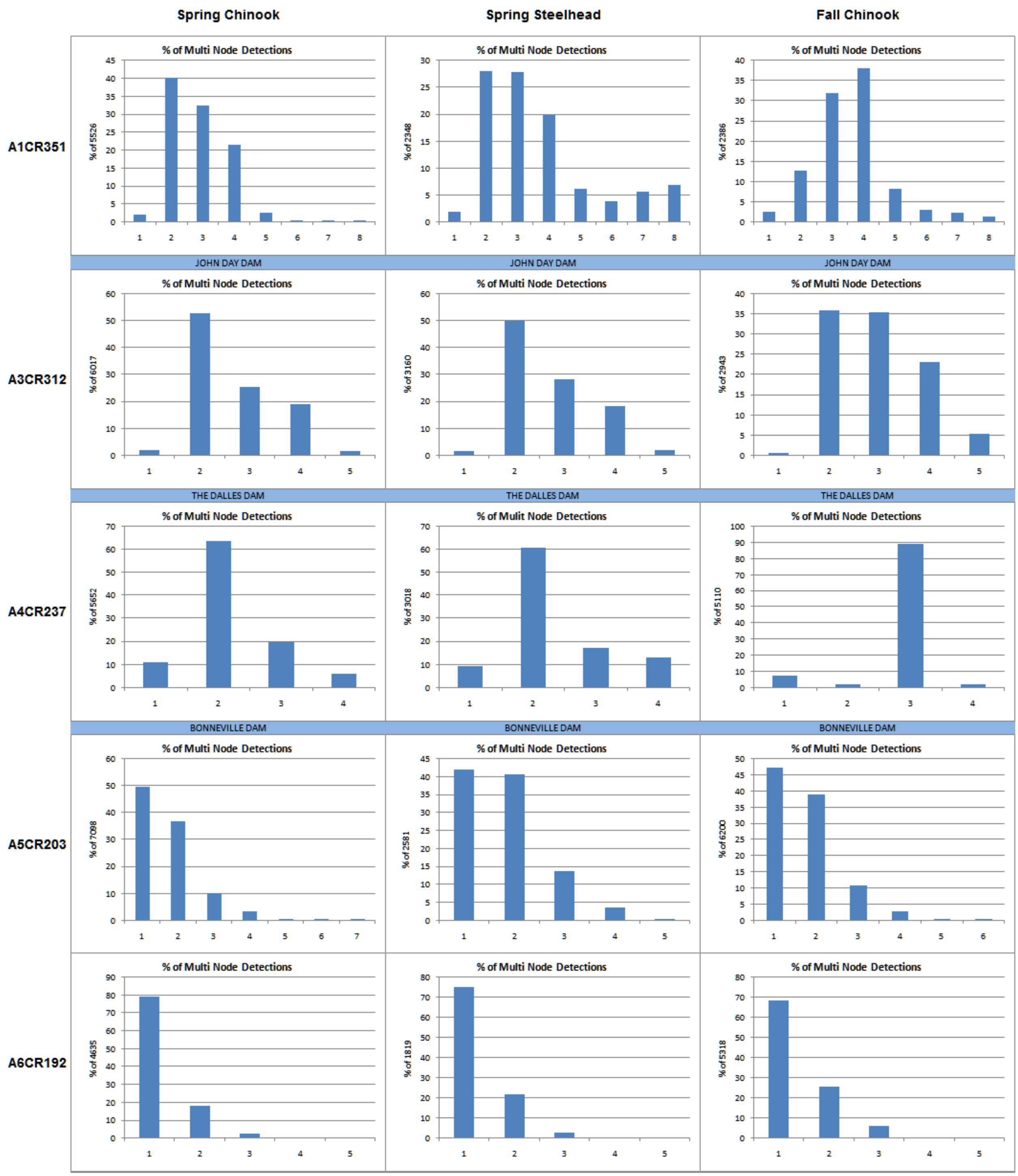

Figure 3.13. Frequency of detections on multiple autonomous nodes in arrays located in the John Day Dam forebay entrance (A1CR351), The Dalles Dam forebay entrance (A3CR312), Bonneville Dam forebay entrance (A4CR237), and Bonneville Dam tailwater (A5CR203 and A6CR192)

Another indicator of performance is the frequency of simultaneous detections on multiple nodes within arrays, and the arrays upstream of Bonneville Dam clearly had more multi-node detections than did arrays downstream of Bonneville Dam (Figure 3.13). For example, the percent of simultaneous YC detections on two or more nodes was 96% on the John Day Dam forebay array, 98% on The Dalles Dam forebay array, and 89% on the Bonneville Dam forebay array. In contrast, the percent detection of YC on two or more nodes was just 50% on the first Bonneville Dam tailwater array and 21% for the second tailwater array. Similar trends were evident for STH and SYC (Figure 3.13), where the percent of multiple-node detections was higher on arrays upstream of Bonneville Dam than on downstream arrays.

Detection probabilities were so high for arrays in the John Day Dam, The Dalles Dam, and Bonneville Dam pools that there was not enough range in the data to correlate them with river discharge. However, for the two reaches below Bonneville Dam, correlations between river discharge and detection probability were readily apparent; as discharge increased, detectability decreased (Figure 3.14).

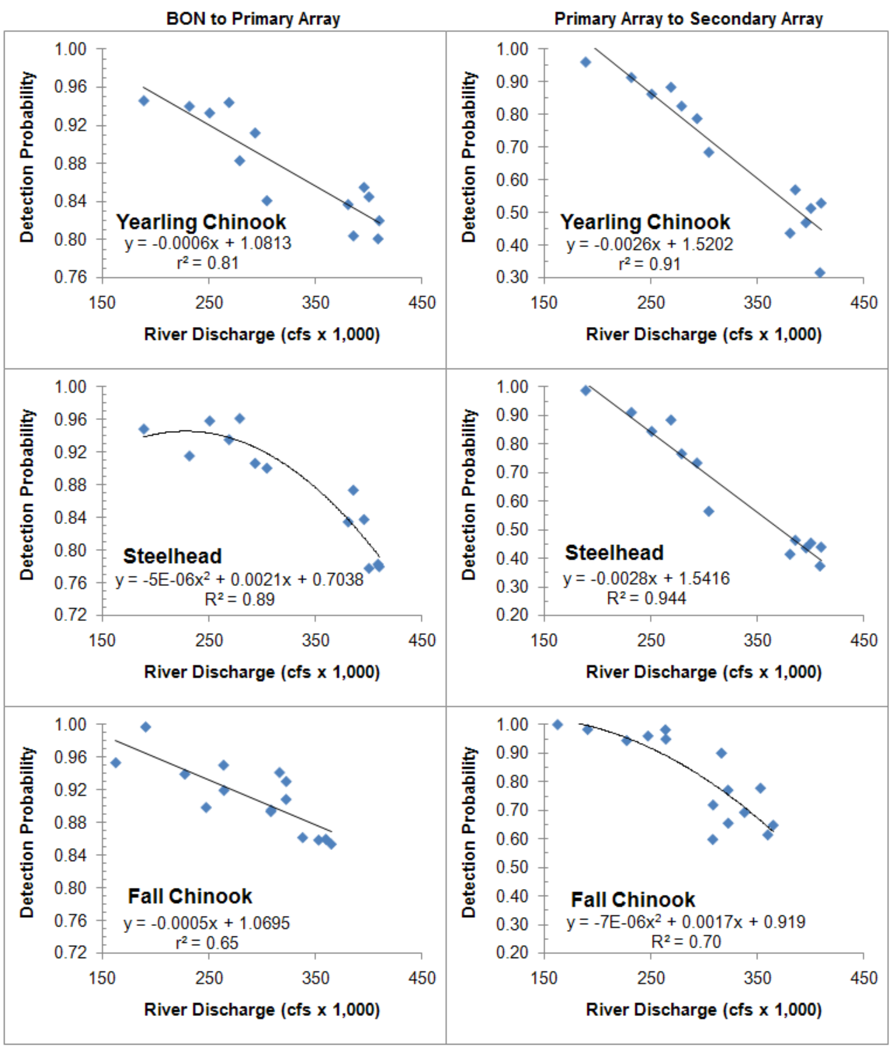

Figure 3.14. Detection probabilities as a function of water discharge in two river reaches below Bonneville Dam

3.2.4 Tag Life

For all stocks of fish studied in 2008, over 99% of the smolts passed the primary, secondary, and tertiary survival-detection arrays before there was any appreciable tag failure (Appendix C). The number of days required for over 99% of smolts to pass the tertiary survival-detection array for John Day Dam was 14 for YC, 16 for STH, and 10 for SYC. Appendix C also contains plots showing the probability of an implanted tag still working by the time it passed the Bonneville Dam survival-detection arrays. This probability exceeded 99% for a tag implanted in any of the three stocks of smolts tagged and released in the John Day Dam pool, John Day Dam tailwater, or The Dalles Dam tailwater. It was about 97% for a tag implanted in YC released on the Snake River below Lower Granite Dam.

3.3 Survival Rates of Yearling Chinook in Spring

The survival and detection history of YC in spring were studied at both John Day Dam and The Dalles Dam.

3.3.1 John Day Dam Concrete-Passage Survival and Detection History

Paired- and single-release results are described here.

3.3.2 Paired Release

Yearling Chinook salmon were released at Arlington, Oregon (rkm 390), and in the John Day Dam tailrace (rkm 346) to provide paired release-recapture data. There was no relationship between survival rate and release date (Figure 3.15). The tag-life-corrected, paired-release, concrete-passage survival estimate was 0.957 ± 0.013 (1/2 95% confidence interval [CI]). It was similarly high for nonturbine routes; however, the turbine-passage survival rate at 0.855 (±0.034) was lower than survival rates for smolts passing through nonturbine routes (Table 3.6). Detailed capture history and survival results by release date are provided in Appendix E.

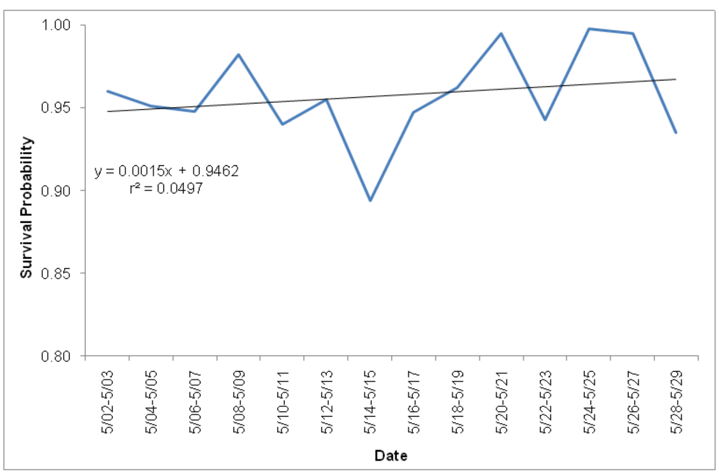

Figure 3.15. Survival rates by release period for yearling Chinook salmon. The black line is the linear regression line with a slope that did not differ significantly from zero.

Table 3.6. Tag-life-corrected, paired-release estimates of survival rates for yearling Chinook salmon smolts regrouped at the corresponding routes at the dam to form virtual releases. Estimates of survival rate were based on pooled data when capture history probabilities were homogeneous and on sample-size-weighted means when probabilities were not homogeneous.

Route	Survival	±1/2 95% CI
Concrete	0.957	0.013
Non-TSW	0.966	0.011
TSW	0.961	0.020
Turbine	0.855	0.034
JBS	0.976	0.045

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.3.2.1 Single Release

Estimates of single-release survival rates [$\hat{S}$ (±1/2 95% CI)] were calculated for YC released at Arlington, Oregon (rkm 390), and regrouped at the John Day Dam face to form virtual releases. The single-release, concrete-passage survival rate for John Day Dam was 0.944 (±0.011). The highest route-specific survival rate was for TSW-passed fish (0.990 ± 0.006), whereas the lowest survival rate came from turbine-passed fish (0.844 ± 0.031; Table 3.7). Detailed capture histories and survival estimates by release are in Appendix E.

Table 3.7. Tag-life-corrected, single-release estimates of route-specific survival rates for yearling Chinook salmon smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Survival estimates were based on pooled data when capture history probabilities were homogeneous and on sample-size-weighted means when probabilities were not homogeneous.

Route	Survival	±1/2 95% CI
Concrete	0.944	0.011
Non-TSW	0.951	0.009
TSW	0.990	0.006
Turbine	0.844	0.031
JBS	0.963	0.044

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.3.3 The Dalles Dam Survival and Detection History

Yearling Chinook salmon released at Arlington, Oregon (rkm 390), and in the John Day Dam tailrace (rkm 346) were regrouped on the The Dalles Dam forebay entrance array and used to estimate The Dalles

Dam-passage survival rate based on subsequent detections on one array in the Bonneville Dam forebay and two in the Bonneville Dam tailwater. The estimate of the tag-life-corrected, single-release dam-passage survival rate for YC smolts traveling from The Dalles Dam forebay entrance array to the Bonneville Dam forebay array was 0.947 ± 0.007 (1/2 95% CI). Detailed capture history and survival results by release are in Appendix F.

3.3.4 John Day Dam Concrete-Passage Survival Rate for Lower Granite Dam Yearling Chinook Salmon

Yearling Chinook salmon were released at Lower Granite Dam and the survival rate was calculated for the fish that were detected passing John Day Dam. We compared the estimated paired-release survival rate of the Lower Granite Dam YC with the estimated paired-release survival rate based on YC released at Arlington, Oregon (rkm 390), and in the John Day Dam tailrace (rkm 346). We used the same downstream detection arrays (primary array at rkm 312.4, secondary array at rkm 237.5, and the tertiary array at rkm 204). There was no significant difference in the estimates of paired-release, concrete-passage survival rates for smolts tagged and released at Lower Granite Dam (0.938 ± 0.028 1/2 95% CI) or at Arlington, Orgeon (0.957 ± 0.013 1/2 95% CI). Detailed capture history and survival results for Lower Granite Dam YC are in Appendix G.

3.4 Survival Rates of Steelhead in Spring

The survival rates of STH are reported in the following sections.

3.4.1 John Day Dam Concrete-Passage Survival and Detection History

Results related to estimates of paired-release and single-release survival rates for STH are described.

3.4.1.1 Paired Release

There was no relationship between paired-release survival estimates for STH smolts passing through John Day Dam and release date (r^2=0.0008; Figure 3.16). The estimate of tag-life-corrected, paired-release, concrete-passage survival rate for STH was 0.986 ± 0.019 1/2 95% CI (Table 3.8). Route-specific survival rates for STH were very high for smolts passing through the JBS (1.002 ± 0.019) and TSW (0.992 ±0.023) and low for turbine-passed fish (0.749 ± 0.062; Table 4.8). Detailed capture history and survival results by release date are in Appendix H.

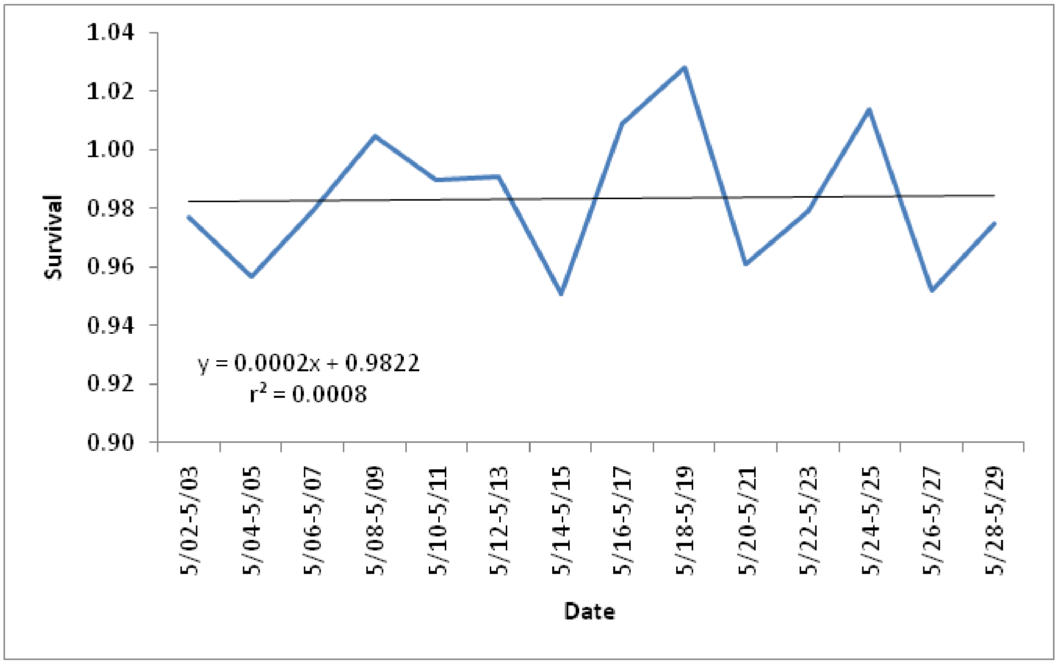

Figure 3.16. Survival rate by release period for yearling steelhead. The black line is the linear regression line with a slope that did not differ significantly from zero.

Table 3.8. Tag-life-corrected, paired-release estimates of survival rates for steelhead smolts regrouped at the corresponding routes at the dam to form virtual releases. Survival estimates were based on pooled data when capture history probabilities were homogeneous and on sample-size-weighted means when probabilities were not homogeneous.

Route	Survival	±1/2 95% CI
Concrete	0.986	0.019
Non-TSW	0.985	0.023
TSW	0.992	0.023
Turbine	0.749	0.062
JBS	1.002	0.019

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.4.1.2 Single Release

Survival estimates were calculated from John Day Dam-face virtual releases of STH originally released at Arlington, Oregon (rkm 390). The estimate of the tag-life-corrected survival rate ($\hat{S}$ ± 1/2 95% CI) for John Day Dam was 0.959 ± 0.011. The single-release survival rate was highest for JBS-passed fish (0.975 ± 0.012), lower for TSW-passed fish (0.965 ± 0.017), and lowest for turbine-passed fish (0.729 ± 0.052; Table 3.9). Detailed capture history and survival results by release date are in Appendix H.

Table 3.9. Cormack-Jolly-Seber, tag-life-corrected, single-release estimates of survival rates for steelhead smolts released near Arlington, Oregon. Survival estimates were based on pooled data when capture history probabilities were homogeneous and on sample-size-weighted means when probabilities were not homogeneous.

Route	Survival	±1/2 95% CI
Concrete	0.959	0.011
Non-TSW	0.959	0.017
TSW	0.965	0.017
Turbine	0.729	0.052
JBS	0.975	0.012

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.4.2 The Dalles Dam Survival and Detection History

Steelhead smolts were released near Arlington, Oregon (rkm 390), and in the John Day Dam tailrace (rkm 343.4), and regrouped on The Dalles Dam forebay entrance array to create virtual releases for estimating single-release dam-passage survival rates for The Dalles Dam. The tag-life-corrected survival rate from 2 km upstream of The Dalles Dam to the Bonneville Dam forebay was 0.959 ± 0.009 1/2 95% CI). Detailed capture history and survival results by release are in Appendix I.

3.5 Survival Rates of Subyearling Chinook Salmon in Summer

The John Day Dam and The Dalles Dam estimated survival rates and detection histories for SYC are described in the following sections.

3.5.1 John Day Dam Concrete-Passage Survival Survival and Detection History

Paired- and single-release results are discussed.

3.5.1.1 Paired Release

There was no relationship between the SYC paired-release survival rate and virtual release date (r^2=0.1383; Figure 3.17). The estimate of the tag-life-corrected, paired-release, concrete-passage survival rate ($\hat{S}$ ± 1/2 95% CI) for SYC was 0.861 ± 0.017. The lowest route-specific estimate was for turbine-passed fish and the highest was for JBS-passed fish (Table 3.10). The 1/2 95% CI on the point estimate for TSW-passed smolts overlapped with that of the point estimate for JBS-passed fish. Survival of TSW-passed smolts was higher than that of smolts passing through non-TSW spill bays or turbines. Detailed capture history and survival results by release date are in Appendix J.

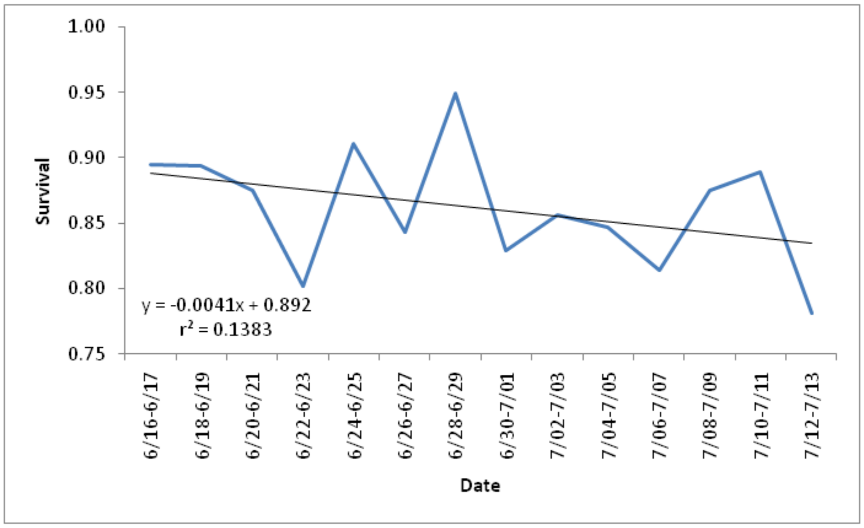

Figure 3.17. Paired-release estimates of concrete-passage survival rate by release date for subyearling Chinook salmon. The black line is the linear regression line with a slope that did not differ significantly from zero.

Table 3.10. Tag-life-corrected, paired-release estimates of survival rates for subyearling Chinook smolts regrouped at the corresponding routes at the dam to form virtual releases. Survival estimates were based on pooled data when capture history probabilities were homogeneous and on sample-size-weighted means when probabilities were not homogeneous.

Route	Survival	±1/2 95% CI
Concrete	0.861	0.017
Non-TSW	0.844	0.044
TSW	0.927	0.016
Turbine	0.728	0.056
JBS	0.973	0.057

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.5.1.2 Single Release

The single-release, tag-life-corrected estimate of the concrete-passage survival rate for SYC smolts was 0.844 ± 0.023 (1/2 95% CI). The highest tag-life-corrected, route-specific point estimate was for JBS-passed smolts (0.954) followed by smolts passing through the TSW (0.910), non-TSW spill bays (0.827), and then turbines (0.714; Table 3.11). Detailed capture history and survival results by release date are in Appendix J.

Table 3.11. Tag-life-corrected, single-release estimates of survival rates for subyearling Chinook smolts in virtual release at John Day Dam based on three downstream arrays. Survival estimates were based on pooled data when capture history probabilities were homogeneous and on sample-size-weighted means when probabilities were not homogeneous.

Route	Survival	±1/2 95% CI
Concrete	0.844	0.023
Non-TSW	0.827	0.039
TSW	0.910	0.012
Turbine	0.714	0.046
JBS	0.954	0.054

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.5.2 The Dalles Dam Survival and Detection History

Subyearling Chinook salmon smolts released at Arlington, Oregon (rkm 390), and in the John Day Dam tailrace (rkm 346) were regrouped to form virtual releases at The Dalles Dam forebay entrance array. There also were paired releases in The Dalles Dam tailrace. The tag-life-corrected, paired-release estimate of survival rate for SYC was 0.931 (±0.013). Detailed capture history and survival results by release date are in Appendix K.

3.6 Spatial and Temporal Trends at John Day Dam and Spill-Condition Effects

In this section, the spatial and temporal trends and spill-condition effects at John Day Dam are discussed for YC, STH, and SYC.

3.6.1 Yearling Chinook Salmon

Passage efficiency and effectiveness, horizontal passage distribution at the dam, powerhouse and spillway passage, the effect of spill conditions on dam-passage survival rate and passage proportions, and diel trends in survival rates and passage efficiencies relative to YC are described below.

3.6.1.1 Passage Efficiency and Effectiveness

For YC smolts in spring 2008, John Day Dam fish-passage efficiency was 92%; spillway-passage efficiency was 76%; and the two spill bays with TSWs passed 24% of all smolts in 6.9% of the water discharged through the dam (Table 3.12). The TSW was more effective than the entire spillway at passing YC smolts. Of the 24% of YC smolts passing into the powerhouse, 66% were diverted by the intake screens into the JBS, and JBS-passage efficiency, relative to total numbers passing through the dam, was 15.9%. About 8% of all YC smolts passed through turbines.

Table 3.12. Estimates of major passage metrics for yearling Chinook salmon during spring

Metric	Spring (±1/2 95% CI)
Fish-Passage Efficiency	92.14 ± 1.30%
Spillway-Passage Efficiency	76.24 ± 2.44%
Fish-Guidance Efficiency	66.90 ± 4.75%
TSW-Passage Efficiency	23.55 ± 2.81%
JBS-Passage Efficiency	15.90 ± 2.11%
Spillway-Passage Effectiveness	2.32 ± 0.07
TSW-Passage Effectiveness	3.41 ± 0.41

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.6.1.2 Horizontal Passage Distribution at the Dam

During spring, the number of tagged YC smolts passing through individual routes was very high at spill bays with TSWs (spill bays 15 and 16) and at nearby regular spill bays 17 and 18 even though 66% of water discharge was through the powerhouse (Figure 3.18). Passage at spill bays 14 and 19 was less than 50% of passage at TSW bays and spill bays 17 and 18, but passage was still two times higher than passage at most other individual routes.

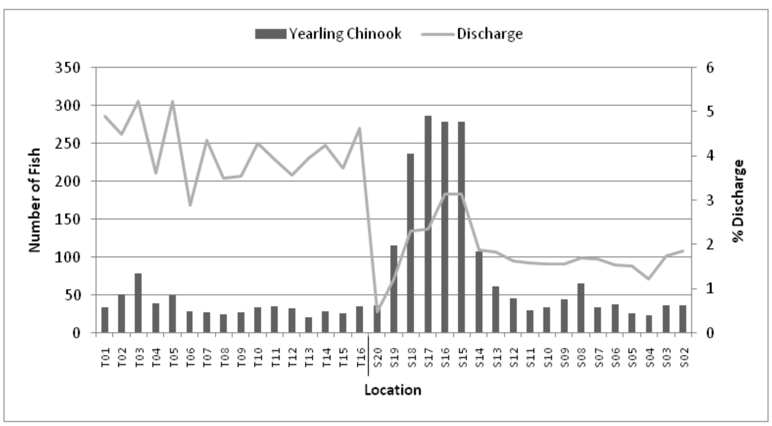

Figure 3.18. Yearling Chinook salmon smolt passage and discharge by individual passage route in spring 2008

3.6.1.3 Powerhouse Passage

During spring, 66.9% of the YC smolts that passed through the dam at the powerhouse were guided through the JBS, and the remaining one-third passed through the turbines (Figure 3.19). Turbine discharge was fairly uniform across the powerhouse, although 1% to 2% higher at turbine units 1, 2, 3, and 5 than it was at most other units.

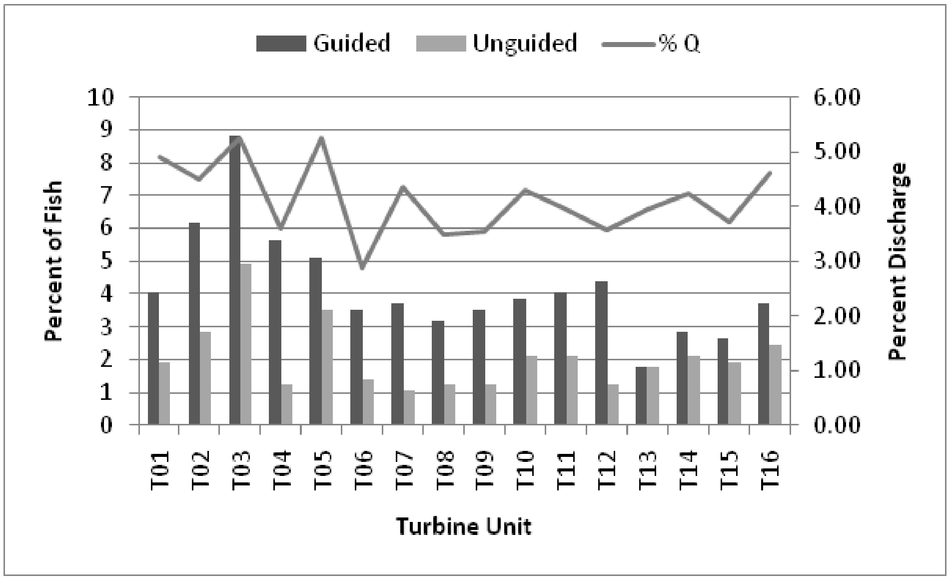

Figure 3.19. Guided and unguided passage of yearling Chinook salmon smolts and discharge ($m^3 \times 100$) by turbine unit

3.6.1.4 Spillway Passage

Of the YC smolts passing through the spillway, 66% passed through the TSW and adjacent spill bays, which also had the highest discharge (Figure 3.20). The average TSW spill bay passed 1.7 times more YC than the average bay from spill bays 17 to 20 and 7.1 times more smolts than the average bay from spill bays 1 to 14 (Figure 3.21).

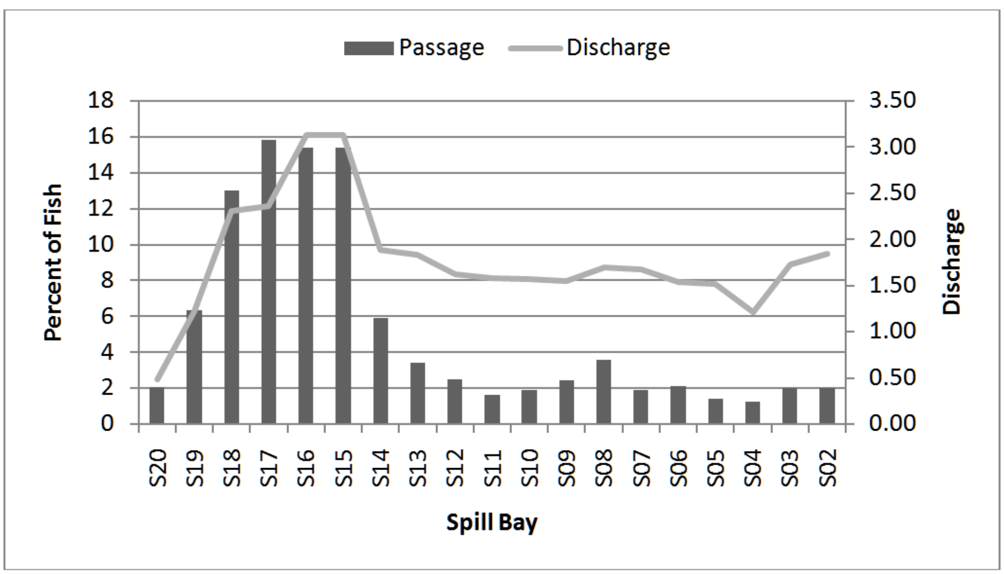

Figure 3.20. Yearling Chinook salmon passage and discharge (showing $m^3 \times 100$) by spill bay

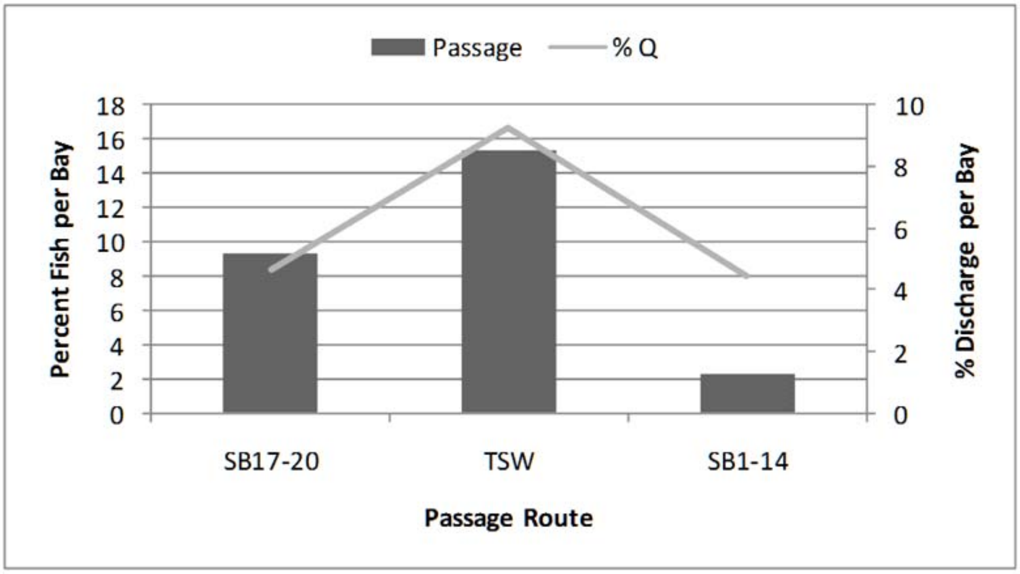

Figure 3.21. Average percent passage of yearling Chinook salmon smolts and percent discharge per spill bay within groups of bays

3.6.1.5 Effect of Spill Condition on Dam Survival and Passage

We defined post-hoc spill conditions to evaluate the effects of spill on dam-passage survival because mean hourly percent of spill discharge at John Day Dam during spring (Figure 3.22) was not similar to the prescribed spill treatments (Figure 2.1). During the middle of the spring season, higher than normal flows caused spill levels to deviate from the planned treatments. The post-hoc 30% spill condition was defined by passage when spill was <35% and the post-hoc 40% spill condition was defined by passage when spill was between 35% and 45%. The survival metric was paired-release dam-passage survival (i.e., survival of YC passing from the forebay entrance array to the tailrace release site).

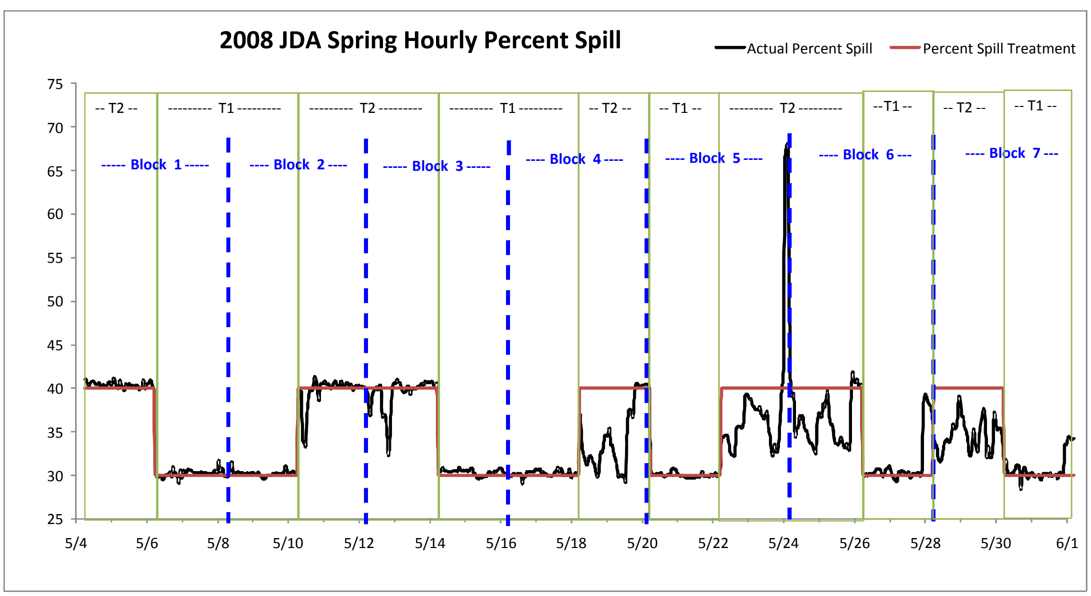

Figure 3.22. Spill treatments as prescribed (red line) and actual conditions (black line) in spring

Paired-release estimates of dam-passage survival did not differ between the 30% and 40% spill conditions (Table 3.13) based on the overlap of 1/2 95% CIs. Similarly, other fish-passage metrics did not differ between the 30% and 40% spill conditions (Table 3.14).

Table 3.13. Estimates of dam-passage survival rates by post-hoc spill condition for yearling Chinook salmon during spring

Condition	Survival Rate (±1/2 95% CI)
30% Spill	94.0 ± 1.2%
40% Spill	94.2 ± 1.6%

CI = Confidence interval.

Table 3.14. Estimates of major passage metrics by spill treatment for yearling Chinook salmon during spring

Metric	Spring (±1/2 95% CI)
FPE 30% Spill	92.85 ± 1.85%
FPE 40% Spill	91.05 ± 2.37%
SE 30% Spill	75.89 ± 3.93%
SE 40% Spill	76.76 ± 4.06%
FGE 30% Spill	70.35 ± 6.87%
FGE 40% Spill	61.47 ± 8.41%
TSWE 30% Spill	25.02 ± 4.75%
TSWE 40% Spill	21.32 ± 4.88%
JBSE 30% Spill	16.96 ± 3.46%
JBSE 40% Spill	14.29 ± 3.31%
SEF 30% Spill	2.48 ± 0.13
SEF 40% Spill	1.98 ± 0.41
TSWEF 30% Spill	3.68 ± 0.70
TSWEF 40% Spill	2.97 ± 0.68

CI = confidence interval.
FGE = fish-guidance efficiency.
FPE = fish-passage efficiency.
JBSE = juvenile bypass system-passage efficiency.
SE = spillway-passage efficiency.
SEF = spillway-passage effectiveness.
TSW = top-spill weir.
TSWE = TSW-passage efficiency.
TSWEF = TSW-passage effectiveness.

3.6.1.6 Diel Trends in Survival and Passage Efficiencies

During spring, data were divided into day and night periods as follows: day = 0600 to 2159 hours and night = 2200 to 0559 hours. Most survival estimates did not differ greatly between day and night (Table 3.15). The point estimate of the turbine passage survival rate appeared to be higher at night than it was during the day, but this difference was not significant.

Table 3.15. Comparison of diel paired-release estimate of survival rates for yearling Chinook salmon during spring. These relative estimates were not corrected for tag life.

Route	Day (±1/2 95% CI)	Night (±1/2 95% CI)
Concrete	95.2 ± 1.7%	95.6 ± 3.1%
Powerhouse	90.6 ±4.8%	92.8 ± 7.3%
Turbine	77.4 ± 14.7%	88.9 ± 9.1%
JBS	96.7 ± 4.1%	95.6 ± 8.1%
Spillway	95.6 ± 1.6%	97.0 ± 2.2%
Spill bays 17–20	94.3 ± 2.0%	97.5 ± 4.3%
TSW (spill bays 15 and 16)	95.6 ± 2.6%	97.9 ± 6.3%
Spill bays 1–14	96.9 ±3.5%	95.9 ± 5.5%

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

Total passage and spillway passage were higher during the day than they were at night, but fish passage estimates for the powerhouse, turbines, and JBS were higher at night than during the day (Figure 3.23). The numbers of YC smolts passing through the dam were divided by total number of hours in “day” (464) and “night” (232) to come up with the number per hour. Passage rates through spill bays 1–14, the TSW, and spill bays 17–20 were higher during the day than they were at night (Figure 3.24). Passage per bay and hour was higher for TSW bays than it was for other spill bays, and day rates were higher than night rates at the TSW bays but not at other spill bays (Figure 3.24).

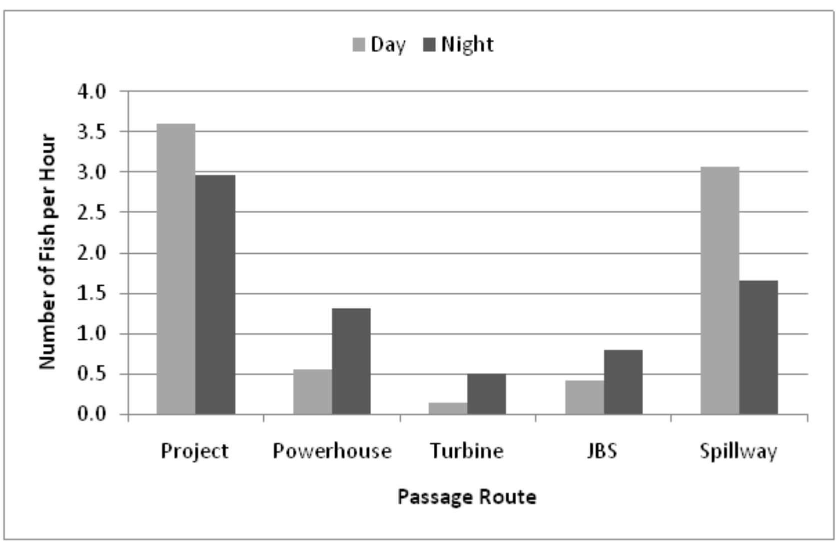

Figure 3.23. Day and night differences in passage rate for yearling Chinook salmon smolts

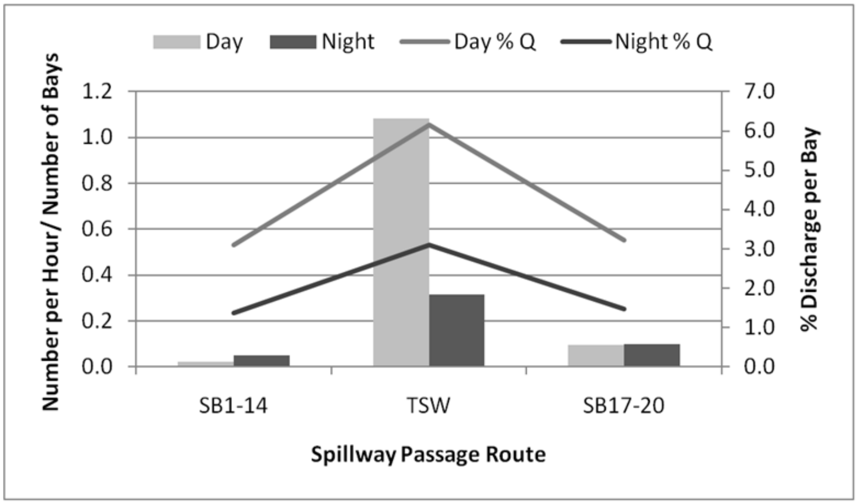

Figure 3.24. Diel passage rates (number/hour/bay) for yearling Chinook salmon smolts and percent of water discharge (Q) for groups of spill bays

3.6.2 Steelhead

Passage efficiency and effectiveness, horizontal passage distribution at the dam, powerhouse and spillway passage, the effect of spill conditions on dam-passage survival rate and passage proportion among routes, and diel trends in survival rates and passage efficiencies relative to STH are described below.

3.6.2.1 Passage Efficiency and Effectiveness

During 2008, estimates of major passage metrics for STH smolts at John Day Dam show that the TSWs passed almost 50% of all STH smolts (Table 3.16). Combining the TSW spill bays with non-TSW spill bays resulted in 74.4% of smolts passing through the spillway. Of the STH smolts passing into the powerhouse, about 89% were diverted by the intake screens into the JBS. Only about 3% of total fish passage was through turbines. The TSW spill bays were more than 3.2 times more effective than regular spill bays at passing STH (Table 3.16).

Table 3.16. Estimates of major passage metrics for yearling steelhead during spring

Metric	Spring (±1/2 95% CI)
Fish-Passage Efficiency	97.2 ± 0.7%
Spillway-Passage Efficiency	74.4 ± 2.6%
Fish-Guidance Efficiency	88.9 ± 2.7%
TSW-Passage Efficiency	49.6 ± 3.3%
JBS-Passage Efficiency	22.7 ± 2.5%
Spillway-Passage Effectiveness	2.25 ±0.08
TSW-Passage Effectiveness	7.21 ± 0.48

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

3.6.2.2 Horizontal Passage Distribution at the Dam

The passage of STH smolts at TSW spill bays was more than six times higher than it was at any other route at John Day Dam in spring, except for adjacent spill bay 17 where TSW bay passage was only 3.3 times higher (Figure 3.25). The majority of STH (75%) used the spillway to pass through the dam even though 66% of water discharge was through the powerhouse (Figure 3.25).

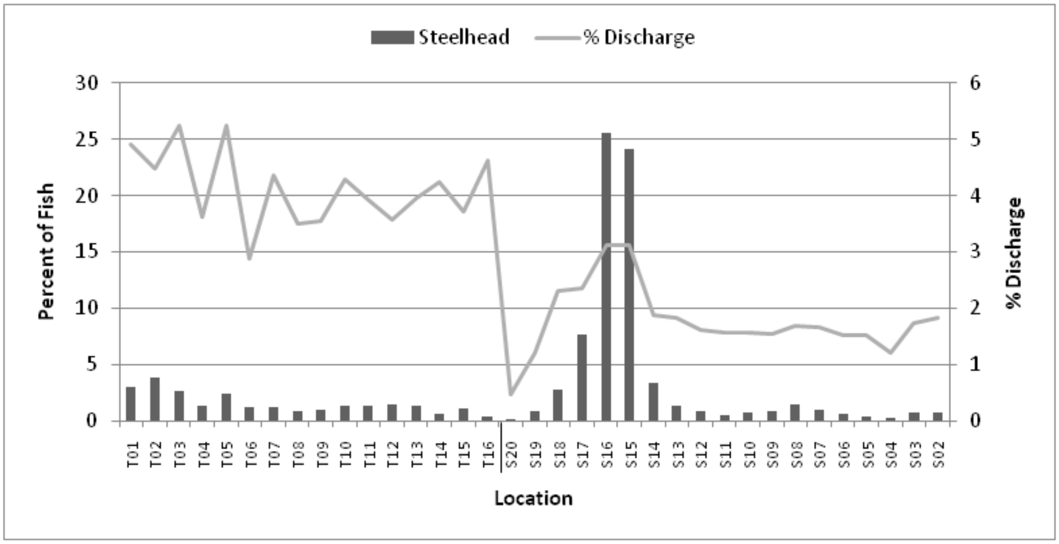

Figure 3.25. Steelhead smolt passage and percent discharge by individual passage route in spring 2008

3.6.2.3 Powerhouse Passage

During spring, 25% of STH smolts passed into the powerhouse; of these, 89% were guided by screens into the JBS (Figure 3.26).

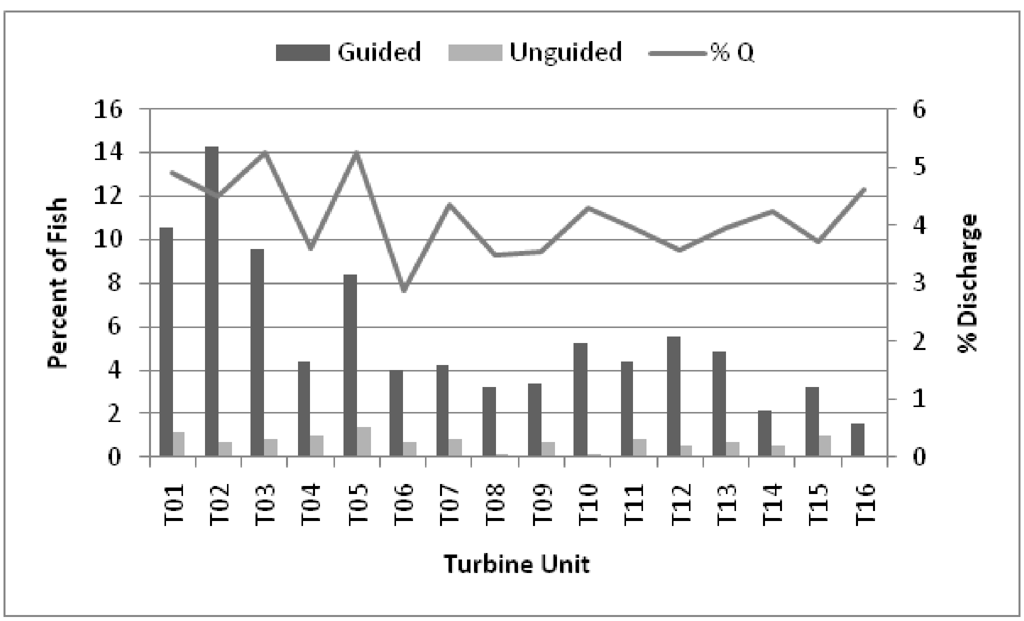

Figure 3.26. Guided and unguided passage of steelhead smolts in spring

3.6.2.4 Spillway Passage

Among routes through the spillway (Figure 3.27), TSW spill bays 15 and 16 passed 66.6% of STH smolts (Figure 3.27). On a per-bay basis, percent passage through an average TSW bay was 22 times higher than that through an average spill bay from spill bays 2 through 14 and 8.3 times higher than that through an average bay from spill bays 17 through 20 (Figure 3.28).

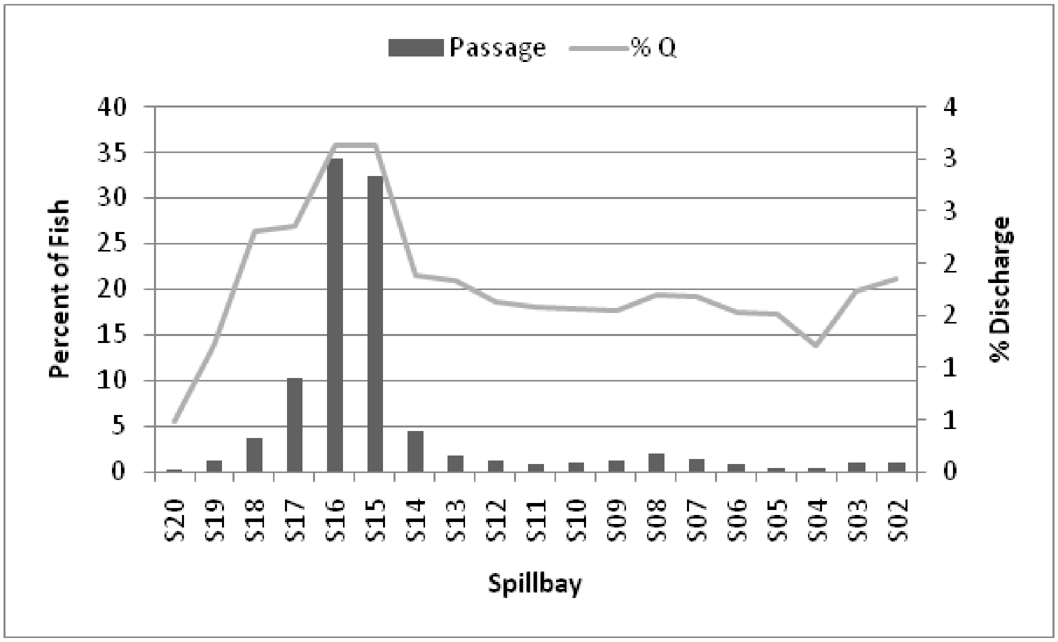

Figure 3.27. Steelhead smolt passage and percent discharge by spill bay

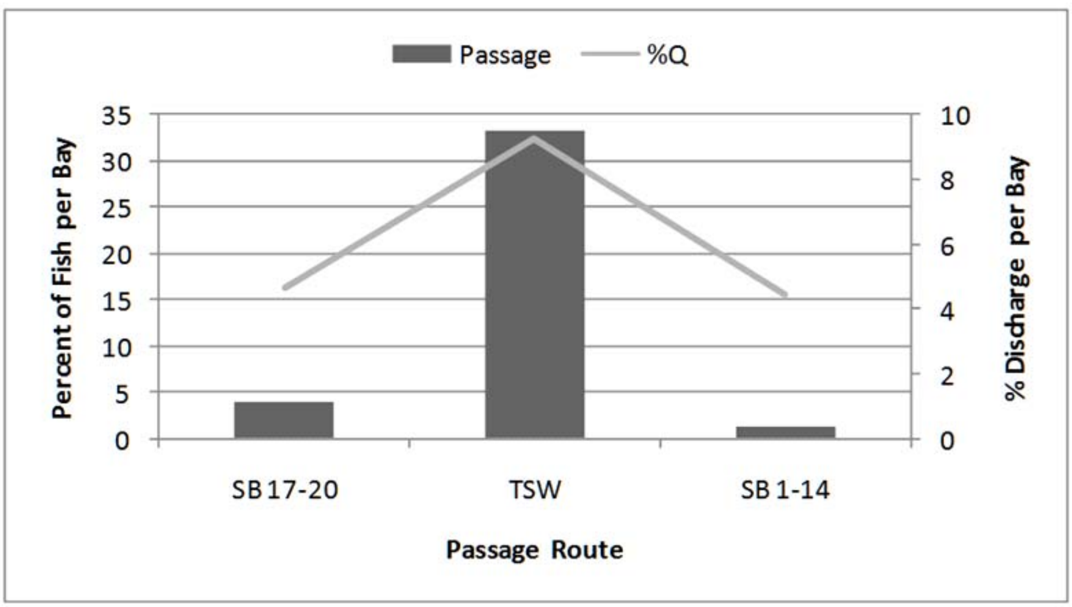

Figure 3.28. Percent passage of steelhead smolts and discharge for an average spill bay within groups of bays

3.6.2.5 Effect of Spill Condition on Dam Survival and Passage

As for YC, we defined post-hoc spill conditions to evaluate the effects of spill on STH dam-passage survival because mean hourly percent spill discharge at John Day Dam during spring (Figure 3.29) was not similar to prescribed spill treatments (Figure 2.1). Higher than normal flows during mid-spring caused spill levels to deviate from planned treatments. The post-hoc 30% spill condition was defined by passage when spill was <35% and the post-hoc 40% spill condition was defined by passage when spill was between 35% and 45%. The survival metric was the paired-release dam-passage survival rate (i.e., survival rate of STH passing from the forebay entrance array to the tailrace release site).

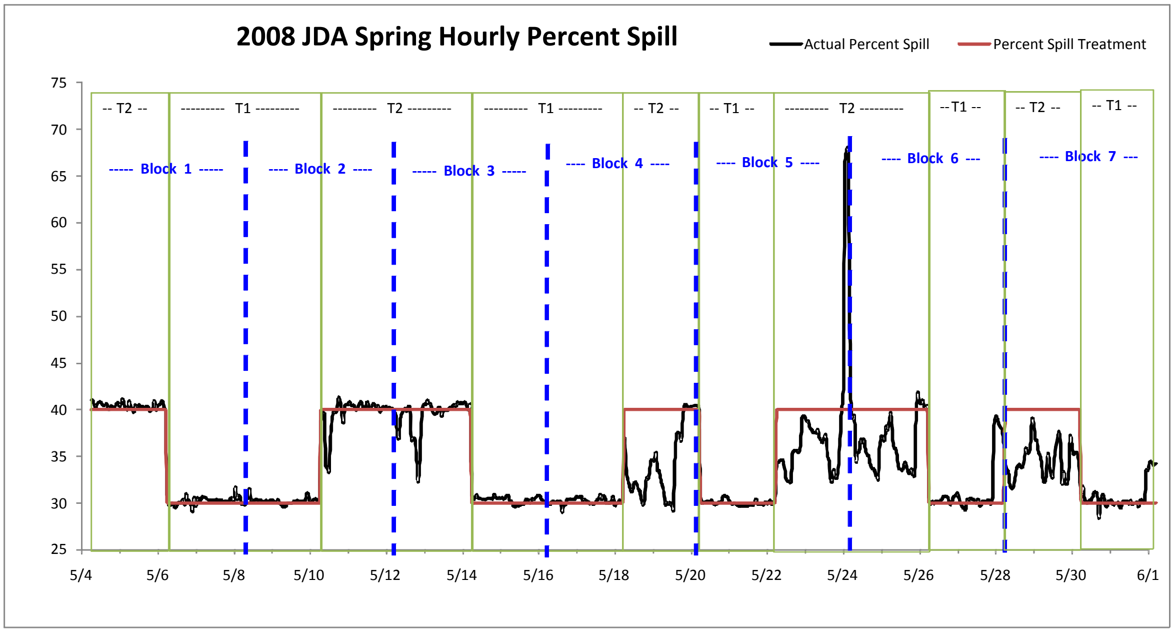

Figure 3.29. Spill treatments as prescribed (red line) and actual conditions (black line) in spring (repeated from Figure 3.22 for ease of reference)

Paired-release estimates of STH dam-passage survival rate did not differ between the 30% and 40% spill conditions based on overlap of 1/2 95% CIs (Table 3.17). Most fish-passage metrics were similar under the 30% and 40% spill conditions (Table 3.18). The single exception was spill-passage effectiveness, which was higher under the 30% spill condition than under the 40% spill condition ($t=2.17$; $n = 8$; one-tailed $P = 0.0293$). The TSW-passage efficiency was 10% higher under the 30% spill condition than it was under the 40% spill condition, but this difference was not significant ($t = 1.22$; $n = 8$; one tailed $P = 0.1308$). The null hypothesis that TSW-passage efficiency under the 30% spill condition was higher than TSW-passage efficiency under the 40% spill condition could not be rejected.

Table 3.17. Estimates of dam-passage survival rates by post-hoc spill condition for steelhead smolts during spring

Condition	Survival (±1/2 95% CI)
30% Spill	99.1 ± 2.8%
40% Spill	97.2 ± 3.7%

CI = confidence interval.

Table 3.18. Estimates of major passage metrics by post-hoc spill condition for steelhead smolts during spring. Only spillway-passage effectiveness differed between the post-hoc definitions of spill condition.

Metric	Spring (±1/2 95% CI)
FPE 30% Spill	97.4 ± 0.9%
FPE 40% Spill	96.7 ± 1.3%
SE 30% Spill	75.8 ± 3.7%
SE 40% Spill	72.4 ± 5.0%
FGE 30% Spill	89.4 ± 3.8%
FGE 40% Spill	88.1 ± 4.6%
TSWE 30% Spill	53.8 ± 4.8%
TSWE 40% Spill	43.9 ± 6.7%
JBSE 30% Spill	21.6 ± 3.6%
JBSE 40% Spill	24.7 ± 4.9%
SEF 30% Spill	2.48 ± 0.12[(a)]
SEF 40% Spill	1.87 ± 0.13[(a)]
TSWEF 30% Spill	7.92± 0.71
TSWEF 40% Spill	6.13 ± 0.93

(a) Spillway-passage effectiveness was higher under the 30% spill condition (t=2.17; n = 8; one-tailed P = 0.0293).
CI = confidence interval.
FGE = fish-guidance efficiency.
FPE = fish-passage efficiency.
JBSE = juvenile bypass system-passage efficiency.
SE = spillway-passage efficiency.
SEF = spillway-passage effectiveness.
TSW = top-spill weir.
TSWE = TSW-passage efficiency.
TSWEF = TSW-passage effectiveness.

3.6.2.6 Diel Trends in Survival and Passage Efficiencies

Survival estimates did not differ much between day and night, except for powerhouse survival, which was higher at night than it was during the day (Table 3.19). The day and night difference in powerhouse survival was entirely due to turbine passage survival because it was higher at night (78.9%) than it was during the day (67.1%), whereas JBS survival was similar during day and night (Table 3.19).

The rates of passage of STH smolts were higher at night than during the day at the powerhouse, turbines, and JBS, whereas day passage rates were higher than night passage rates for the entire spillway (Figure 3.30). On a per-bay basis, the TSW had a higher passage rate than did other locations within the spillway, and the rate was much higher during the day than it was at night (Figure 3.31). The night passage rate was slightly higher than the day passage rate at non-TSW bays, and differences in day-night trends for TSW and non-TSW spill bays indicate that the predominance of day passage for the entire spillway (Figure 3.30) was mostly due to high daytime passage at TSW bays (Figure 3.31).

Table 3.19. Comparison of diel non-tag-life-corrected paired-release survival rate trends for steelhead smolts during spring

Metric	Day (±1/2 95% CI)	Night (±1/2 95% CI)
Concrete	97.5 ± 1.6%	98.7 ± 2.0%
Powerhouse	90.9 ± 4.7%	98.0 ± 2.7%
JBS	99.0 ± 0.6%	99.7 ± 2.1%
Spillway	97.9 ± 1.7%	98.5 ± 1.7%
Spill bays 17–20	97.3 ± 2.1%	96.7 ± 3.3%
TSW (spill bays 15 and 16)	98.5 ± 2.0%	96.2 ± 0.3%
Spill bays 1–14	95.3 ± 3.7%	101.4 ± 1.6%

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

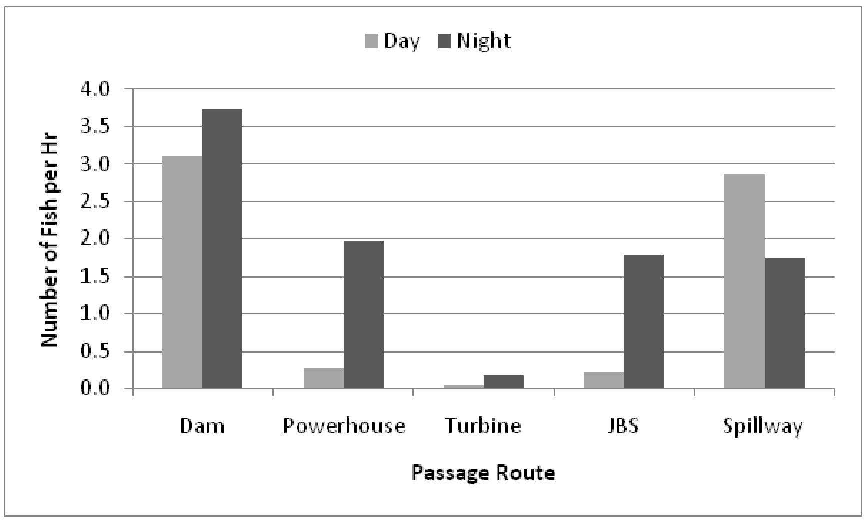

Figure 3.30. Hourly rate of steelhead passage by passage route

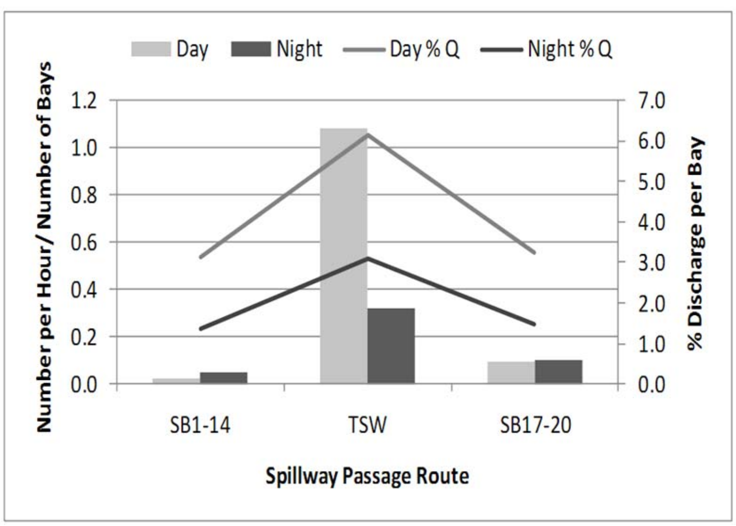

Figure 3.31. Diel passage rates (number/hour/bay) for steelhead and percent discharge for groups of bays

3.6.3 Subyearling Chinook Salmon

Passage efficiency and effectiveness, horizontal passage distribution at the dam, powerhouse and spillway passage, the effect of spill conditions on dam-passage survival rate and fish passage proportions among routes, and diel trends in survival rates and passage efficiencies relative to SYC are described below.

3.6.3.1 Passage Efficiency and Effectiveness

During 2008, the FPE of SYC smolts was 83.3%, with 14.7% guided by in-turbine screens to the JBS and 68.6% passing through the spillway (Table 3.20). The passage efficiency of the TSW bays was 20.6% relative to the numbers passing through the dam and 30% relative to numbers passing through the spillway. About 17% of total fish passage was through turbines (1-FPE), and the FGE of powerhouse screens was 46.8% (Table 3.20). The TSW was more effective than the entire spillway for passing SYC smolts (Table 3.20).

3.6.3.2 Horizontal Passage Distribution at the Dam

The passage of tagged SYC smolts at TSW bays was higher than passage at any other individual passage route at John Day Dam (Figure 3.32). On average, each TSW bay passed five times more smolts than individual turbines or spill bays from 2 to 13. Passage also was high at spill bays near TSW bays (i.e., at spill bays 14, 17, 18, and 19). The majority (69%) of smolts passed at the spillway despite 65% of water discharge passing through the powerhouse, and the two TSW bays passed 30% of the total number of SYC passing through the spillway (Figure 3.32).

Table 3.20. Estimates of major passage metrics for subyearling Chinook salmon smolts

Metric	Estimate ±1/2 95% CI
Fish-Passage Efficiency	83.30 ± 1.86%
Spillway-Passage Efficiency	68.60 ± 2.37%
Fish-Guidance Efficiency	46.80 ± 4.41%
TSW-Passage Efficiency	20.60 ± 2.13%
JBS-Passage Efficiency	14.70 ± 1.79%
Spillway-Passage Effectiveness	1.94 ± 0.07
TSW-Passage Effectiveness	3.14 ± 0.32

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

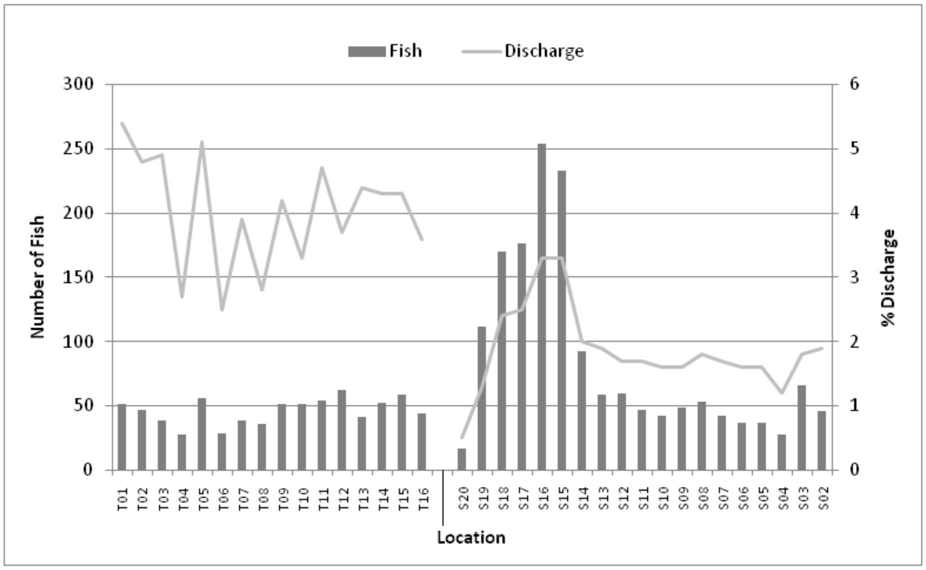

Figure 3.32. Subyearling Chinook salmon passage and discharge by individual passage route in spring 2008

3.6.3.3 Powerhouse Passage

During summer, only 46.8% of the fish that passed through the dam at the powerhouse were guided through the JBS, and the remaining 53.2% passed through turbines (Figure 3.33). Guided passage exceeded unguided passage at turbine units 1, 5, 6, 8, and 10, but was less than unguided passage at the other 11 units.

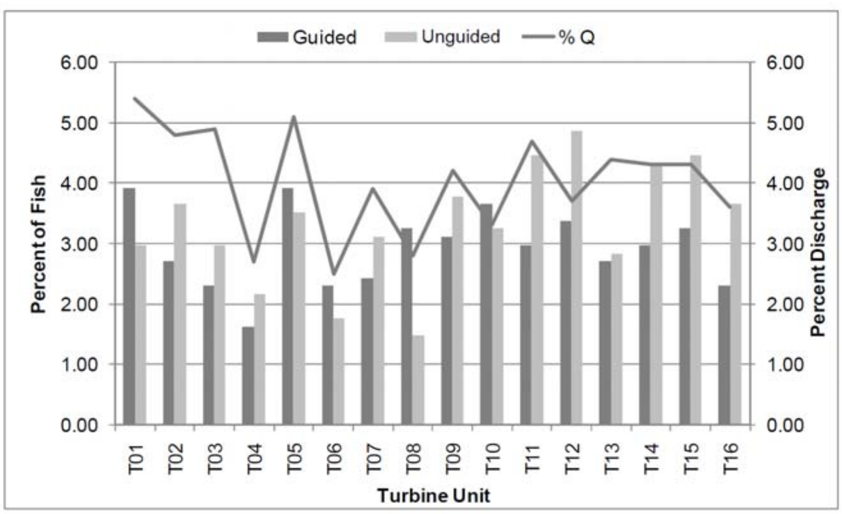

Figure 3.33. Guided and unguided passage of subyearling Chinook salmon in summer

3.6.3.4 Spillway Passage

The highest percent passage and discharge within the spillway occurred at TSW spill bays 15 and 16 and nearby non-TSW spill bays 14, 17, and 18 (Figure 3.34). On a per-bay basis, an average TSW bay passed 1.6 times more fish than an average non-TSW bay to the south (spill bays 17–20) and 4.3 times more fish than an average bay to the north (spill bays 2–14; Figure 3.35).

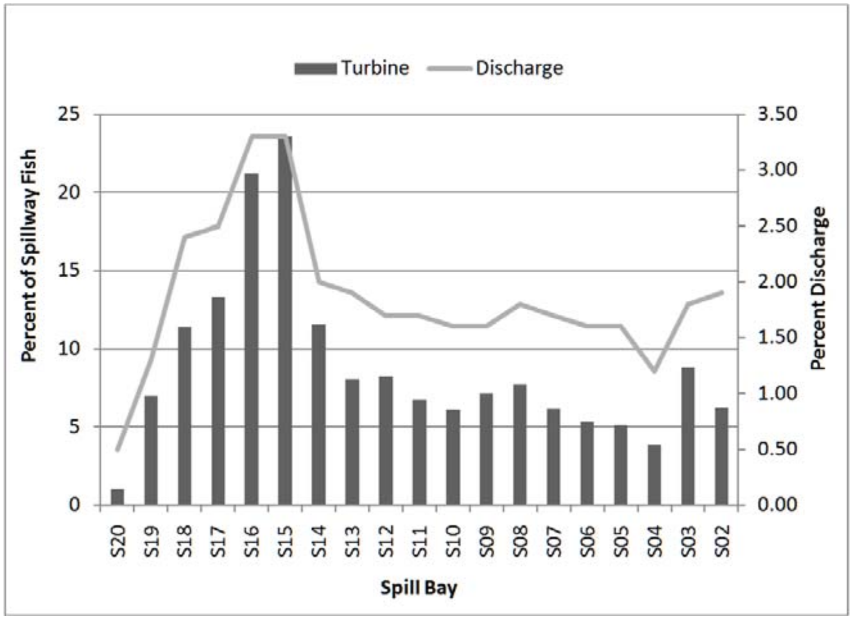

Figure 3.34. Percent discharge and passage of subyearling Chinook salmon smolts by spill bay

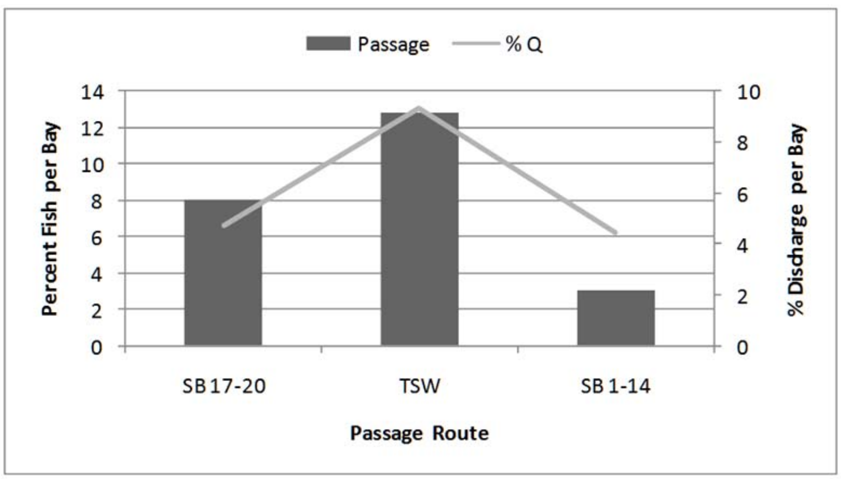

Figure 3.35. Percent discharge and passage for subyearling Chinook salmon per individual spill bay within groups of bays

3.6.3.5 Effect of Spill Condition on Dam Survival and Passage

We defined post-hoc spill conditions because mean hourly percent spill discharge at John Day Dam during the summer deviated a lot from some of the prescribed treatments (Figure 3.26). During the 30% treatments, spill ranged from 29% to 68%, with a mean of 36%, and during the 40% treatments, spill ranged from 29% to 58%, with a mean of 35%. Spill bay discharge ranged from 37 to 240 kcfs during the summer study period. The post-hoc 30% spill condition was defined by passage when spill was <35% and the post-hoc 40% spill condition was defined by passage when spill was between 35% and 45%. The survival metric was the paired-release dam-passage survival rate (i.e., the survival rate of SYC passing from the forebay entrance array to the tailrace release site).

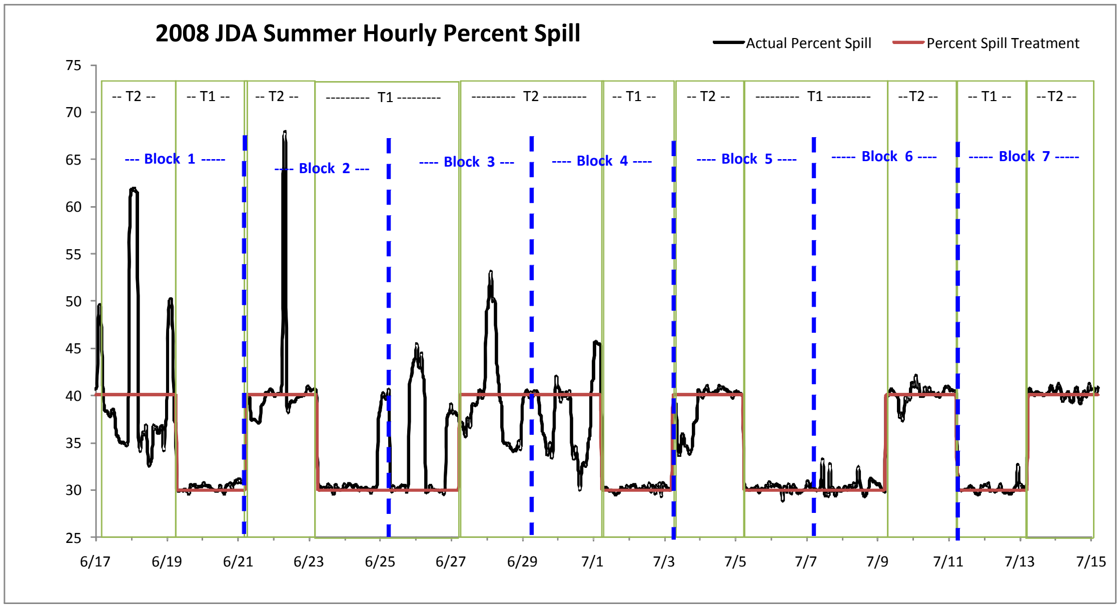

Figure 3.36. Spill conditions during summer

Paired-release estimates of dam-passage survival rate did not differ between the 30% and 40% spill conditions (Table 3.21) based on the overlap of 1/2 95% CIs and on a one-tailed t-test ($P = 0.4027$). The null hypothesis for the one-tailed test was that the dam-passage survival rate during 40% spill conditions was not significantly greater than the dam-passage survival rate during 30% spill conditions. Other fish-passage metrics (Table 3.22) also showed no significant difference between 30% and 40% spill conditions, except for spill-passage effectiveness, which was significantly higher under the 30% spill condition than it was under the 40% spill condition ($t = 3.545$; $n = 8$; $P = 0.0020$).

Table 3.21. Paired-release estimates of dam-passage survival rates by post-hoc spill condition for subyearling Chinook salmon during summer

Spill Condition	Survival (±1/2 95% CI)
30% Spill	0.852 ± 0.024
40% Spill	0.866 ± 0.024
CI = confidence interval.	

Table 3.22. Estimates of major passage metrics by spill treatment for subyearling Chinook salmon

Metric	Summer (±1/2 95% CI)
FPE 30% Spill	82.03 ± 2.96%
FPE 40% Spill	84.43 ± 2.92%
SE 30% Spill	65.71 ± 3.80%
SE 40% Spill	71.08 ± 3.79%
FGE 30% Spill	47.61 ± 6.61%
FGE 40% Spill	46.15 ± 7.39%
TSWE 30% Spill	21.41 ± 3.36%
TSWE 40% Spill	20.79 ± 3.52%
JBSE 30% Spill	16.33 ± 2.95%
JBSE 40% Spill	13.35 ± 2.79%
SEF 30% Spill	2.14 ± 0.12
SEF 40% Spill	1.81 ± 0.10
TSWEF 30% Spill	3.38 ± 0.52
TSWEF 40% Spill	3.00 ± 0.52

CI = confidence interval.
FGE = fish-guidance efficiency.
FPE = fish-passage efficiency.
JBSE = juvenile bypass system-passage efficiency.
SE = spillway-passage efficiency.
SEF = spillway-passage effectiveness.
TSW = top-spill weir.
TSWE = TSW-passage efficiency.
TSWEF = TSW-passage effectiveness.

3.6.3.6 Diel Trends in Survival and Passage Efficiencies

The survival rate of SYC was higher at night than it was during the day for smolts passing through the dam, powerhouse, turbines, spillway, and spill bays 17–20 (Table 3.23). Day and night estimates of survival rate were similar for SYC passing through the JBS, TSW, and spill bays 1–14.

Table 3.23. Comparison of diel non-tag-life-corrected paired-release survival trends for subyearling Chinook salmon during summer

Route	Day (±1/2 95% CI)	Night (±1/2 95% CI)
Dam	82.3 ± 3.3%	93.8 ± 2.3%
Powerhouse	75.1 ± 10.3%	91.9 ± 2.9%
Turbine	60.8 ± 14.1%	86.5 ± 5.0%
JBS	93.5 ± 8.9%	99.0 ± 5.1%
Spillway	84.2 ± 3.4%	96.4 ± 2.8%
Spill bays 17−20	60.6 ± 12.2%	97.5 ± 6.1%
TSW (spill bays 15 and 16)	91.8 ± 2.4%	97.2 ± 1.1%
Spill bays 1−14	96.4 ± 2.5%	93.0 ± 8.1%

CI = confidence interval.
JBS = juvenile bypass system.
TSW = top-spill weir.

The hourly rate of passage of SYC through the dam, powerhouse, turbines, and JBS was slightly higher at night than it was during the day (Figure 3.37). Only the spillway passed more SYC during the day (2.2 fish/hr) than it did at night (1.9 fish/hr). On a per-bay hourly basis, the passage rate through the TSW bay was higher than the passage rate through other spill bays within day and night periods, and passage rates per bay were higher during the day than they were at night for all groups of spill bays (Figure 3.38).

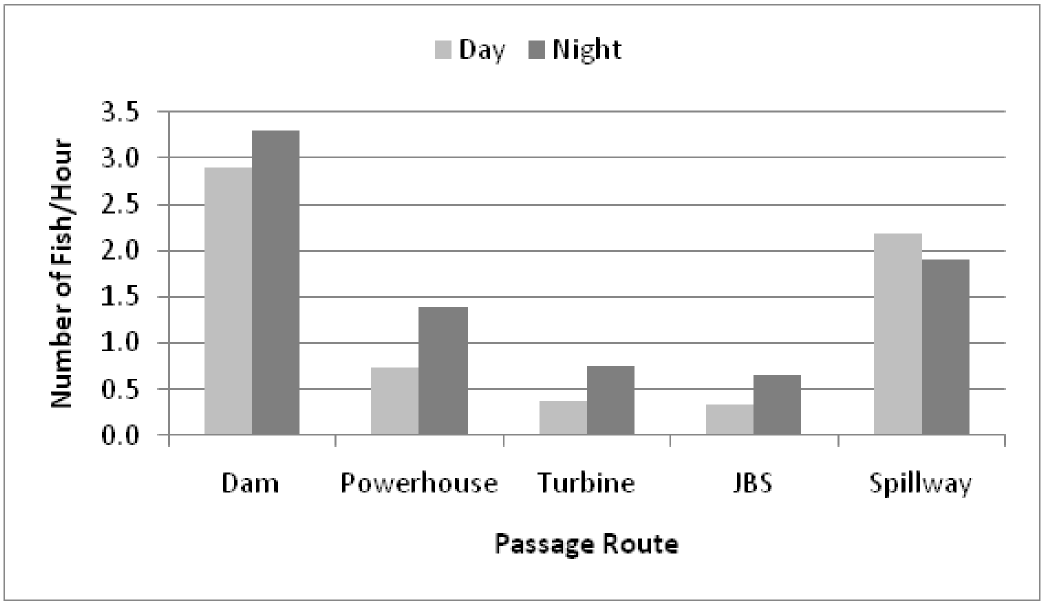

Figure 3.37. Day and night passage rates by route for subyearling Chinook salmon smolts

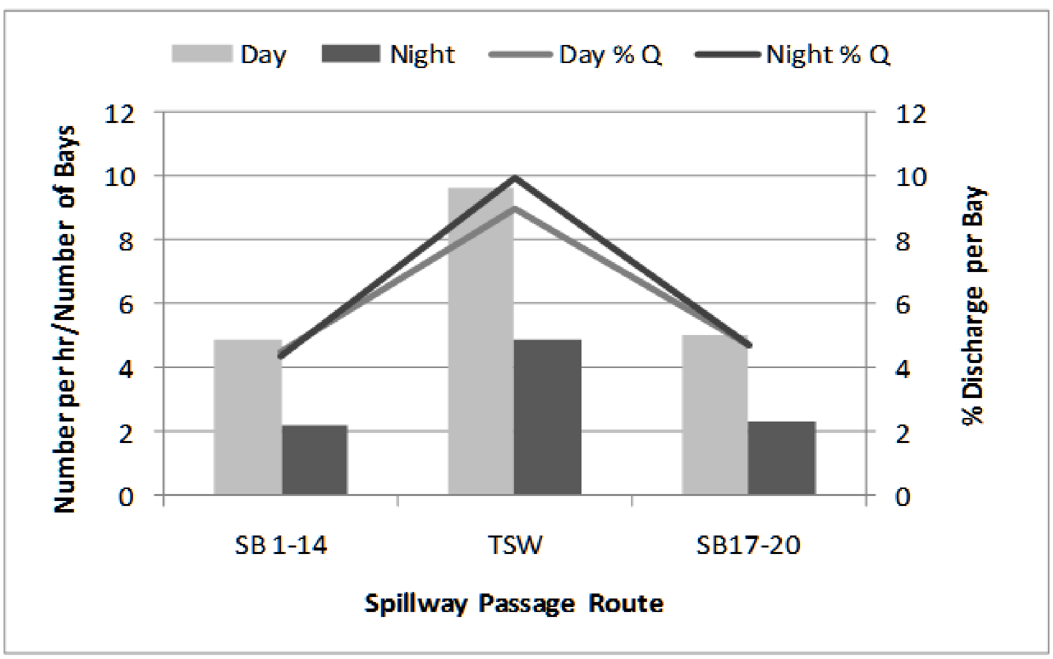

Figure 3.38. Hourly passage rates and percent discharge per bay for subyearling Chinook salmon within groups of spill bays

3.6.4 Travel Times

In spring, 2384 YC smolts were released from Arlington, Oregon, and subsequently detected on the John Day Dam forebay array; median travel time was 25.4 hours (Table 3.24). For tagged smolts detected on the forebay array (2370 fish), the median travel time until passage through John Day Dam was 2.2 hours. Median travel time from the John Day Dam face to the tailrace egress array 10 km downstream of the dam was 1.5 hours. Median travel time for 3179 YC from the John Day Dam egress array to The Dalles Dam forebay array was 10.7 hours. These fish (n = 5628) had a median travel time of 24.4 hours to reach the Bonneville Dam forebay array.

For STH, 2348 fish were released at Arlington, Oregon, and detected on the John Day Dam forebay node array with a median travel time of 1 day (Table 3.25). Of these, 2325 were detected and passed the dam with a median passage time of 4.3 hours. Of the STH passing John Day Dam, 2240 were detected on the egress array with a median travel time of 1.2 hours for all passage routes pooled. Median travel time for steelhead from the John Day Dam egress array to The Dalles Dam forebay array was 7.6 hours. Median travel time for these fish (n = 2995) to reach the Bonneville Dam forebay array was 22 hours.

Table 3.24. Distance of travel and median travel time (±1/2 95% CI) for yearling Chinook salmon smolts passing through specific river reaches between Arlington, Oregon, and the Bonneville Dam forebay

Reach	Distance (km)	Time (hr)
Arlington to John Day Dam Forebay	38.9	25.4 ± 14.0
John Day Dam Forebay to John Day Dam Passage	2.0	
Dam		2.2 ± 1.0
JBS		2.7 ± 1.2
Turbine		2.7 ± 1.2
TSW		2.1 ± 0.9
John Day Dam Passage to John Day Dam Egress	5.2	
Dam		1.5 ± 1.0
JBS		3.6 ± 1.9
Turbine		1.6 ± 1.1
TSW		1.6 ± 1.0
John Day Dam Passage to John Day Dam Egress 30% Spill	5.2	
Dam		1.4 ± 1.0
JBS		5.4 ± 2.2
Turbine		1.6 ± 1.2
TSW		1.5 ± 1.0
John Day Dam Passage to John Day Dam Egress 40% Spill	5.2	
Dam		1.5 ± 1.0
JBS		2.9 ± 3.7
Turbine		1.5 ± 1.1
TSW		1.8 ± 1.1
John Day Dam Egress to The Dalles Dam Forebay	31.0	10.7 ± 7.0
The Dalles Dam Forebay to Bonneville Dam Forebay	74.9	24.4 ± 0.52

JBS = juvenile bypass system.
TSW = top-spill weir.

Table 3.25. Distance of travel and median travel time (±1/2 95% CI) for steelhead smolts passing through specific river reaches between Arlington, Oregon, and the Bonneville Dam forebay

Reach	Distance (km)	Time (hr)
Arlington to John Day Dam Forebay	38.9	24.1 ± 15.1
John Day Dam Forebay to John Day Dam Passage	2.0	
Dam		4.3 ± 1.0
JBS		5.9 ± 1.7
Turbine		4.0 ± 1.5
TSW		3.7 ± 0.9
John Day Dam Passage to John Day Dam Egress	5.2	
Dam		1.2 ± 0.9
JBS		3.9 ± 2.3
Turbine		1.8 ± 1.1
TSW		1.2 ± 0.9
John Day Dam Passage to John Day Dam Egress 30% Spill	5.2	
Dam		1.2 ± 0.9
JBS		3.7 ± 3.1
Turbine		1.6 ± 1.1
TSW		1.2 ± 0.9
John Day Dam Passage to John Day Dam Egress 40% Spill	5.2	
Dam		1.3 ± 1.0
JBS		3.9 ± 3.5
Turbine		2.2 ± 1.3
TSW		1.3 ± 1.0
John Day Dam Egress to The Dalles Dam Forebay	31.0	7.6 ± 5.4
The Dalles Dam Forebay to Bonneville Dam Forebay	74.9	21.7 ± 0.45

JBS = juvenile bypass system.
TSW = top-spill weir.

The median travel time of the 2386 SYC released at Arlington, Oregon, to the John Day Dam forebay array was 22.6 hours (Table 3.26). Of these, 2360 passed through the John Day Dam with a median passage time of 2.2 hours. This time used the last detection time at the dam face. Based on a sample size of 2029 fish, the median travel time from the dam to the tailrace egress array was 1.5 hours. Released fish at Arlington were timed with the John Day Dam tailwater releases to ensure that adequate mixing would occur for John Day Dam passage. The median travel time for 2934 SYC from the John Day Dam egress array to The Dalles Dam forebay was 11.2 hours. The median travel time for these fish (n = 2694) to reach the Bonneville Dam forebay was 30 hours. Table 3.26 shows travel times from Arlington, Oregon, to the Bonneville Dam forebay including the reach, subroutes, and spill treatments as they passed John Day Dam.

Table 3.26. Distance of travel and median travel time (±1/2 95% CI) for subyearling Chinook salmon smolts passing through specific river reaches between Arlington, Oregon, and the Bonneville Dam forebay

Reach	Distance (km)	Time (hr)
Arlington to John Day Dam Forebay	38.9	22.6 ± 14.9
John Day Dam Forebay to John Day Dam Passage	2.0	
Dam		2.2 ± 0.9
JBS		2.4 ± 1.0
Turbine		2.5 ± 1.1
TSW		2.1 ± 0.8
John Day Dam Passage to John Day Dam Egress	5.2	
Dam		1.5 ± 1.1
JBS		6.5 ± 1.6
Turbine		1.7 ± 1.3
TSW		1.5 ± 1.1
John Day Dam Passage to John Day Dam Egress 30% Spill	5.2	
Dam		1.5 ± 1.1
JBS		6.9 ± 2.0
Turbine		1.7 ± 1.2
TSW		1.5 ± 1.1
John Day Dam Passage to John Day Dam Egress 40% Spill	5.2	
Dam		1.4 ± 1.1
JBS		6.4 ± 2.9
Turbine		1.6 ± 1.3
TSW		1.5 ± 1.1
John Day Dam Egress to The Dalles Dam Forebay	31.0	11.2 ± 8.2
The Dalles Dam Forebay to Bonneville Dam Forebay	74.9	30.1 ± 0.37

JBS = juvenile bypass system.
TSW = top-spill weir.

3.7 Fish Behavior

This section contains a description of the arrival and passage distributions, day and night differences in behavior, vertical distributions, and horizontal distributions of tagged fish released upstream of and approaching John Day Dam. The autonomous node array located 2 rkm upstream of John Day Dam was used to assign approach locations and dam-mounted hydrophones were used to assign passage locations. Forebay residence times are described by passage route and for combinations of arrival and passage location.

3.7.1 Yearling Chinook

3.7.1.1 Approach and Route of Passage

The approach of YC smolts at John Day Dam was skewed toward first detections at the powerhouse (46%) and then the spillway (37%; Figure 3.39). Smolts first detected at the powerhouse or skeleton bays made up 62% of all fish arriving at John Day Dam. Of those fish, 60% would eventually pass through the spillway. Fish detected in the spillway were much more likely to pass through the dam at the spillway (37%) than they were to be pass through the dam at the powerhouse (<1%).

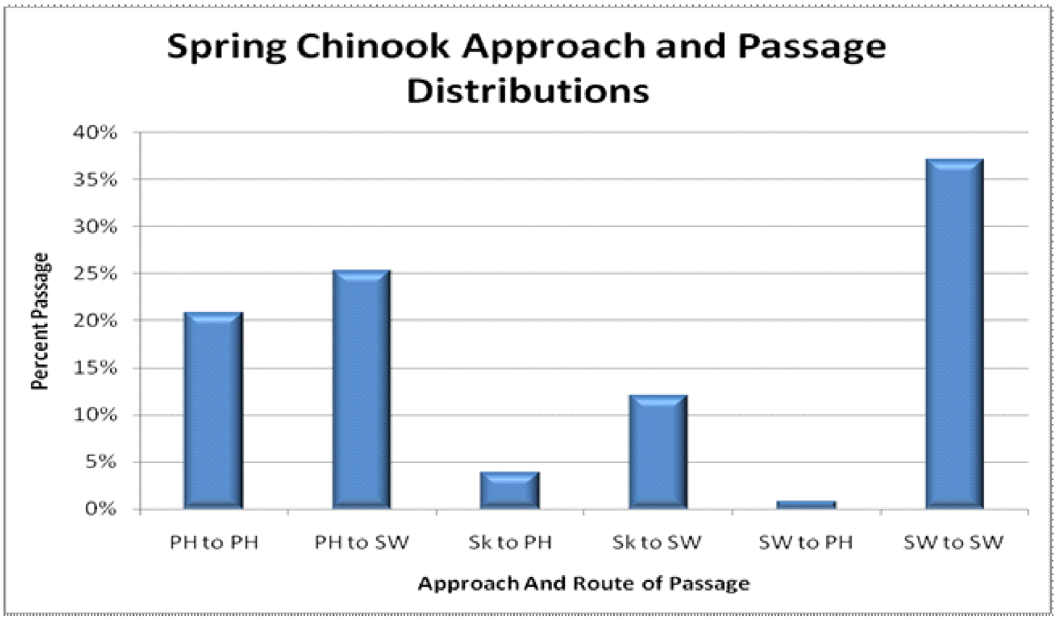

Figure 3.39. Yearling Chinook salmon approach and passage distributions at John Day Dam. The first abbreviation is for the approach location and the second is for the passage location. Abbreviations are as follows: PH = powerhouse; Sk = skeleton bay; SW = spillway.

Fish arriving at John Day Dam were grouped into arrival blocks and passage-route blocks. The arrival blocks were assigned from autonomous nodes located in the John Day Dam forebay, and passage-route blocks were assigned from detections on the dam-face arrays. These blocks included powerhouse units 1–8, 9–16, skeleton bays 17–20, spill bays 1–14, 15–16 (TSW), and spill bays 17–20 (Figure 4.40). Yearling Chinook arriving at the powerhouse in spring made up 62% of all fish released upstream at Arlington, Oregon. Of these, only 11% would eventually pass through spillway block (SW) 15–16 in which the TSW was installed. A greater number of powerhouse-arrived fish, 22%, were eventually passed through SW 17–20, which is located near the transition of the powerhouse to the spillway. More than half of the powerhouse-arrived YC were attracted to the spillway.

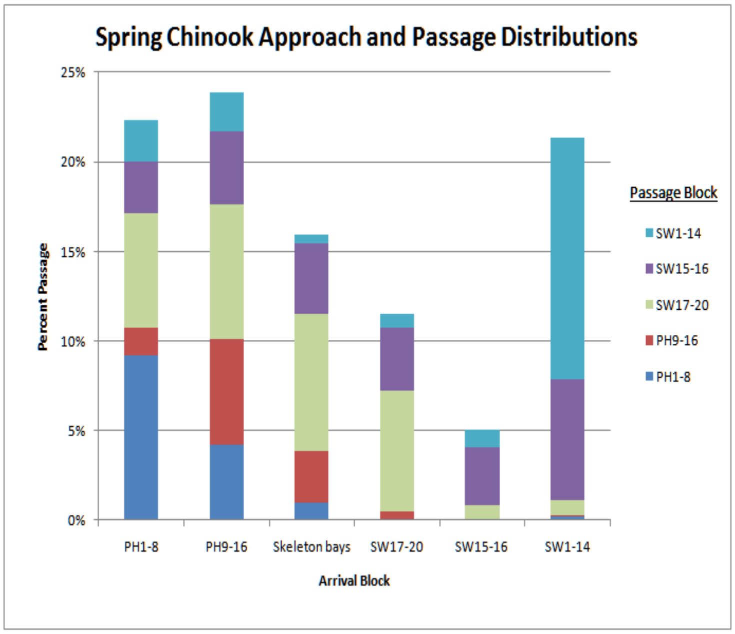

Figure 3.40. Yearling Chinook salmon approach and passage distributions by passage blocks at John Day Dam

3.7.1.2 Diel Behavior Patterns

About 68% of YC smolts passed through John Day Dam during the day primarily because daytime spillway passage predominated, but powerhouse passage, regardless of approach location, was higher at night than it was during the day (Figure 3.41). The spillway was more effective at attracting fish approaching the powerhouse during the day than at night. Smolts approaching the powerhouse at night tended to pass through the powerhouse rather than move to the spillway.

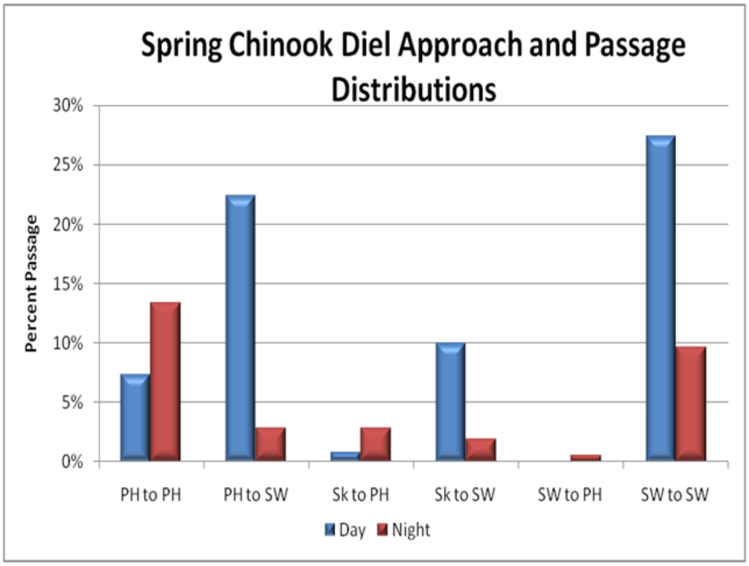

Figure 3.41. Yearling Chinook salmon smolt approach and passage distributions during day and night

Passage distributions during the day were similar to pooled distributions for day and night periods. Most YC arriving at the powerhouse during the day eventually passed through spill bays 17–20 (Figure 3.42). This was not the case at night when most YC arriving at the powerhouse also passed there (Figure 3.43). Night detections of YC at the powerhouse (67%) were much greater than night detections at the spillway (33%; Figure 3.43).

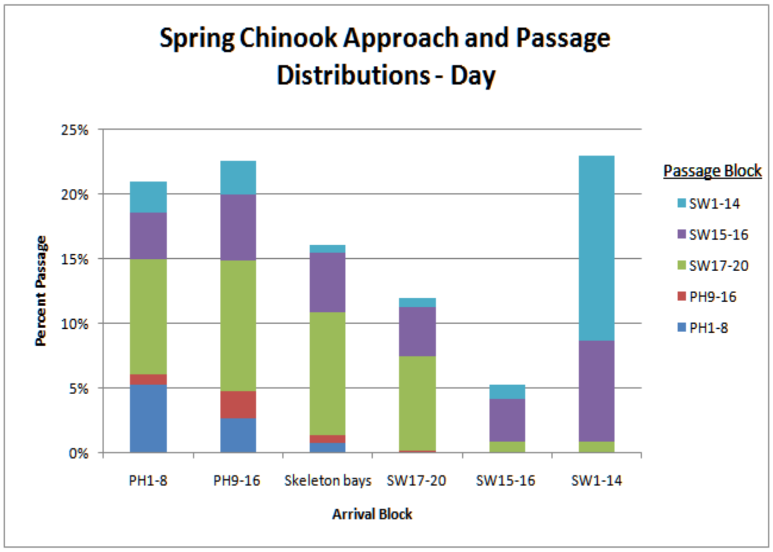

Figure 3.42. Approach and passage distributions for yearling Chinook salmon during daytime at John Day Dam

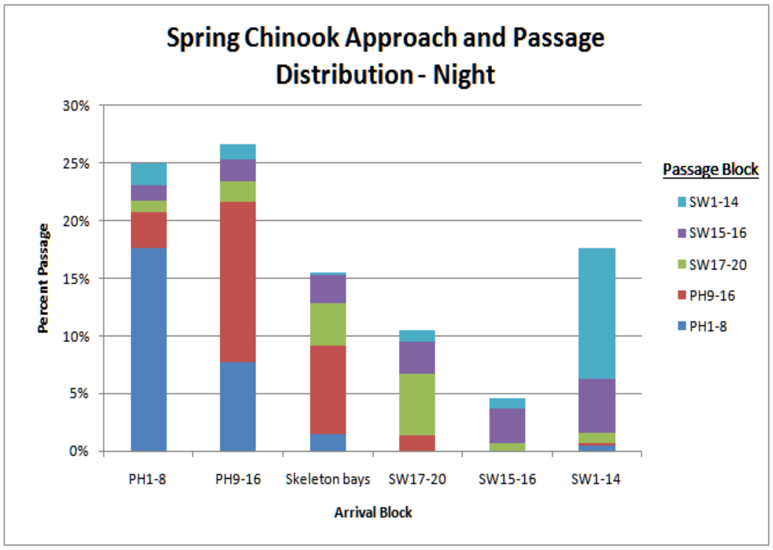

Figure 3.43. Approach and passage distributions for yearling Chinook salmon passing John Day Dam at night

The number of YC passing through the powerhouse was slightly higher at night than it was during the day, whereas the opposite was true for the spillway, particularly at the TSW, where daytime passage predominated (Figure 3.44). Most YC passed evenly at the TSW and nearby bays during the day, but passage was highest at TSW bay 16 at night.

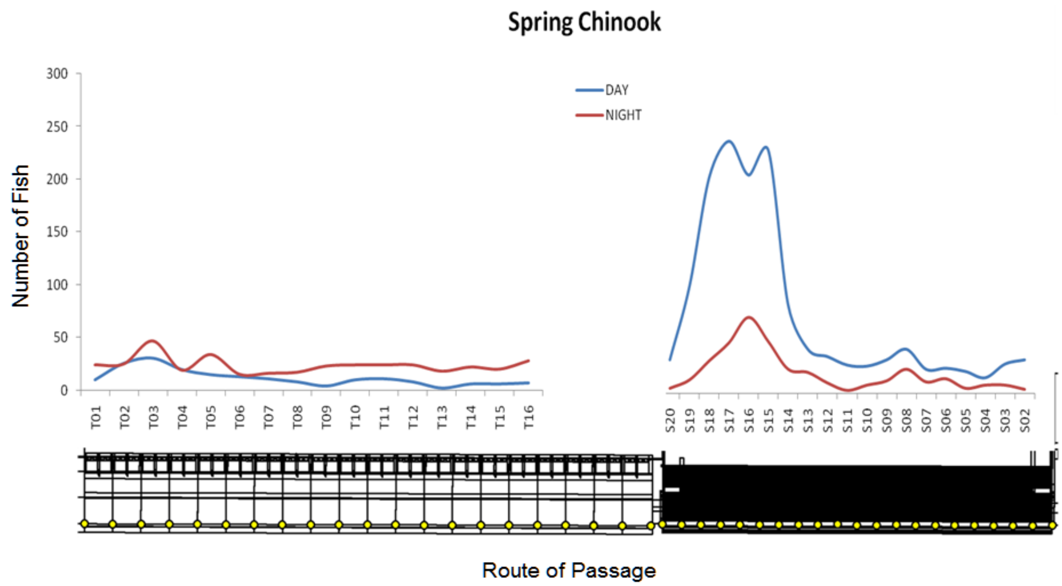

Figure 3.44. Day and night passage of acoustic tagged juvenile yearling Chinook salmon at each passage route at John Day Dam. The powerhouse is on the left and the spillway is on the right as if viewed from the forebay looking downstream. The blank space indicates the location of the skeleton bays, through which fish cannot pass.

3.7.1.3 Vertical Distributions

As arriving fish moved from 75 to 10 m from the face of the powerhouse, travel depth gradually decreased, but at <5 m from the dam face, detection depths increased to over 20 m (Figure 3.45). This was expected because turbine- and JBS-passed fish must pass at much greater depths than spillway-passed fish. The YC smolts approaching the spillway also move up slightly in the water column. However, sudden increases in depth associated with passage under tainter gates was not detected because hydrophones were mounted on piers well upstream of the spill gates. There were no day and night differences in vertical distributions for powerhouse- or spillway-passed fish.

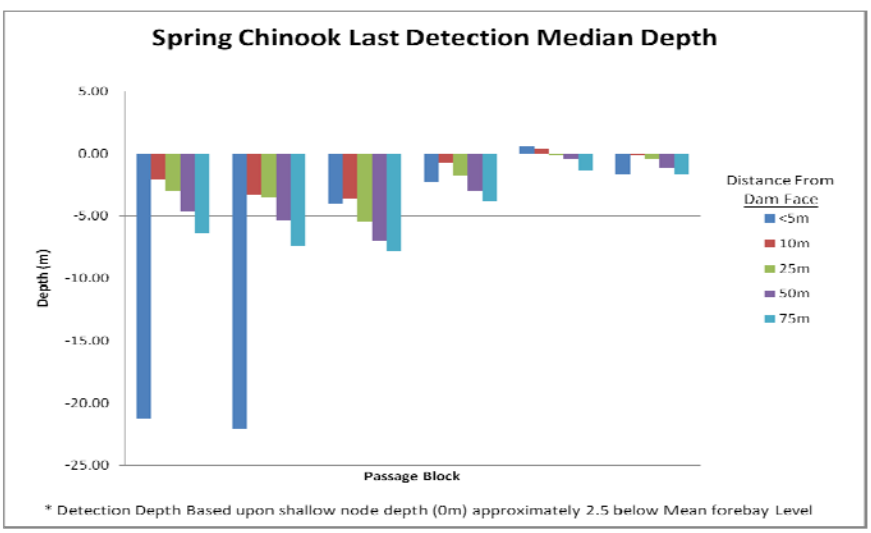

Figure 3.45. Median depths of last detection of tagged yearling Chinook salmon smolts at John Day Dam

Turbine- and JBS-passed YC smolts had median last-detection depths of 25 m and 20 m, respectively (Figure 3.46). Fish that pass into the JBS at John Day Dam are intercepted by screens in the upper part of the turbines whereas deeper fish are not intercepted and pass into turbines. The difference in median last-detection depths of these two routes is consistent with the depths of submerged traveling screens.

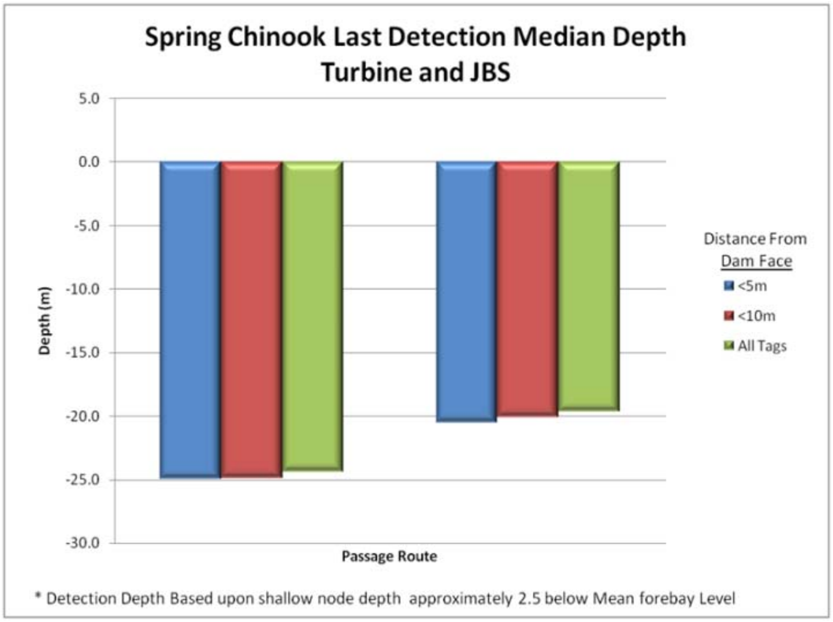

Figure 3.46. Differences in the median depths of the last detection of yearling Chinook salmon smolts that passed into the JBS and turbines

3.7.1.4 Residence Times

The YC arriving and passing at the spillway had a median residence time of 4 minutes, whereas fish arriving and passing through the powerhouse had a median residence time that was 8-fold higher (Figure 3.47). Fish arriving at the powerhouse and later passing through the spillway had a median residence time of over 2 hours, while fish approaching the spillway and passing through the powerhouse had median residence times of 49 minutes.

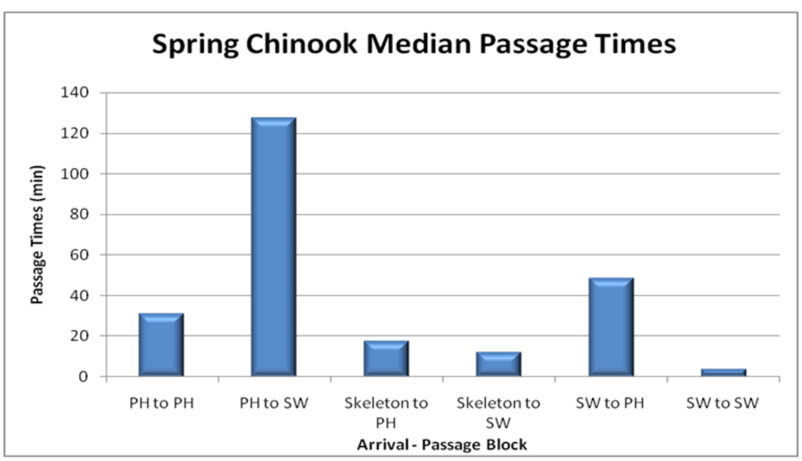

Figure 3.47. Spring Chinook salmon median passage times

For YC approaching the powerhouse and passing the spillway, residence times were three times greater at night than during the day (Figure 3.48). In contrast, YC approaching the spillway and passing there had a median residence time of just 4 minutes.

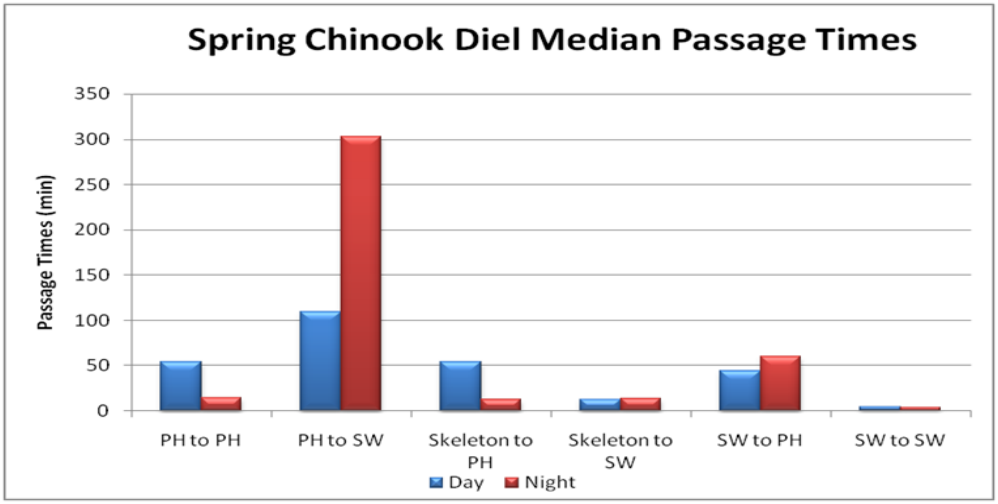

Figure 3.48. Spring Chinook salmon diel median passage times by approach and passage blocks at John Day Dam

3.7.2 Steelhead

3.7.2.1 Approach and Route of Passage

The STH approach to John Day Dam was similar to that of YC with 64% of fish approaching at the powerhouse and 34% approaching at the spillway. However, 32% of the STH that approached the powerhouse eventually passed through the dam at the spillway (Figure 3.49). Most STH approaching the spillway passed there; only 3% of the STH approaching the spillway passed at the powerhouse.

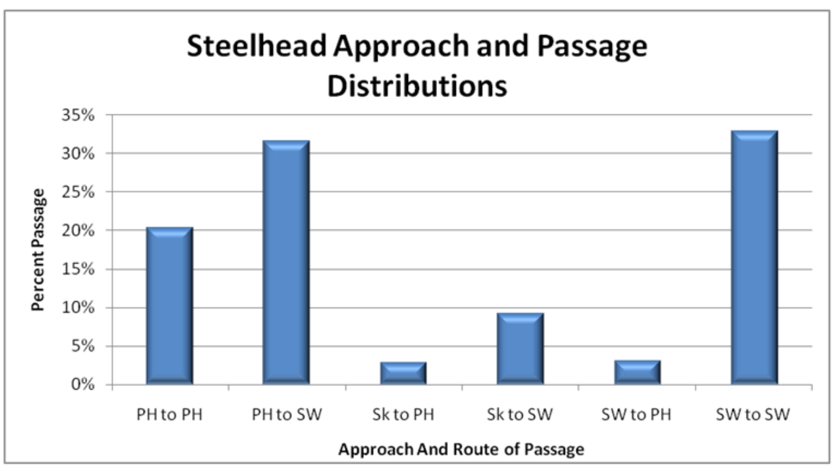

Figure 3.49. Steelhead percent passage by approach and passage blocks at John Day Dam. Abbreviations are as follows: PH = powerhouse; Sk = skeleton bay; SW = spillway.

Of the 64% of STH approaching on the powerhouse side in spring, 29% would eventually pass the TSW in spill bays 15 and 16 (Figure 3.50). In contrast, only 7.7% of the STH approaching on the powerhouse side passed at spill bays 17–20 even though spill bays 17–20 were between the powerhouse and TSW. Most STH approaching the spillway side passed there. Again, only 3% of STH approaching the spillway passed at the powerhouse.

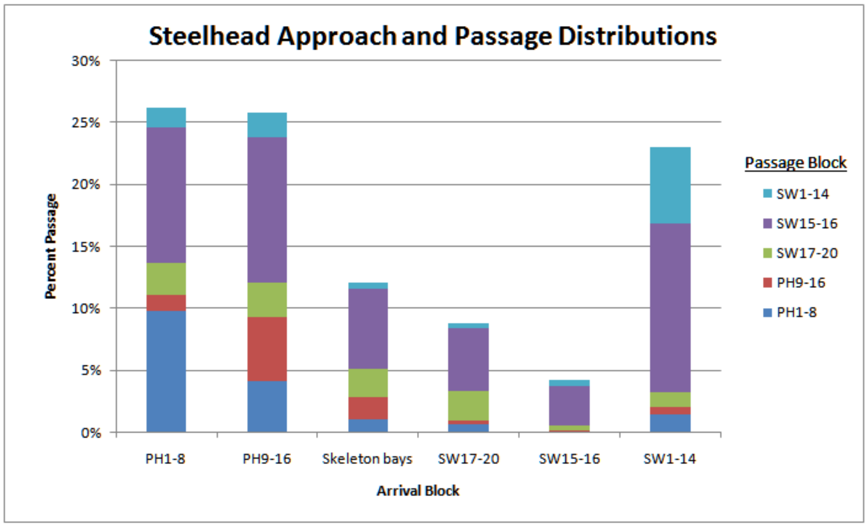

Figure 3.50. Steelhead approach and passage distributions by approach and passage blocks at John Day Dam

3.7.2.2 Diel Behavior Patterns

Steelhead approaching the powerhouse during the day had a much greater tendency to pass the spillway than they did at night; 55% during day and 18% at night (Figure 3.51). The powerhouse was much more effective at passing STH that arrived at night, as seen previously with YC. The spillway was more effective at retaining approaching STH with 38% passage during the day and 25% passage at night.

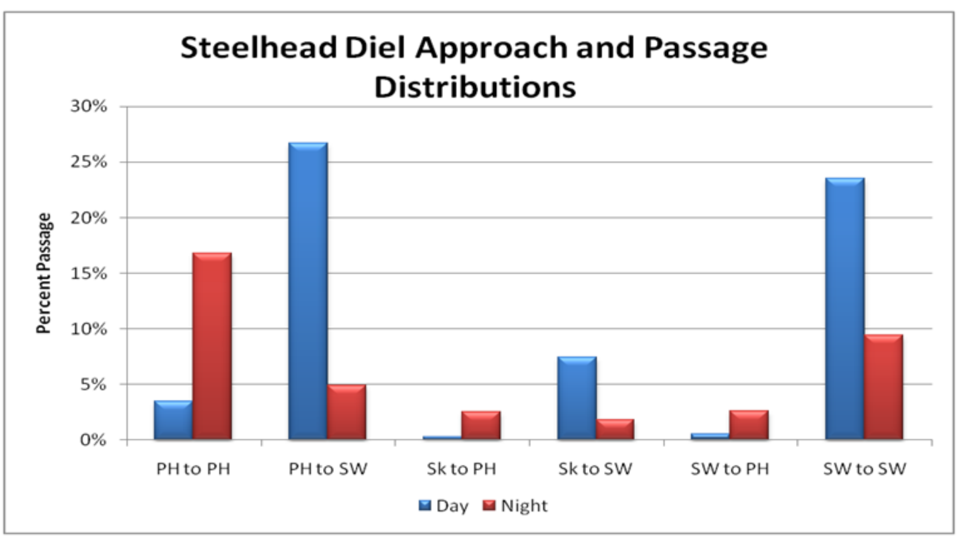

Figure 3.51. Steelhead approach and passage distributions during day and night

During the day, the spillway was effective at attracting powerhouse-arrived fish, whereas at night the powerhouse was more effective at passing arriving STH (Figures 3.52 and 3.53). Passage SW 15–16 (TSW bays) was overwhelmingly effective at passing arriving STH, regardless of how fish approached the dam. About 74% of all fish arriving at John Day Dam during the day passed at the TSW bays (SW 15–16).

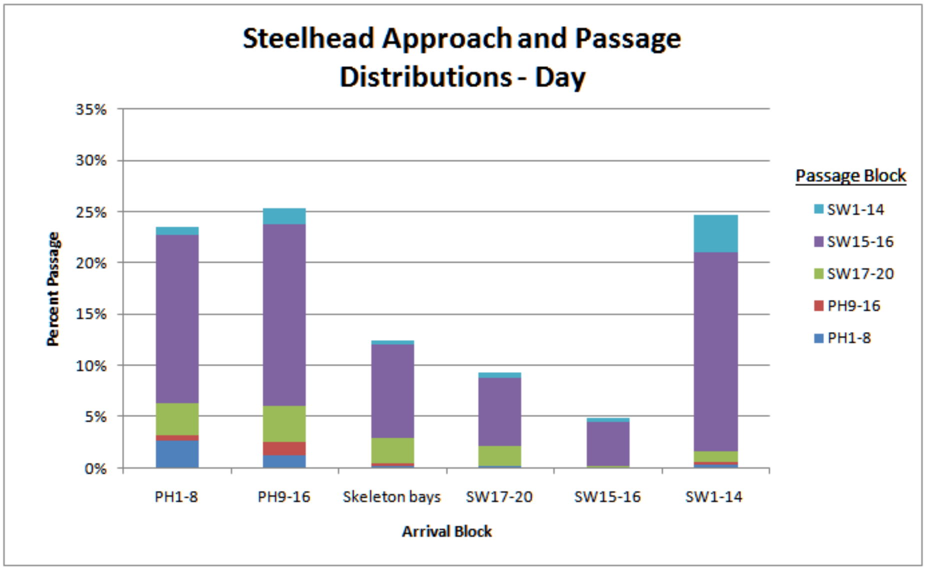

Figure 3.52. Steelhead day passage behaviors by blocks at John Day Dam

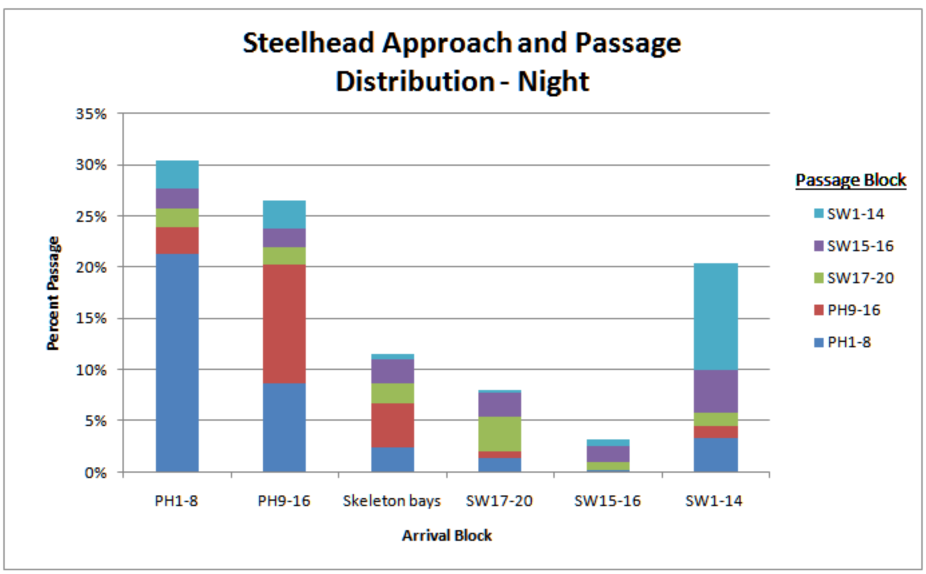

Figure 3.53. Steelhead night passage behaviors by blocks at John Day Dam

The horizontal distribution of STH passage was much higher at the TSW and adjacent bays than any other locations during the day, whereas nighttime passage was only slightly higher at the TSW and turbine units 1 and 2 than at other locations (Figure 3.54). Tagged STH passed in greater numbers at more locations at night than during the day, particularly at the powerhouse, except at the TSW and adjacent bays where daytime passage was much higher than nighttime passage.

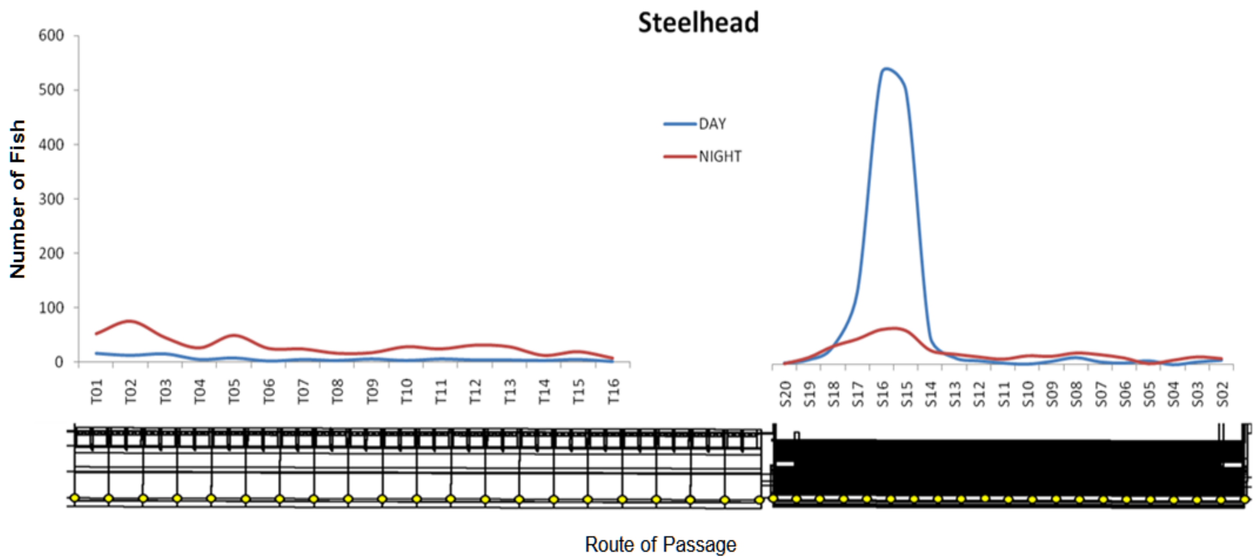

Figure 3.54. Day and night passage of acoustic-tagged steelhead smolts at each passage route at John Day Dam. The powerhouse is on the left and the spillway is on the right as if viewed from the forebay looking downstream. The blank space indicates the location of the skeleton bays, through which fish cannot pass.

3.7.2.3 Vertical Distributions

The median depths of smolts approaching within 10 m of the powerhouse or spillway were <5 m, which is typical for STH (Figure 3.55). The median depths of detection at TSW and conventional spill bays remained shallow to within 5 m of the piers, and increasing depths associated with passing under tainter gates were not detected because hydrophones were mounted on piers well upstream of the gates. The median last-detection depths at the powerhouse at distances <5 m were much deeper and this is consistent with passage into turbines and the ability of hydrophones on piers very near the dam face to detect such activity.

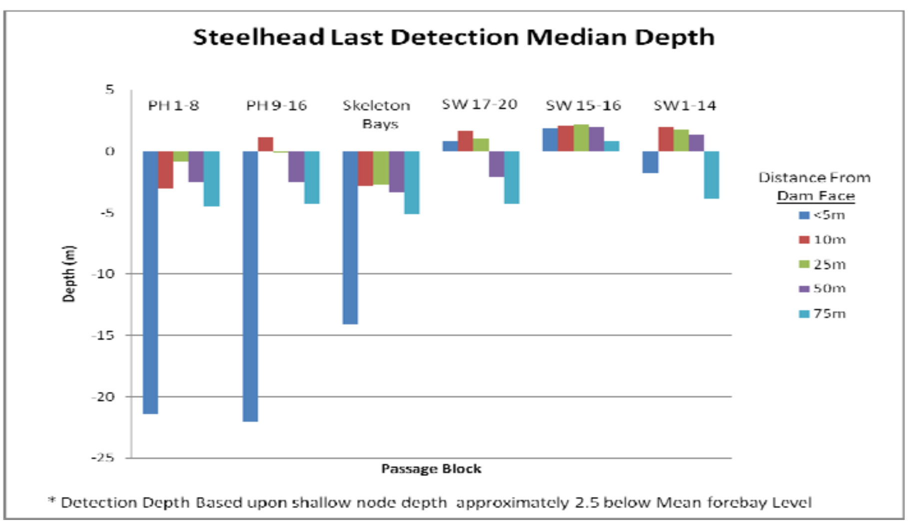

Figure 3.55. Median depths of last detection of tagged steelhead smolts at John Day Dam

Trends in vertical distributions of passage during the day (Figure 3.56) and night (Figure 3.57) were similar, although depths of fish >5 m from the dam were slightly greater at night than they were during the day, regardless of the final route of passage. The depths of STH ultimately passing through turbines was about 5 m greater than the depth of STH routed into the JBS (Figure 3.58).

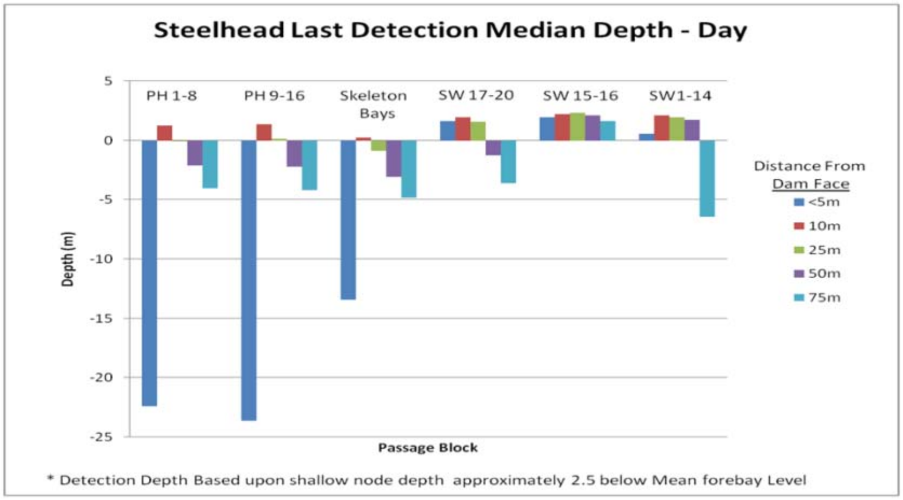

Figure 3.56. Median depths of last detection of tagged steelhead smolts at John Day Dam during the day

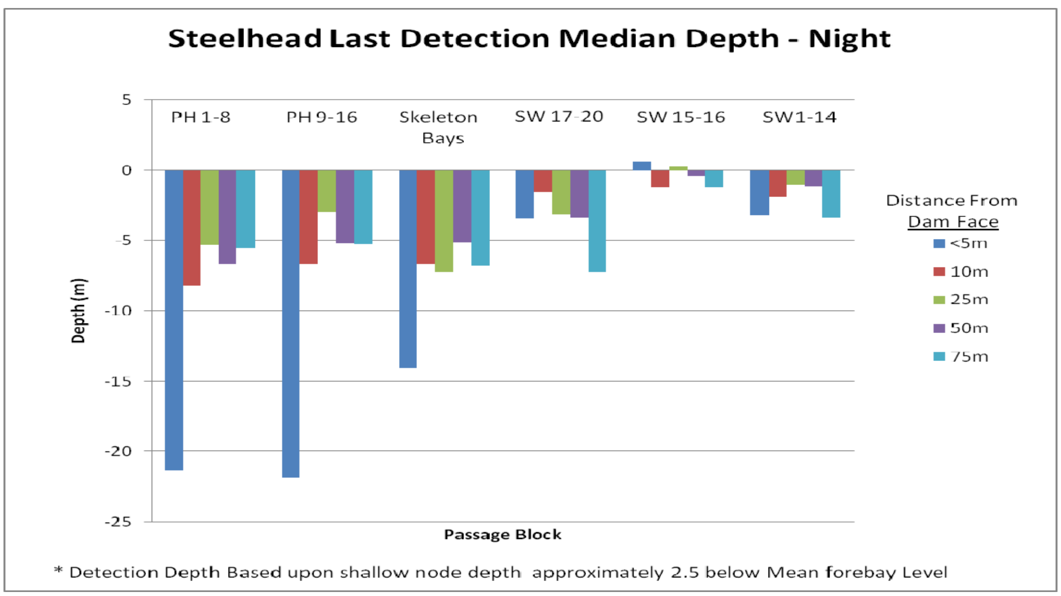

Figure 3.57. Median depths of last detection of tagged steelhead smolts at John Day Dam at night

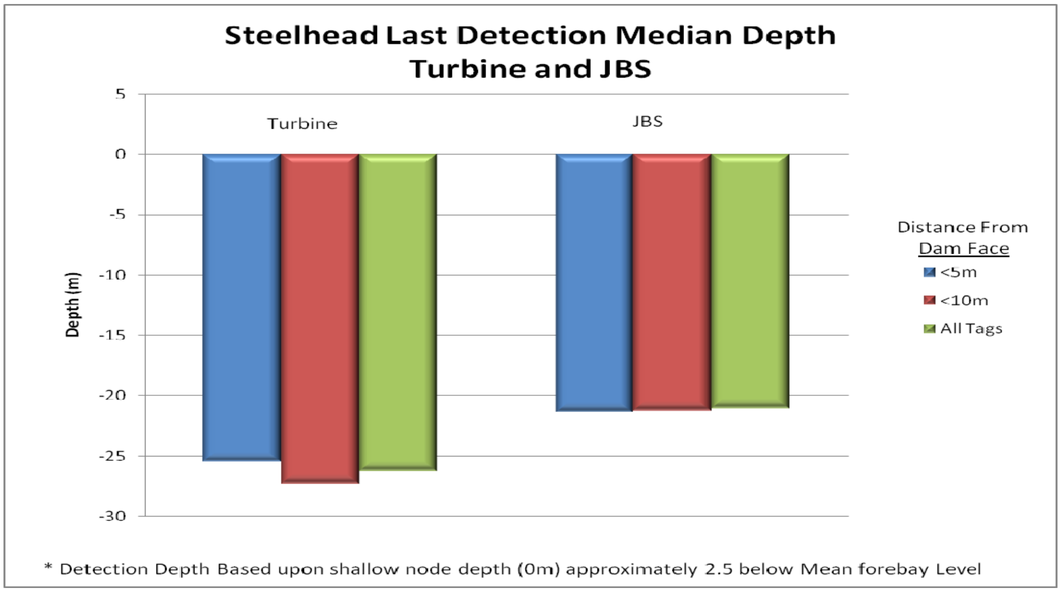

Figure 3.58. Steelhead median last-detection depths for turbine and JBS-passed fish

3.7.2.4 Residence Times

Steelhead approaching the spillway but eventually passing through the dam at the powerhouse had a median residence time that was slightly less than 7 hours, whereas fish approaching the powerhouse and passing at the spillway had a median residence time of 3 hours (Figure 3.59). The opposite trend was observed for YC. The STH approaching the spillway and passing there had the lowest residence time (8 minutes), and this was similar to the forebay residence time observed for tagged YC exhibiting the same behavior.

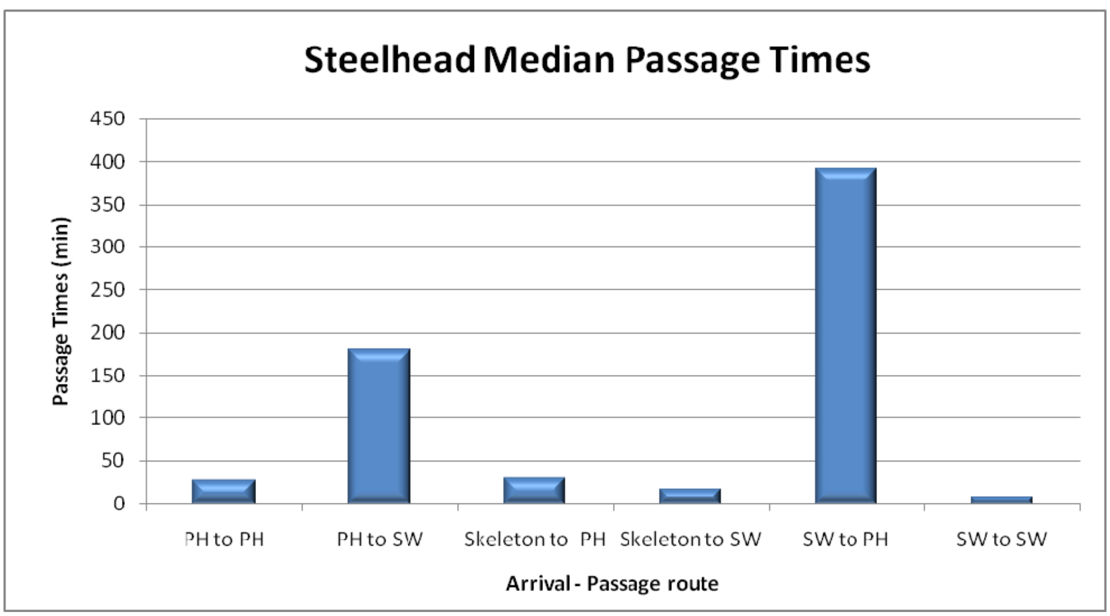

Figure 3.59. Steelhead median passage times by approach and passage routes at John Day Dam

As evident for YC, STH that approached either the powerhouse or spillway and subsequently passed by the other route showed the highest median residence times (Figure 3.60). This was especially true for STH approaching the spillway during the day but eventually passing the powerhouse a median 16 hours later.

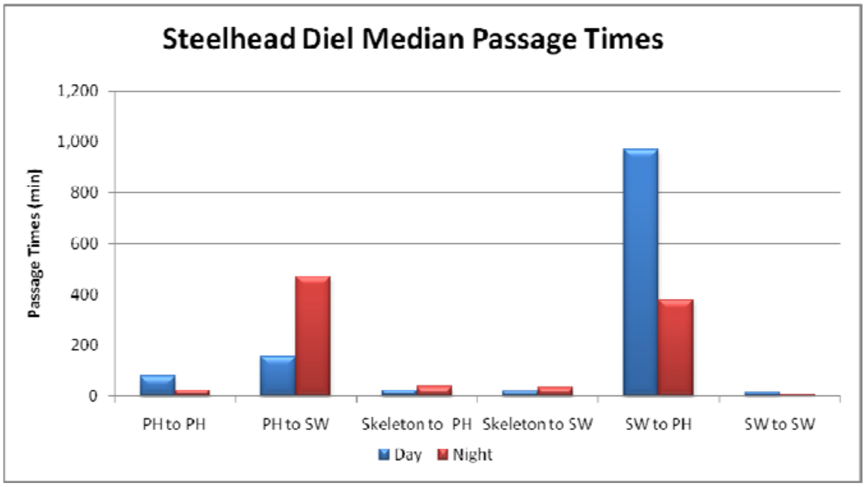

Figure 3.60. Steelhead diel median passage times at John Day Dam

3.7.3 Subyearling Chinook Salmon

3.7.3.1 Approach and Route of Passage

The SYC approach to John Day Dam was similar to spring with 60% of first detections at the powerhouse and skeleton bays (Figure 3.61). Of the SYC first detected at the powerhouse, nearly 47% would eventually pass the through the dam at the spillway, showing a similar trend to that observed for spring stocks. The SYC approaching the spillway were more likely to pass at the spillway than at the powerhouse.

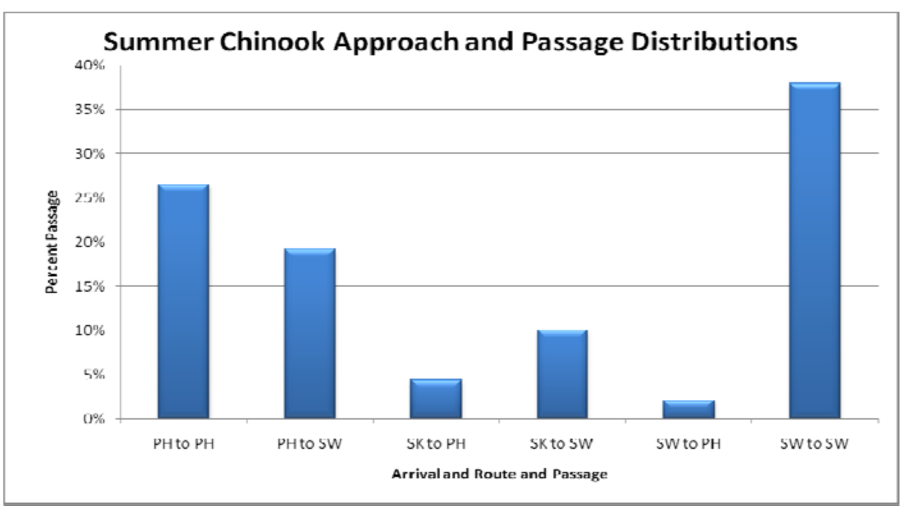

Figure 3.61. Subyearling Chinook salmon approach and passage behaviors at John Day Dam. Abbreviations are as follows: PH = powerhouse; Sk = skeleton bay; SW = spillway.

The SYC arriving at the powerhouse in summer composed 60% of all fish released upstream at Arlington, Oregon, and of these, 30% passed at the spillway (13% at spill bays 17–20, 9% at the TSW, and 8% at spill bays 1–14; Figure 3.62). This again illustrates the tendency of smolts approaching the powerhouse to travel along it until they reach the spillway.

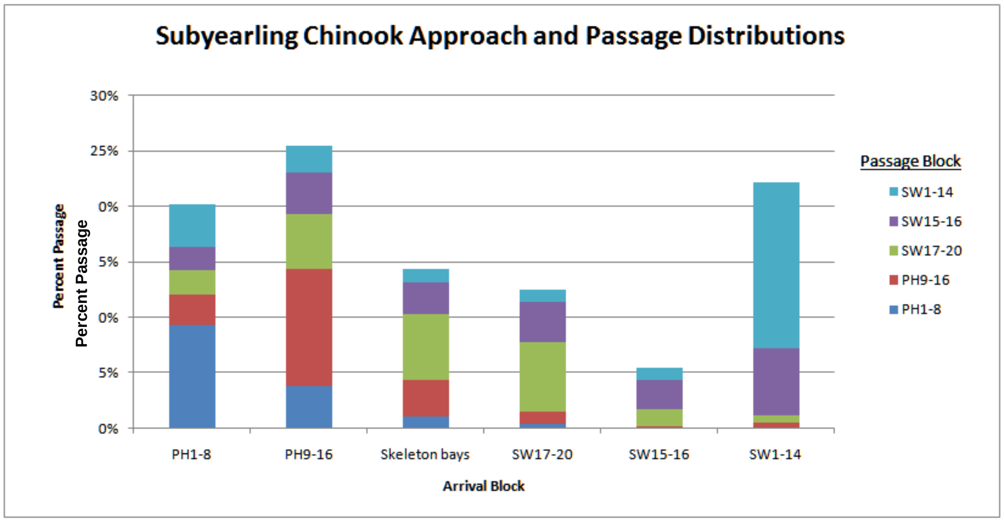

Figure 3.62. Subyearling Chinook salmon approach and passage distributions by blocks at John Day Dam

3.7.3.2 Diel Behavior Patterns

Of the SYC that approached the powerhouse during the day, 15% would eventually pass through the dam at the spillway (Figure 3.63). At night, only 3% of SYC approaching on the powerhouse side ended up passing at the spillway. The percentage of SYC approaching the powerhouse or spillway and eventually passing at the other location was higher during the day than it was at night (Figure 3.63).

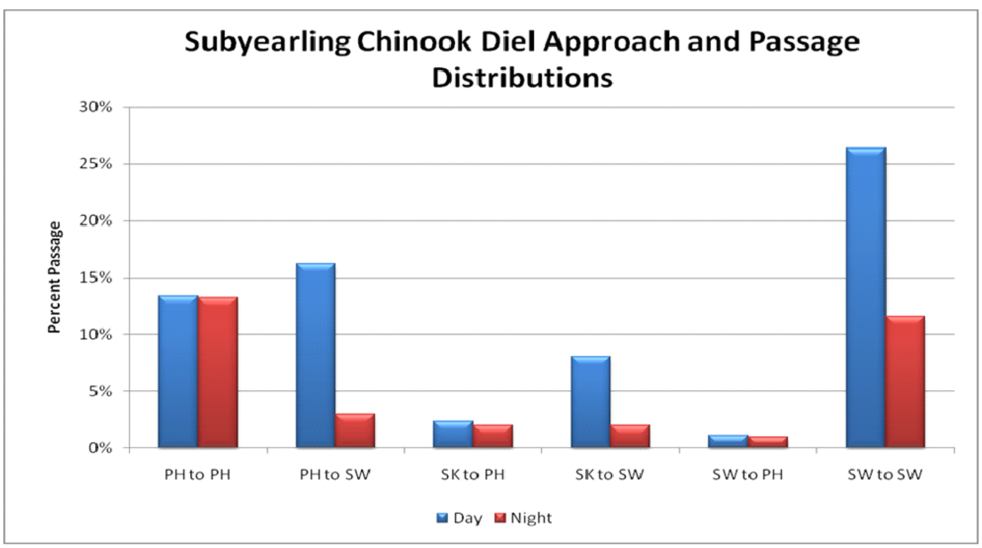

Figure 3.63. Subyearling Chinook salmon smolt approach and passage distributions at John Day Dam during day and night

Passage distributions for SYC during the day were similar to the pooled distributions for day and night periods, with a tendency for powerhouse-arriving fish to move laterally along the powerhouse and pass at the spillway (Figure 3.64). This trend does not seem as evident at night (Figure 3.65). At night, SYC tended to pass through the same block that they first approached. A majority of fish arriving at the powerhouse passed there while fish arriving at the spillway passed at the spillway. Fish arriving at the skeleton bays favored the spillway over the powerhouse.

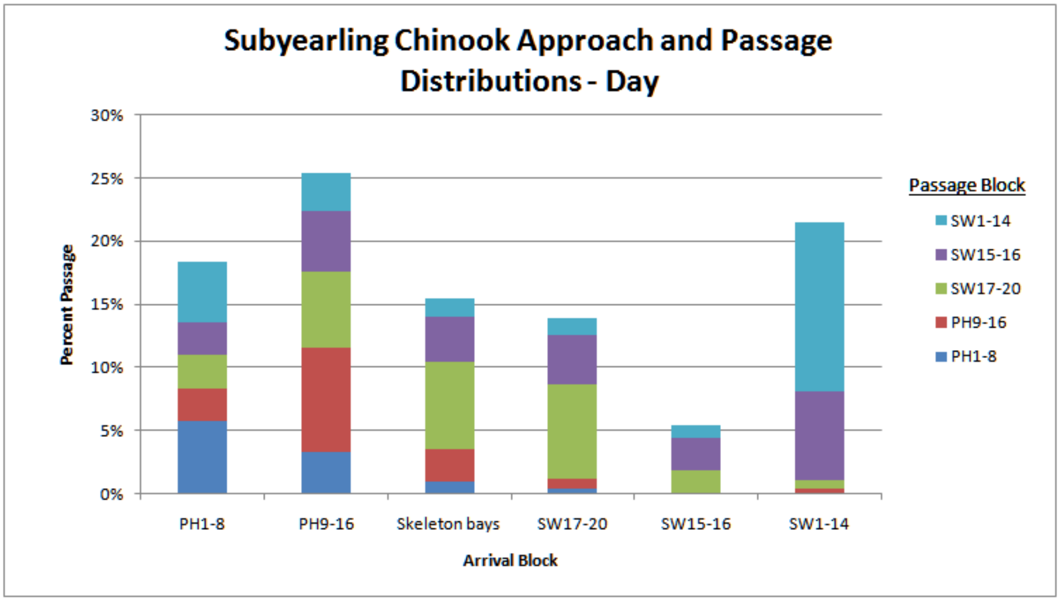

Figure 3.64. Subyearling Chinook salmon day approach and passage distributions at John Day Dam

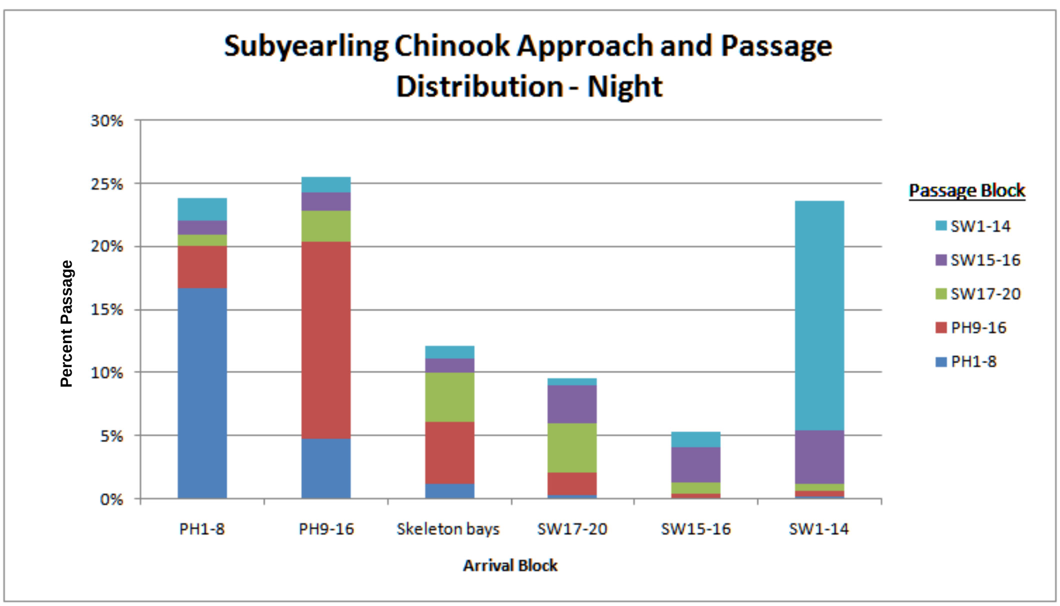

Figure 3.65. Subyearling Chinook salmon night approach and passage distributions at John Day Dam

Day and night passage rates were similar at the powerhouse, much higher during the day than at night for at TSW bays 15 and 16 and nearby bays (17–19) than at other spill bays, and slightly higher during the day at bays 2–14 (Figure 3.66). Passage distributions were relatively uniform at night compared to the daytime when the TSW and nearby bays passed very high numbers of SYC.

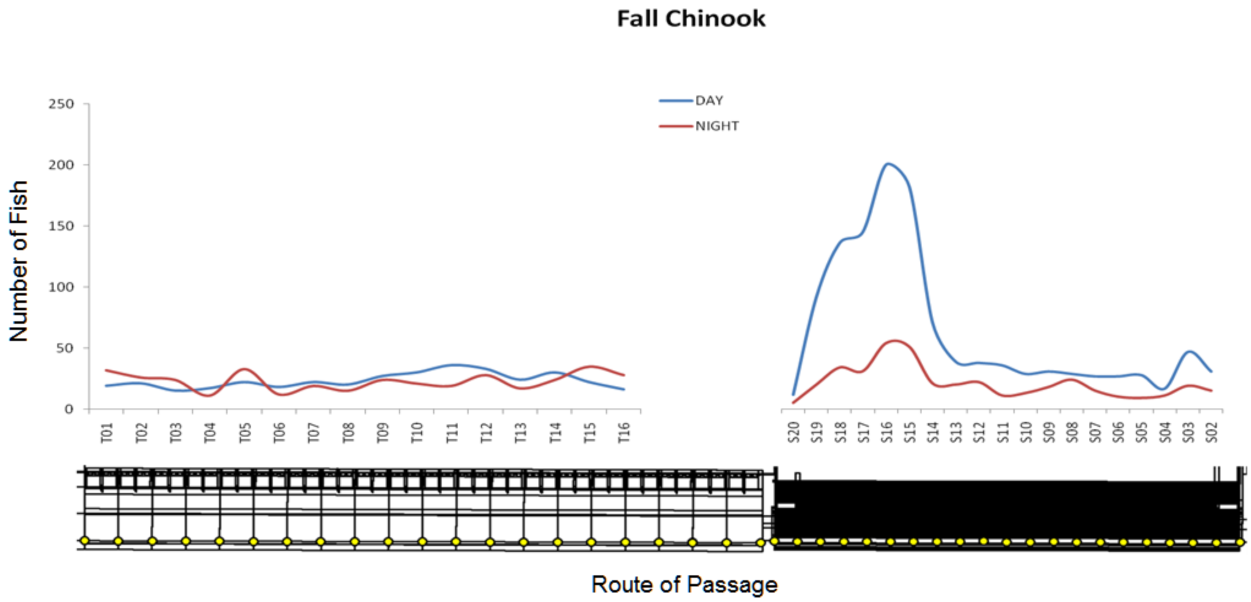

Figure 3.66. Day and night passage of acoustic-tagged subyearling Chinook salmon smolts at each passage route at John Day Dam. The powerhouse is on the left and the spillway is on the right as if viewed from the forebay looking downstream. The blank space indicates the location of the skeleton bays, through which fish cannot pass.

3.7.3.3 Vertical Distributions

Most SYC >5 m upstream from the powerhouse and skeleton bays traveled at depths between 5 and 11 m, while the median depths of smolts within 5 m of the powerhouse or skeleton bays were detected to be between depths of 20 and 25 m (Figure 3.67). Turbine intake depths at John Day Dam are deep (>20 m). In contrast, the last-detection depths were relatively shallow at the spillway. As SYC approached the TSW, they migrated up in the water column, but this trend was not evident for smolts approaching other spill bays. There were few obvious differences between vertical distributions of approach between day and night periods. The SYC that passed turbines were approximately 5 m deeper than those that were screened into the JBS (Figure 3.68).

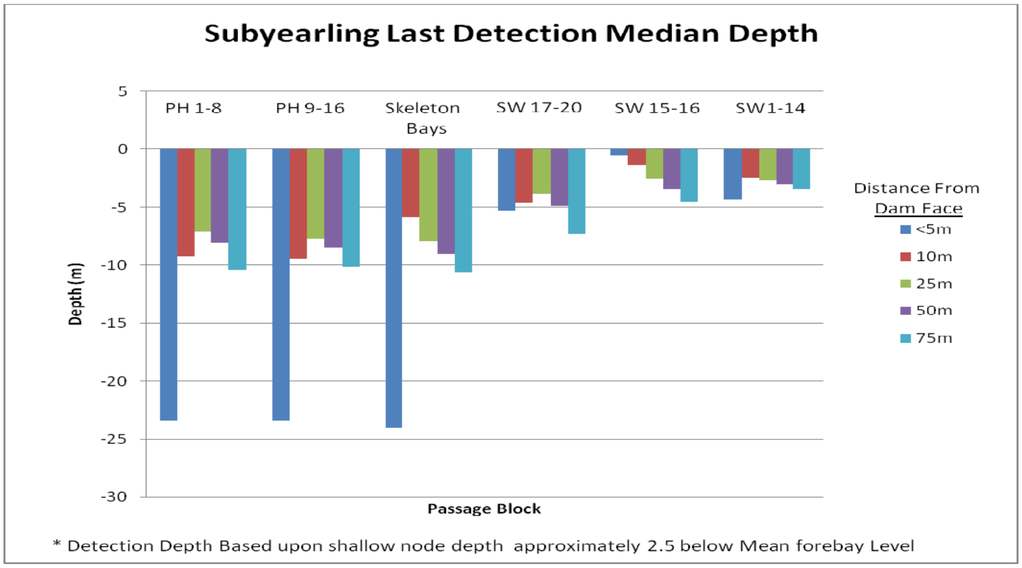

Figure 3.67. Median depths of the last detection of tagged subyearling Chinook salmon smolts at John Day Dam

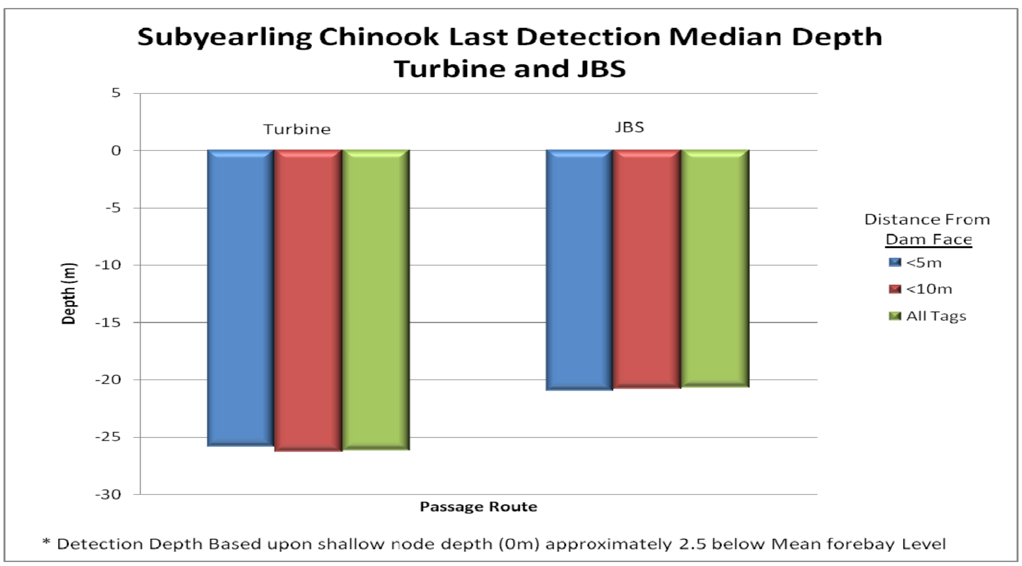

Figure 3.68. Subyearling Chinook salmon median last-detection depths for turbine- and JBS-passed fish

3.7.3.4 Residence Times

The median residence times of SYC were similar to those of YC and STH. Fish approaching and passing through the dam at the spillway had the shortest residence times (<5 minutes), whereas fish approaching the powerhouse but passing at the spillway had a 90-minute residence time (Figure 3.69). Fish approaching the spillway and passing through the powerhouse had a median residence time of 25 minutes.

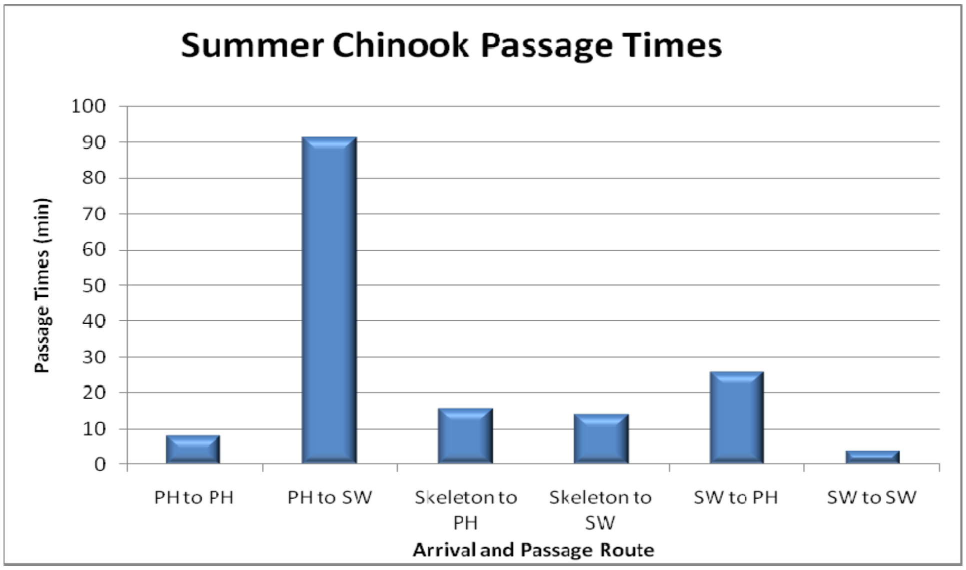

Figure 3.69. Median residence times of subyearling Chinook salmon smolts at John Day Dam

The median residence time of smolts arriving at the powerhouse but passing through the dam at the spillway at night was nearly 2.8 times longer than that of smolts exhibiting the same behavior during the day (Figure 3.70). This trend also was observed for YC in spring.

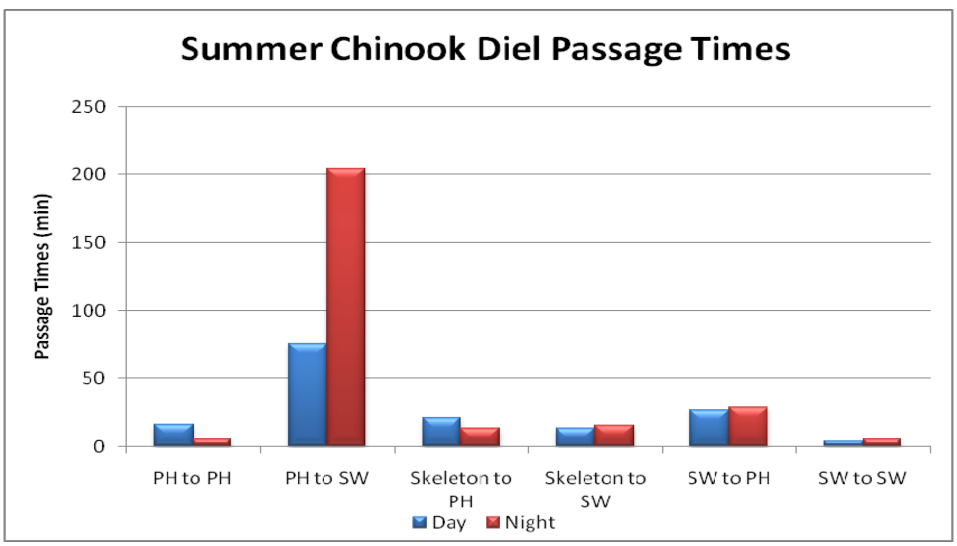

Figure 3.70. Subyearling Chinook salmon diel median passage times at John Day Dam. Abbreviations are as follows: PH = powerhouse; SW = spillway; Skeleton = skeleton bays.

3.8 Detailed Data on Tagging, Release, Virtual Releases, and Dam Operations

Appendix L describes the large comma-separated variable files that are on a CD that accompanies the hard-copy version of this report. These data sets combine all data on fish tagging, fish releases, and virtual releases at John Day Dam with hourly dam operations data and subsequent capture history data on downstream survival-detection arrays. The date and hour that each fish was last detected on the dam-face array is the key to linking forebay detections with hourly dam operations and subsequent capture history data (i.e., the date and time of detection on the dam-face and downstream survival-detection arrays). These data are provided to allow for multi-year post-hoc analyses of the effects of dam operations on the dam and route-specific survival after several years of similar data have been acquired.

3.9 Tests of Survival-Model Assumptions

We already compared the length frequencies of tagged and untagged fish of each stock in Section 3.1.4 to help assess whether tagged fish were reasonably representative of the run at large.

In the following sections, we describe the results of two types of model assumption tests:

- Burnham et al. (1987) Test 2 and Test 3 to assess the assumption that upstream and downstream detection and survival probabilities are independent
- Comparison of the TOAs of tagged smolts at the primary survival-detection array to verify that the releases mixed reasonably well in the common tailwater below a dam. The assumption is that treatment and reference releases of fish passed through the common tailwater at similar times of day and likely experienced similar survival processes.

3.9.1 Burnham Test Results

A major assumption of the survival models used in this study is that upstream detections do not affect downstream detection or survival probabilities, and this can be tested using Burnham Test 2 and Test 3. Appendix M tables probabilities of chi square tests on 2 × 2 contingency tables for every release by fish stock and survival metric reported in this study.

A majority of the Burnham test could not be calculated because of exceptionally high detection probabilities on John Day Dam survival-detection arrays, and of those that could be calculated, none were significant at $\alpha = 0.1$ (Appendix M).

3.9.2 Arrival Distribution Tests

We examined the cumulative frequency of arrivals of tagged fish in virtual and reference releases at the primary survival-detection arrays for John Day Dam and The Dalles Dam to determine whether the model assumption of mixing of fish in the common tailwater was violated. For all stocks of tagged fish, cumulative frequencies of arrivals were very similar and no consistent large deviation of arrival times of the two releases was evident for any stock of fish or either dam (Appendix N). Scatter plots of arrival hour at the primary array showed that arrivals of virtually released fish were relatively uniform throughout each day. Arrivals of smolts released in the John Day tailrace at The Dalles Dam forebay array were loosely clustered around three times of day, although some reference smolts could be found passing through The Dalles Dam pool during any hour of the day. Arrivals of SYC smolts released in The Dalles tailrace at the Bonneville Dam forebay array were relatively uniform, and it was much harder to discern that there were three releases in The Dalles Dam tailrace each day in summer (Appendix N; Table N.4).

4.0 Discussion and Conclusions

In this section, we discuss study integrity, a comparison of 2008 results with previous survival and passage studies at John Day Dam, and the performance of the prototype TSW SFOs. The section closes with study conclusions.

4.1 Study Integrity

The JSATS acoustic telemetry study at John Day Dam during 2008 provided reliable data on fish survival rates, passage rates, and behavior, as indicated by the following evidence.

The tagged fish population reasonably represented the run-at-large for each run of smolts. The goal of tagging the middle 80% of each of the YC, STH, and SYC runs was reasonably well met. The start and end times, respectively, for tagging relative to the percentage of passage according to the smolt-monitoring index of passage were 8.2% and 76.5% for YC, 2.4% and 85.0% for STH, and 10% and 65.6% for SYC. The median length of tagged fish was from 6 to 11 mm longer than that of untagged fish of the same stock (11 mm for STH, 8 mm for YC, and 6 mm for SYC), and this shift was observed over most length classes, reflecting a small but consistent bias in fish selection. We believe that this slight bias could have resulted from a preference for clipped hatchery fish over unclipped fish of unknown origin. Clipped fish tend to be slightly larger than unclipped fish of the same stock. It is also possible that smaller smolts were unintentionally sampled less frequently because they were not as visible to collectors as were larger individuals. We recommend that survival-study managers emphasize the importance of random sampling of smolts from all length classes without regard to fin clip status (clipped or unclipped). The >95-mm-length requirement on candidate fish for tagging did not restrict the lengths of fish that could be tagged in the spring and only excluded about 9% of the run-of-river subyearlings from tagging in 2008 (Figure 4.1). In 2007, 40% of subyearlings could not be tagged because they were too small (Ploskey et al. 2008), presumably because growth was slower that year. Tagging must include 80- to 95-mm smolts to be fully representative of the run-of-river population in summer, but only the production of smaller lighter tags than those available in 2008 will make that possible.

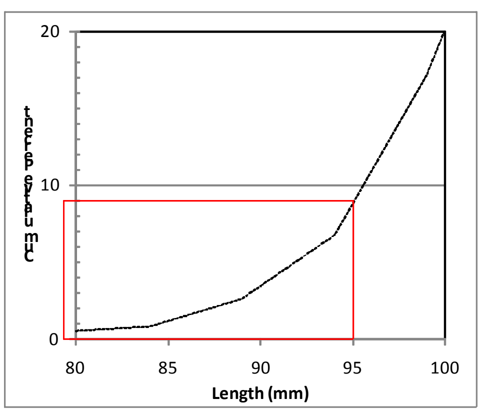

Figure 4.1. Plot of the lower end of the cumulative length frequency distribution of subyearlings in routine SMF samples. The red box highlights the 9% of smolts that could not be tagged because of a >95-mm-length requirement in 2008.

Zero detection rates for acoustic-tagged dead fish verified that tailwater detection arrays were placed far enough downstream. Small subsamples of fish were sacrificed and released during the season to help determine if detection arrays were far enough downstream. This was done to determine if a fish would be detected on a downstream array if it died from passing through a previous dam. For spring and summer, a combined total of 62 tagged dead fish were released at either Arlington, below John Day Dam, or below The Dalles Dam. None of these fish was detected on downstream arrays.

Detection probabilities at the dam-face cable array exceeded expectations. The combined probability of detection for the two independent arrays exceeded 99.99% for every stock of fish in the study. The detection ability of the JSATS cable array, when deployed and maintained properly, is exceptional.

Detection performance for arrays above Bonneville Dam was excellent, and it was acceptable for those below Bonneville Dam. Detection rates were 99% for both the spring and summer tagging season above Bonneville Dam, but 8% to 10% lower for those arrays below Bonneville Dam. Multi-node detections in the Bonneville Dam tailrace arrays were 50% for the first array and 21% for the second. Possible reasons for poor performance on the Bonneville Dam tailwater arrays include the structure of the river in that particular reach, including depth, bathymetry, and location of islands and sandbars that interfere with sound reception. We recommend increasing node densities in arrays downstream of Bonneville Dam in future studies to improve detection performance.

Two other testable assumptions of the survival models were met. There were no significant results of Burnham et al. (1987) Test 2 or Test 3. In fact, a majority of the Burnham test could not be calculated because of exceptionally high detection probabilities on John Day Dam survival-detection arrays, and of those that could be calculated, none were significant at $\alpha = 0.1$. The cumulative frequencies of arrivals of tagged fish of each stock in virtual and reference releases at the primary survival-detection arrays for John Day Dam and The Dalles Dam were very similar, and this demonstrates that the model assumption of mixing of fish in the common tailwater was not violated.

4.2 Comparison with Previous Survival and Passage Studies at John Day Dam

4.2.1 Yearling Chinook Salmon

The FPE estimate of 92.14 ± 1.30% for YC in spring was among the highest values of FPE observed at John Day Dam (Table 4.1). Higher than normal FPE could be explained by the addition of the two TSWs in spill bays 15 and 16 that increased non-turbine passage in 2008. Estimates of FPE ranged from 82.4% to 93.8% from 1999 to 2008. Five FPE values were different from the values observed in 2008; of these values only one had a similar spill pattern (2002 RT 24 h 30/30). Spill-passage efficiency can vary considerably from one year to the next. The highest estimate of SE was observed in 2000 at 86.2%, while the lowest (21%) was estimated in 1985. Spillway passage efficiency in 2008 was on the higher side of all estimates at 76%. The high percent SE could be attributed to the TSWs in spill bays 15 and 16 and the increase in flow through the TSWs and surrounding spill bays. In 2002, a hydroacoustics study recorded FGE estimates of 69.5% and 55%, and these were similar to FGE in 2008. In 2002 and 2003, radio-telemetry studies estimated JBSE between 25% and 36%. In 2008, JBSE estimates ranged from 14% to 17%. The difference in JBSE between radio-telemetry and acoustic telemetry was significant. The low

JBSE in 2008 could be associated with the installation of the two TSW surface passage routes at the spillway. Spillway passage effectiveness was calculated in most years with the highest being observed in 1995 at 6.3 while the lowest SEF was recorded in 1985 at 0.75. A majority of the estimates of SEF fall between 1.5 and 3. Estimates in 2008 were no different, with estimates of SEF ranging from 1.98 (40% spill) to 2.48 (30% spill) with an overall average of 2.32. There were also two estimates used at John Day Dam that were not used in previous studies. Surface outlet efficiency (TSWE) and surface outlet effectiveness (TSWEF) were estimated for the new TSWs installed in spill bays 15 and 16. The TSWE for John Day Dam in 2008 was 23.55% with a TSWEF of 3.41. The estimates at John Day Dam in 2008 were very similar to the results observed at McNary Dam in 2007 (Adams and Counihan 2008).

Table 4.1. Estimates of major fish passage metrics for yearling Chinook salmon smolts from previous radio-telemetry studies relative to estimates from this 2008 acoustic telemetry study. We also show estimates from previous hydroacoustic studies, although they would represent composite estimates for all stocks of juvenile salmon because hydroacoustic sampling cannot differentiate between species. Studies prior to 2002 were summarized by Anglea et al. (2001) and subsequent references are footnoted in the table.

Year	Spill	FPE	SE	FGE	JBSE	SEF
1983	HA (33%)		39%			0.79
1984	RT (42%)		74%			1.8
1985	HA (38%)		21%			0.75
1995	RT (3.9%)		24.5%			6.3
1996	RT (20.7%)		43.1%			2.1
1997	HA (35%)		53%			2.32
	RT (33%)		64.2%			1.9
1998	HA (32%)		63%			2.92
	RT (43%)		74.7%			
1999	HA (27%)		82%			2.74
	RT 12 h(0/45)	82.5% (75.5, 88.1)	52.6% (44.4, 60.7)			3.0
	RT 24 h(30/45)	87.5% (81.4, 92.2)	65.6% (57.7, 72.9)			1.4
2000	HA (36%)		79%			2.79
	RT 12 h(0/53)	84.6% (74.8, 91.8)	66.5% (59.5, 73.0)			2.4
	RT 24 h(30/53)	91.3% (83.7, 96.2)	86.2% (77.4, 87.0)			1.4
2002[(a)]	HA 12 h(0/60)	93.8 ±2.5%	78.2 ± 5.6%	69.5 ± 12.6%		2.90 ± 0.3
	HA 24 h(30/30)	89.3 ±2.4%	72.2 ± 5.2%	55.0 ± 9.9%		2.68 ± 0.26
2002[(b)]	RT 12 h(0/45)	84.7% (79.2, 87.9)	48.3% (43.2, 53.4)		36.4% (30.1, 42.0)	1.35
	RT 24 h(30/30)	82.4% (79.2, 85.3)	56.7% (51.6, 61.7)		25.7% (20.9, 31.0)	2.48/1.39
2003[(c)]	RT 12 h(0/45)	83.6% (80.6, 86.4)	47.4% (40.0, 54.9)		36.2% (29.2, 43.6)	1.6
	RT 12 h(0/60)	85.7 % (83.0, 88.2)	56.7% (49.7, 63.6)		29.0% (22.9, 35.7)	1.3
2008	AT	92.14 ± 1.30%	76.24 ± 2.44%	66.90 ± 4.75%	15.90 ± 2.11%	2.32 ± 0.07

(a) Moursund et al. (2003).
(b) Beeman et al. (2006).
(c) Hansel et al. (2004).
AT = acoustic telemetry.
FPE = fish-passage efficiency.
FGE = fish-guidance efficiency.
HA = hydroacoustic.
JBSE = juvenile bypass system-passage efficiency.
RT = radio telemetry.
SE = spillway-passage efficiency.
SEF = spillway-passage effectiveness.

4.2.2 Steelhead

In 2008, we recorded the highest FPE for STH passing at John Day Dam (97.2%; Table 4.2). The next highest FPE was observed with radio telemetry in 1999 at 94.2%. As with YC, and particularly for STH, we attribute high FPE to the TSW installations, which provided an ideal route of passage. Steelhead smolts typically migrate at shallow depths, prefer surface passage routes, and in 2008 passed in high numbers at TSW spill bays during the day (Figure 3.54). The SE for 2008 was similar to estimates in 1999, 2000, and 2002. The FGE of in-turbine screens also was very high in 2008 (88.9%) and considerably higher than estimates ranging from 55% to 70% in a 2002 hydroacoustics report. Of course, the hydroacoustic estimates would have been based on a mix of spring stocks most of which are less guidable than STH. JBSE and SEF showed similar results to past studies with values for JBSE near 25% and SPS values of around 2.0 (Table 4.2).

Table 4.2. Estimates of major fish passage metrics for steelhead smolts from previous radio-telemetry studies relative to estimates from this 2008 acoustic telemetry study. We also show estimates from previous hydroacoustic studies, although they would represent composite estimates for all stocks of juvenile salmon because hydroacoustic sampling cannot differentiate between species. Studies prior to 2002 were summarized by Anglea et al. (2001) and subsequent references are footnoted in the table.

Year	Spill Condition	FPE	SE	FGE	JBSE	SEF
1983	HA (33%)		39%			0.79
1985	HA (38%)		21%			0.75
1997	HA (35%)		53%			2.32
	RT (33%)		54.6%			1.7
1998	HA (32%)		63%			2.92
	RT (43%)		52.3%			1.2
1999	HA (27%)		82%			2.74
	RT 12 h(0/45)	94.2% (88.9, 97.5)	44.9% (36.5, 53.6)			1.6
	RT 24 h(30/45)	90.4% (84.6, 94.5)	52.6% (44.4, 60.6)			1.1
2000	HA (36%)		79%			2.79
	RT 12 h(0/53)	93.0% (89.0, 96.0)	68.6% (61.8, 74.9)			2.3
	RT 24 h(30/53)	91.3% (87.2, 94.5)	73.4% (67.3, 78.9)			1.4
2002[a]	HA 12 h(0/60)	93.8 ±2.5%	78.2 ± 5.6%	69.5 ± 12.6%		2.90 ± 0.3
	HA 24 h(30/30)	89.3 ±2.4%	72.2 ± 5.2%	55.0 ± 9.9%		2.68 ± 0.26
	RT 12 h(0/54)	91.0% (86.9, 94.1)	64.2% (53.4, 74.1)		26.8% (17.1, 38.2)	1.34
	RT 24 h(30/30)	88.4% (83.1, 92.6)	54.3% (41.5, 66.8)		34.1% (21.7, 48.3)	1.55
2008	AT	97.2 ± 0.7%	74.4 ± 2.6%	88.9 ± 2.7%	22.7 ± 2.5%	2.25 ± 0.08

(a) Beeman et al. (2006).
AT = acoustic telemetry.
FPE = fish-passage efficiency.
FGE = fish-guidance efficiency.
HA = hydroacoustic.
JBSE = juvenile bypass system-passage efficiency.
RT = radio telemetry.
SE = spillway-passage efficiency.
SEF = spillway-passage effectiveness.

4.2.3 Subyearling Chinook Salmon

Data collected in 2008 using acoustic telemetry were compared to past metrics with data collected using hydroacoustics and radio telemetry (Table 4.3). Fish-passage efficiency for 30% spill conditions in

2008 (82.7%) was higher than the same treatment in 2002 (70.4%) and 2003 (74.8%) as determined by radio telemetry, but was lower than an estimate in a 2002 hydroacoustics study (88.0%). Spillway-passage efficiency in 2008 (68.6%) was much higher than during the 1980s and comparable to estimates from within the last 10 years. Fish-guidance efficiency in 2008 was much lower than that reported 1996, but higher than estimates reported for 2000. Direct comparisons of current estimates with estimates from past studies were difficult because many previous spill treatments only had a 12-hour monitoring period and 0% daytime spill, whereas 2008 treatments consisted of 24-hour spill at a 30% or 40% level. The JBS-passage efficiency for SYC in 2008 was only comparable to an estimate made in a 2003 radio-telemetry study (Beeman et al. 2006).

Table 4.3. Estimates of major fish passage metrics for subyearling Chinook salmon smolts from previous radio-telemetry studies relative to estimates from this 2008 acoustic telemetry study. We also show estimates from previous hydroacoustic studies, which should reasonably represent subyearling metrics because subyearlings are the only outmigrating juvenile salmonids passing the dam in summer. Studies prior to 2002 were summarized by Anglea et al. (2001) and subsequent references are footnoted in the table.

Year	Spill Condition	FPE	SE	FGE	JBSE	SEF
1983	HA (33%)		40%			1.04
1984	HA (30%)		38%			0.76
1986	HA (30%)		32%			1.04
1987	HA (18%)		23%			1.30
1988	HA (18%)		19%			1.10
1989	HA (21%)		28%			1.40
1996	RT (18.4%)		39.50%			2.1:1
	HA (21%)		NA	75%		
1997	HA (35%)		85%			3.92
	RT (19.9%)		49.60%			2.5:1
1998	HA (32%)		49%			1.89
	RT (53.2%)		76.50%			1.4:1
1999	HA 24 h(0/30%)		63%			4.75
	HA 24 h(30/30%)		93%			2.76
2000	RT 12 h(0/30%)	78.70% (71.5-84.9)	53.90% (45.7-62.0)			1.14-1.58
	RT 24 h(30/30%)	91.10%	81.50%			2.57-3.01 day
		75.0-87.1	75.0-87.1			1.29-1.56 night
	HA 12 h(0/60)	72.00%	61.00%	28%		28.36
	HA 24 h(30/60)	91.30%	87.00%	30%		2.25
2002[(a)]	RT 12 h(0/60%)	71.8 (67.8, 75.6)	41.6 (34.6, 48.9)			
	RT 24 h(30/30%)	70.4 (6.66, 74.1)	57.8 (51.0, 64.4)			
2002[(b)]	HA 12 h(0/60%)	91.60 (±1.0)	58.40 (±11.0)			2.10 (±0.30)
	HA 24 h(30/30%)	88.00 (±0.9)	60.90 (±11.5)			2.30 (±0.32)
2003[(c)]	RT 12 h(0/60)	70.70 (64.7-76.4)	48.10 (38.7, 57.6)		22.6 (17.8-28.0	1.3
	RT 24 h(30/30)	74.80 (69.5, 79.7)	61.70 (53.1-69.9)		13.1 (9.6-17.1)	1.6-2.3
2008	AT	83.30 ± 1.86%	68.60 (±2.37)	46.80 (± .41)	14.70 ± 1.79%	1.94 (±0.07)
	AT 30%	82.03 ± 2.96%	65.71 ± 3.80%	47.61 ± 6.61%	16.33 ± 2.95%	2.14 ± 0.12
	AT 40%	84.43 ± 2.92%	71.08 ± 3.79%	46.15 ± 7.39%	13.35 ± 2.79%	1.81 ± 0.10

(a) Beeman et al. (2006).
(b) Moursund et al. 2003.
(c) Hansel et al. (2004).
AT = acoustic telemetry.
FPE = fish-passage efficiency.
FGE = fish-guidance efficiency.
HA = hydroacoustic.
JBSE = juvenile bypass system-passage efficiency.
NA = not applicable.
RT = radio telemetry.
SE = spillway-passage efficiency.
SEF = spillway-passage effectiveness.

4.3 Performance of the Prototype TSW Surface Flow Outlets

The prototype TSW SFO tested for the first time at John Day Dam during 2008 performed comparably to other SFOs on the main stem Columbia and Snake rivers (Table 4.4). In fact, SFO passage efficiency and effectiveness for the John Day Dam TSW were similar to its cousin, the McNary TSW. Neither SFO, though, performed as well as the SFOs at Wells Dam or the Bonneville Dam second powerhouse (B2). The John Day Dam TSW out-performed the Lower Granite Dam and Ice Harbor Dam removable spillway weirs for STH, but not for YC or SYC. The SFOs at Wells Dam and B2 benefit from a pronounced horizontal concentration of juvenile salmonid emigrants due to physical features of the dam structure and forebay circulation patterns (Sweeney et al. 2007). Lower Granite and Ice Harbor dams have a horizontal concentrating mechanism due to relatively small forebay widths in the Snake River compared to main stem dams downstream in the Columbia River.

Table 4.4. Comparison of performance for various surface-flow outlets

			SFO Efficiency			SFO Effectiveness		
Year	Dam	SFO Type	YC	STH	SYC	YC	STH	SYC
1990–1992[(a)]	WEL	Retrofit baffle	0.89[(b)]		0.89	17.9[(b)]		17.8
2004–2005[(c)]	B2	Sluice Chute	0.33	0.70	0.39	6.5[(d)]	13.7[(d)]	5.8[(d)]
2006[(e)]	LGR	RSW	0.30	0.26	0.57	6.0	5.4	4.6
2006[(f)]	IHR	RSW	0.42	0.34	0.68	6.9	5.6	4.6
2007[(g)]	MCN	Temp. SW	0.25	0.66	0.28	3.4	8.9	3.1
2008[(h)]	JDA	Top SW	0.24	0.50	0.21	3.4	7.2	3.1

(a) Skalski et al. (1996).
(b) Run-at-large in spring comprised of yearling Chinook salmon and steelhead.
(c) Counihan et al. (2006a, 2006b).
(d) Re: Total B2 Q, not the entire Bonneville complex.
(e) Beeman et al. (2007); the two values are for spring and summer periods.
(f) Data for spring are from Axel et al. (2007); values are averages of data for the BiOp and 30%/40% spill treatments. Data for summer are from Ogden et al. (2008).
(g) Adams and Counihan (2009); the two values are for spring and summer periods.
(h) This study.
B2 = Bonneville Dam second powerhouse.
IHR = Ice Harbor Dam.
JDA = John Day Dam.
LGR = Lower Granite Dam.
MCN = McNary Dam.
SFO = surface-flow outlet.
STH = steelhead
SYC = subyearling Chinook salmon.
WEL = Wells Dam
YC = yearling Chinook salmon.

Because John Day Dam does not have a pre-existing mechanism to concentrate fish horizontally, the SFO design relied on relatively high SFO discharge and a correspondingly large flow net in the forebay to attract or intercept downstream migrants, which are naturally surface-oriented and reluctant to sound during emigration (Andrew and Geen 1960). Accordingly, the intent of the John Day Dam TSW and associated spill operation was to pass fish that approached the spillway at the spillway and pass an appreciable number of fish approaching the powerhouse at the spillway. Researchers wanted to know whether fish approaching the powerhouse would move to the north to pass through the spillway. The forebay behavior data showed that this was indeed the case for about one-half to two-thirds of the tagged fish. This is an important finding given the huge size of the John Day Dam powerhouse. This effect possibly could be enhanced by locating the TSW closer to the powerhouse.

Besides efficient and effective collection of fish in a dam forebay, SFO performance must also be assessed in terms of survival rates (Johnson and Dauble 2006; Sweeney et al. 2007). Route-specific survivals (dam face through the tailrace) for the TSW were high (92% to 99%, depending on stock), indicating that conveyance and outfall conditions for the TSW were satisfactory. Non-TSW spill improves tailrace passage conditions for TSW-passed fish by inhibiting eddy formation and providing fast water velocities to deter predation. The survival and passage-efficiency data, however, did not reveal a benefit of 40% spill over 30% spill. Future evaluations might consider a lower spill level as a study treatment. Regardless of spill level, the prototype TSW SFO at John Day Dam during 2008 performed very well.

4.4 Predation

Mortality associated with route-specific dam passage is direct or indirect. Direct mortality is immediate and results from mechanical injury from fish contacting structure, hydraulic injury from shear or cavitation, or barotrama associated with rapid pressure changes. Indirect mortality results from disease or predation because smolts are weakened by passage injuries or loss of equilibrium. In 2009, piscivorous birds arrived in large numbers during smolt runs (Figure 4.2), and bird counts were correlated with the number of smolt passing the dam (Figure 4.3). Despite the obvious correlation between gull numbers and smolt numbers, we found no significant correlations between concrete-passage survival estimates or route-specific survival estimates and the number of gulls counted per day in the tailrace area for any run of fish. Nevertheless, nighttime survival estimates were significantly higher than daytime estimates for steelhead passing through turbines and for SYC passing through the dam, powerhouse, turbines, the spillway, and spill bays 17-20. These day-and-night differences likely result from bird predation, which is intense during the day and minimal at night.

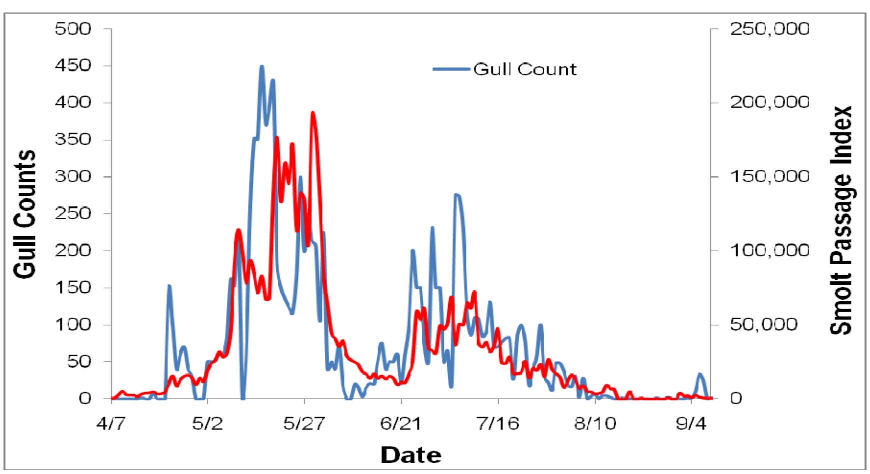

Figure 4.2. Plot of seasonal trends in the smolt index and the number of gulls counted in the John Day tailrace in 2009. Smolt index estimates were obtained from the Fish Passage Center and gull counts were provided by Jim Dillon, Biological Technician for the U.S. Army Corps of Engineers at The Dalles/John Day Projects.

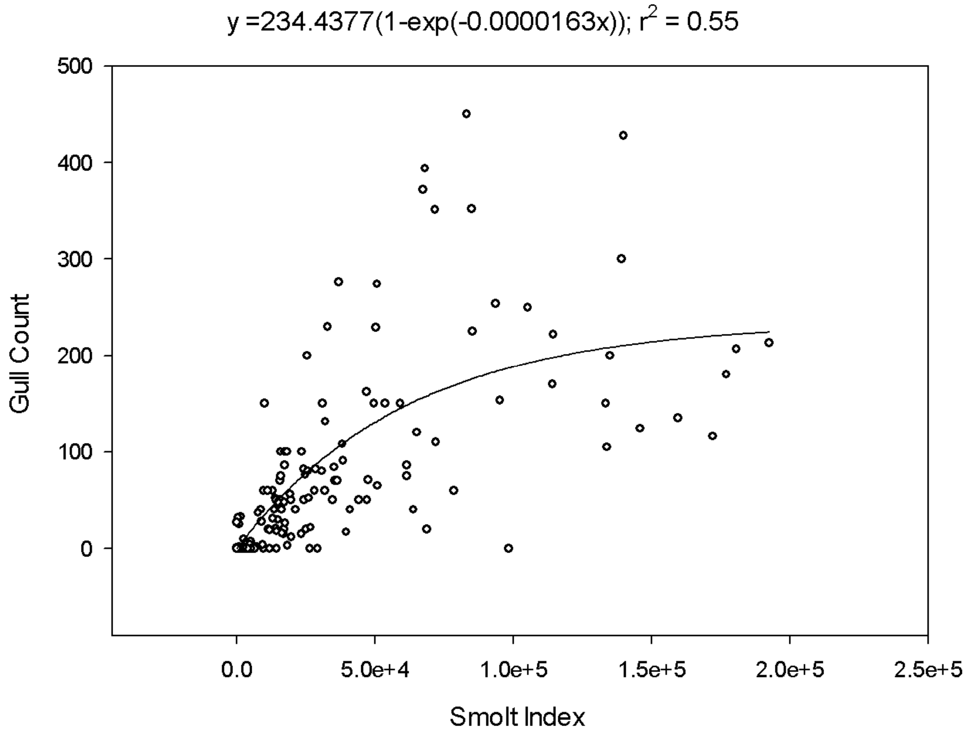

Figure 4.3. Regression line fit to daily gull counts and smolt indices by date. Smolt index estimates were obtained from the Fish Passage Center and gull counts were provided by Jim Dillon, The Dalles / John Day Project Biological Technician.

4.5 Conclusions

During the 2008 evaluation of juvenile salmonids at John Day Dam, the JSATS provided reliable data about survival, fish passage, and fish behavior.

Tag-life-corrected paired-release estimates of concrete-passage survival rates for YC [0.957 ± 0.013 (1/2 95% CI)] and STH [0.986 ± 0.019 (1/2 95% CI] were high and close to the 96% performance standard set forth in the 2008 BiOp. Similar estimates for SYC, however, were about 86%, which would be 7% below the BiOp standard of 93%. The highest route-specific survival rates were for the JBS and TSW (~97%); fish passing through turbines had the lowest survival rates (73% to 86%).

Fish-passage metrics were generally highest for STH and lowest for SYC. Proportionately more SYC than YC or STH passed through the dam via turbines.

The comparison of 30% versus 40% post-hoc spill conditions was inconsequential. Stock-specific survival estimates, passage efficiencies, and fish behaviors were similar between the two spill conditions. The increase in spill discharge from 30% to 40% of total water discharge through the dam basically served to pass incrementally more fish at non-TSW bays and incrementally fewer fish at the TSW bays. Spillway-passage effectiveness was significantly higher at 30% spill than it was at 40% spill for STH smolts (one tailed P = 0.0293) and for SYC smolts (P = 0.0020).

Spill and TSW operations attracted downstream migrant juvenile salmonids. About half of the tagged fish arriving in the forebay of the powerhouse and skeleton bays moved toward and passed at the spillway. In contrast, few smolts approaching the spillway passed at the powerhouse, and fish approaching the spillway had the shortest median residence time. The longest residence time was for fish approaching the powerhouse and then passing through the dam at the spillway or vice versa.

Tagged fish were surface-oriented, being distributed in the upper portion of the water column on approach to the dam. The median depths of smolts last detected within 5 m of the powerhouse ranged from 21 to 24 m depending on the stock of fish, and turbine-passed fish had median depths that were about 5 m deeper than the median depth of JBS-passed fish. Most fish approaching the spillway piers were high in the water column.

The prototype TSWs performed well. Using about 20 kcfs, the TSW bays passed half of the STH, a quarter of the YC, and a fifth of the SYC of the respective totals passing through John Day Dam. As was the intent of the design, the TSW surface flows appeared to attract, or at the least provide a surface outlet opportunity, for fish that had originally arrived at the dam in the powerhouse forebay. Passage at the TSW bays was much higher during the day than it was at night, which is consistent with observations at many other SFOs (Johnson and Dauble 2006; Sweeney et al. 2007).

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Appendix A

Tagging Tables

Table A.1. 2008 spring tagging at John Day Dam

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
4/30/2008	5/1/2008	240	Arlington	Steelhead	120	1
				Yearling Chinook	120	1
5/1/2008	5/2/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/2/2008	5/3/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/3/2007	5/4/2008	246	Arlington	Steelhead	87	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/4/2008	5/5/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	1
				Yearling Chinook	36	1
5/5/2008	5/6/2008	123	Arlington	Steelhead	45	0
				Yearling Chinook	48	1
			JDA Tailwaters(8)	Steelhead	15	0
				Yearling Chinook	15	0
5/6/2008	5/7/2008	254	Arlington(2)	Steelhead	90	0
				Yearling Chinook	90	0
			JDA Tailwaters(12)	Steelhead	37	0
				Yearling Chinook	37	0
5/7/2008	5/8/2008	252	Arlington(6)	Steelhead	90	0
				Yearling Chinook	89	0
			JDA Tailwaters(9)	Steelhead	36	0
				Yearling Chinook	37	0
5/8/2008	5/9/2008	259	Arlington	Steelhead	89	0
				Yearling Chinook	92	1
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/9/2008	5/10/2008	256	Arlington	Steelhead	88	0
				Yearling Chinook	90	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0

Table A.1. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
5/10/2008	5/11/2008	265	Arlington(4)	Steelhead	97	0
				Yearling Chinook	90	2
			JDA Tailwaters(9)	Steelhead	39	0
				Yearling Chinook	39	0
5/11/2008	5/12/2008	264	Arlington(4)	Steelhead	95	0
				Yearling Chinook	91	0
			JDA Tailwaters(7)	Steelhead	39	0
				Yearling Chinook	39	0
5/12/2008	5/13/2008	186	Arlington	Steelhead	63	0
				Yearling Chinook	63	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	33	0
5/13/2008	5/14/2008	270	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	1
5/14/2008	5/15/2008	213	Arlington	Steelhead	72	0
				Yearling Chinook	72	0
			JDA Tailwaters	Steelhead	33	0
				Yearling Chinook	36	0
5/15/2008	5/16/2008	270	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/16/2008	5/17/2008	226	Arlington(1)	Steelhead	78	0
				Yearling Chinook	78	0
			JDA Tailwaters	Steelhead	35	0
				Yearling Chinook	35	0
5/17/2008	5/18/2008	269	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters(3)	Steelhead	39	0
				Yearling Chinook	38	0
5/18/2008	5/19/2008	276	Arlington(2)	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters(11)	Steelhead	43	1
				Yearling Chinook	41	0

Table A.1. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
5/19/2008	5/20/2008	191	Arlington(6)	Steelhead	69	0
				Yearling Chinook	66	0
			JDA Tailwaters(10)	Steelhead	27	0
				Yearling Chinook	29	0
5/20/2008	5/21/2008	281	Arlington(4)	Steelhead	98	2*
				Yearling Chinook	99	0
			JDA Tailwaters(10)	Steelhead	43	0
				Yearling Chinook	41	3*
5/21/2008	5/22/2008	223	Arlington(5)	Steelhead	78	0
				Yearling Chinook	74	0
			JDA Tailwaters(10)	Steelhead	37	0
				Yearling Chinook	34	0
5/22/2008	5/23/208	280	Arlington(4)	Steelhead	104	0
				Yearling Chinook	104	0
			JDA Tailwaters(10)	Steelhead	36	0
				Yearling Chinook	36	0
5/23/2008	5/24/2008	192	Arlington	Steelhead	68	1
				Yearling Chinook	72	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	25	0
5/24/2008	5/25/2008	292	Arlington	Steelhead	100	0
				Yearling Chinook	106	0
			JDA Tailwaters	Steelhead	44	0
				Yearling Chinook	42	0
5/25/2008	5/26/2008	294	Arlington	Steelhead	104	1
				Yearling Chinook	107	0
			JDA Tailwaters(11)	Steelhead	40	0
				Yearling Chinook	43	0
5/26/2008	5/27/2008	295	Arlington	Steelhead	108	0
				Yearling Chinook	108	1
			JDA Tailwaters	Steelhead	37	4*
				Yearling Chinook	42	4*
5/27/2008	5/28/2008	194	Arlington	Steelhead	56	0
				Yearling Chinook	60	0
			JDA Tailwaters	Steelhead	42	5*
				Yearling Chinook	36	3*

Table A.1. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
5/28/2008	5/29/2008	36	JDA Tailwaters	Steelhead	19	4*
				Yearling Chinook	17	2*
Totals	Totals	6894	Arlington	Steelhead	2453	5[(a)]
				Yearling Chinook	2451	6
			JDA Tailwaters	Steelhead	995	15[(b)]
				Yearling Chinook	995	14[(c)]

*Sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.

(a) 2 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(b) 13 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(c) 12 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(1) Fish were released at grain elevator due to weather condition for 6 AM release.
(2) Fish were released at grain elevator due to weather condition for 6 PM release.
(3) Fish were released at the dock due to weather condition for 1 AM release.
(4) Fish were released at grain elevator due to weather condition for all releases.
(5) Fish were released at grain elevator for 6 AM and 6 PM releases and at the shore for 12 PM release due to weather condition.
(6) Fish were released at grain elevator due to weather condition for 12 PM and 6 PM releases.
(7) Fish were released at the dock due to weather condition for all releases.
(8) Fish were released at the dock due to weather condition for 7 PM and 1 AM releases.
(9) Fish were released at the dock for 7 PM and 1 AM releases and at the shore for 1 PM release due to weather condition.
(10) Fish were released at JDA_SMF due to weather condition for all releases.
(11) Fish were released at JDA_SMF due to weather condition for 7 PM and 1 AM releases.
(12) Fish were released at the shore due to weather condition for 7 PM and 1 AM releases.

Table A.2. 2008 summer steelhead tagging at John Day Dam

Tag Date	Release Date	Number Tagged	Release Location	Number Released	Mortalities
6/14/2008	6/15/2008	117	Arlington	117	1
6/15/2008	6/16/2008	210	Arlington(3)	87	0
			JDA Tailwaters(7)	37	1*
			TDA Tailwaters(11)	86	0
6/16/2008	6/17/2008	210	Arlington(4)	87	1
			JDA Tailwaters(7)	35	0
			TDA Tailwaters	88	0
6/17/2008	6/18/2008	210	Arlington	87	0
			JDA Tailwaters	36	0
			TDA Tailwaters	87	0
6/18/2008	6/19/2008	210	Arlington	87	0
			JDA Tailwaters	36	0
			TDA Tailwaters	87	0
6/19/2008	6/20/2008	210	Arlington	87	0
			JDA Tailwaters	38	2*
			TDA Tailwaters	85	0
6/20/2008	6/21/2008	210	Arlington	87	2
			JDA Tailwaters(7)	34	0
			TDA Tailwaters(11)	89	0
6/21/2008	6/22/2008	210	Arlington(3)	87	0
			JDA Tailwaters(8)	36	0
			TDA Tailwaters(10,11)	87	0
6/22/2008	6/23/2008	210	Arlington(3)	87	1
			JDA Tailwaters(7)	36	0
			TDA Tailwaters(11)	87	1
6/23/2008	6/24/2008	210	Arlington	86	0
			JDA Tailwaters(7)	37	1
			TDA Tailwaters(11)	87	0
6/24/2008	6/25/2008	210	Arlington(2,3)	87	0
			JDA Tailwaters(8)	36	0
			TDA Tailwaters(12)	87	0
6/25/2008	6/26/2008	210	Arlington(1,2)	88	0
			JDA Tailwaters(8)	35	0
			TDA Tailwaters(9,10)	87	0
6/26/2008	6/27/2008	210	Arlington	86	0
			JDA Tailwaters	37	1
			TDA Tailwaters	87	0
6/27/2008	6/28/2008	210	Arlington	87	0
			JDA Tailwaters(7)	36	0
			TDA Tailwaters	87	0

Table A.2. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
6/28/2008	6/29/2008	210	Arlington(3)	Subyearling	87	0
			JDA Tailwaters(6,7)	Subyearling	36	0
			TDA Tailwaters(11)	Subyearling	87	0
6/29/2008	6/30/2008	210	Arlington(3)	Subyearling	88	0
			JDA Tailwaters(7)	Subyearling	35	0
			TDA Tailwaters(11)	Subyearling	87	0
6/30/2008	7/1/2008	210	Arlington	Subyearling	86	0
			JDA Tailwaters	Subyearling	37	1
			TDA Tailwaters(9)	Subyearling	87	0
7/1/2008	7/2/2008	145	Arlington	Subyearling	57	0
			JDA Tailwaters(7)	Subyearling	27	0
			TDA Tailwaters(11)	Subyearling	61	0
7/2/2008	7/3/2008	278	Arlington(3)	Subyearling	119	0
			JDA Tailwaters(7)	Subyearling	45	1
			TDA Tailwaters(11)	Subyearling	114	0
7/3/2008	7/4/2008	209	Arlington(4)	Subyearling	90	0
			JDA Tailwaters(7)	Subyearling	32	0
			TDA Tailwaters	Subyearling	87	0
7/4/2008	7/5/2008	210	Arlington(3)	Subyearling	90	0
			JDA Tailwaters(7)	Subyearling	33	0
			TDA Tailwaters	Subyearling	87	0
7/5/2008	7/6/2008	213	Arlington(3)	Subyearling	92	0
			JDA Tailwaters(7)	Subyearling	34	1
			TDA Tailwaters(11)	Subyearling	87	0
7/6/2008	7/7/2008	211	Arlington	Subyearling	88	0
			JDA Tailwaters(7)	Subyearling	36	2*
			TDA Tailwaters	Subyearling	87	0
7/7/2008	7/8/2008	126	Arlington(1)	Subyearling	53	0
			JDA Tailwaters(7)	Subyearling	22	0
			TDA Tailwaters	Subyearling	51	0
7/8/2008	7/9/2008	295	Arlington(3)	Subyearling	122	0
			JDA Tailwaters(7)	Subyearling	51	2
			TDA Tailwaters(11)	Subyearling	122	0
7/9/2008	7/10/2008	216	Arlington(2,3)	Subyearling	90	0
			JDA Tailwaters(5,6)	Subyearling	36	0
			TDA Tailwaters	Subyearling	90	0
7/10/2008	7/11/2008	216	Arlington	Subyearling	90	0
			JDA Tailwaters	Subyearling	36	0
			TDA Tailwaters	Subyearling	90	1

Table A.2. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
7/11/2008	7/12/2008	216	Arlington	Subyearling	90	1
			JDA Tailwaters(7)	Subyearling	36	1
			TDA Tailwaters	Subyearling	90	0
7/12/2008	7/13/2008	119	JDA Tailwaters	Subyearling	31	1*
			TDA Tailwaters	Subyearling	88	0
Totals	Totals	5931	Arlington	Subyearling	2489	6
			JDA Tailwaters	Subyearling	996	14(a)
			TDA Tailwaters	Subyearling	2446	2

*Sacrificed to reach a goal of tagging and releasing 40 dead fish in summer.
(a) 6 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 20 dead fish in summer.
(1) Fish were released at grain elevator due to weather condition for 6 AM release.
(2) Fish were released at grain elevator due to weather condition for 12 PM release.
(3) Fish were released at grain elevator due to weather condition for 9 PM release.
(4) Fish were released at grain elevator due to weather condition for all releases.
(5) Fish were released at JDA_SMF due to weather condition for 1 PM release.
(6) Fish were released at JDA_SMF due to weather condition for 7 PM release.
(7) Fish were released at JDA_SMF due to weather condition for 1 AM release.
(8) Fish were released at JDA_SMF due to weather condition for all releases.
(9) Fish were released at the boat dock due to weather condition for 7 AM release.
(10) Fish were released at the boat dock due to weather condition for 2 PM release.
(11) Fish were released at the boat dock due to weather condition for 12 AM release.
(12) Fish were released at the boat dock due to weather condition for all releases.

Appendix B

Hydrophone and Autonomous Node Deployment Tables

Table B.1. 2008 John Day Dam-face hydrophone deployment table

System	Pier Nose	Elevation Category	Trailer	Y-Block Color	Channel	Y-Block Location	Beldon Cable Length (ft)	Deck Cable Length (ft)	Node Type	Node SN	Northing	Easting	Elevation (MSL)
P1	0-1	S	PH South	Red	4	0-1	100	250	D	107	745814.842	8153758.415	255.480
		D		Yellow	3		250		C	117	745819.012	8153763.507	169.423
	1-2	S		Blue	2		150		D	108	745886.286	8153706.834	255.593
		D		Green	1		250		C	115	745890.456	8153711.927	169.536
P2	2-3	S	PH South	Red	4	2-3	100	250	D	105	745959.263	8153654.155	255.592
		D		Yellow	3		250		C	118	745963.433	8153659.248	169.535
	3-4	S		Blue	2		150		D	106	746032.140	8153601.580	255.521
		D		Green	1		250		C	121	746036.309	8153606.673	169.464
P3	4-5	S	PH South	Red	4	4-5	100	500	D	100	746104.930	8153548.783	255.506
		D		Yellow	3		250		C	109	746109.100	8153553.875	169.449
	5-6	S		Blue	2		150		D	101	746178.072	8153496.125	255.459
		D		Green	1		250		C	125	746182.241	8153501.217	169.402
P4	6-7	S	PH Unit 8	Red	4	7-8	150	250	D	102	746251.006	8153443.515	255.618
		D		Yellow	3		250		C	116	746255.176	8153448.607	169.561
	7-8	S		Blue	2		100		D	103	746324.071	8153390.801	255.485
		D		Green	1		250		C	112	746328.240	8153395.894	169.428
P5	8-9	S	PH Unit 8	Red	4	8-9	100	250	D	104	746397.006	8153338.144	255.391
		D		Yellow	3		250		C	29	746401.175	8153343.236	169.334
	9-10	S		Blue	2		150		D	96	746469.786	8153285.298	255.542
		D		Green	1		250		C	128	746473.956	8153290.391	169.485
P6	10-11	S	PH Unit 8	Red	4	10-11	100	500	D	97	746542.776	8153232.562	255.558
		D		Yellow	3		250		C	127	746546.945	8153237.655	169.501
	11-12	S		Blue	2		150		D	98	746615.964	8153179.896	255.513
		D		Green	1		250		C	130	746620.134	8153184.988	169.456
P7	12-13	S	PH Unit 8	Red	4	12-13	100	500	D	95	746688.829	8153127.264	255.588
		D		Yellow	3		250		C	126	746692.998	8153132.356	169.531
	13-14	S		Blue	2		150		D	99	746761.826	8153074.494	255.402
		D		Green	1		250		C	135	746765.995	8153079.586	169.345
P8	14-15	S	PH Unit 8	Red	4	14-15	150	750	D	94	746834.781	8153022.149	255.412
		D		Yellow	3		250		C	131	746838.950	8153027.242	169.355
	15-16	S		Blue	2		150		D	93	746907.727	8152969.353	255.491
		D		Green	1		250		C	134	746911.896	8152974.445	169.434

Table B.1. (contd)

System	Pier Nose	Elevation Category	Trailer	Y-Block Color	Channel	Y-Block Location	Beldon Cable Length (ft)	Deck Cable Length (ft)	Node Type	Node SN	Northing	Easting	Elevation (MSL)
P9	16-17	S	PH Unit 19	Red	4	17-18	150	500	D	109	746980.621	8152916.494	255.601
		D		Yellow	3		250		C	140	746984.790	8152921.587	169.544
	17-18	S		Blue	2		150		D	107	747053.519	8152863.773	255.417
		D		Green	1		250		C	133	747057.688	8152868.865	169.360
P10	18-19	S	PH Unit 19	Red	4	19-20	150	500	D	52	747126.386	8152811.128	255.468
		D		Yellow	3		250		C	132	747130.555	8152816.220	169.411
	19-20	S		Blue	2		150		D	70	747199.333	8152758.451	255.521
		D		Green	1		250		C	138	747203.502	8152763.544	169.464
P11	20-0 PH	S	PH Unit 19	Red	4	20-0	150	250	D	110	747273.236	8152705.030	255.521
	20-0 PH	D		Yellow	3		250		C	136	747277.406	8152710.123	169.464
	20-0 SP	S		Blue	2		150	250	C	74	747297.216	8152677.926	259.699
	20-0 SP	D		Green	1		150		C	40	747297.216	8152677.926	232.529
S11	1-2	S	SP North	Blue	2	1-2	150		D	53	748251.896	8151988.454	259.899
		D		Green	1		150		C	13	748251.896	8151988.454	232.729
S12	2-3	S	SP North	Red	4	2-3	100	500	D	54	748201.453	8152024.735	259.554
		D		Yellow	3		100		C	14	748201.453	8152024.735	232.384
	3-4	S		Blue	2		150		D	55	748151.050	8152060.869	259.757
		D		Green	1		150		C	15	748151.050	8152060.869	232.587
S13	4-5	S	SP North	Red	4	4-5	100	500	D	56	748101.134	8152097.002	259.470
		D		Yellow	3		100		C	16	748101.134	8152097.002	232.300
	5-6	S		Blue	2		150		D	57	748050.729	8152133.202	259.810
		D		Green	1		150		C	17	748050.729	8152133.202	232.640
S14	6-7	S	SP North	Red	4	6-7	100	750	D	58	748000.695	8152169.330	259.792
		D		Yellow	3		100		C	18	748000.695	8152169.330	232.622
	7-8	S		Blue	2		150		D	59	747949.842	8152205.888	259.862
		D		Green	1		150		C	19	747949.842	8152205.888	232.692
S15	8-9	S	SP North	Red	4	8-9	150	750	D	60	747899.708	8152242.057	259.867
		D		Yellow	3		150		C	20	747899.708	8152242.057	232.697
	9-10	S		Blue	2		100		D	61	747849.496	8152278.533	259.807
		D		Green	1		100		C	21	747849.496	8152278.533	232.637

Table B.1. (contd)

System	Pier Nose	Elevation Category	Trailer	Y-Block Color	Channel	Y-Block Location	Beldon Cable Length (ft)	Deck Cable Length (ft)	Node Type	Node SN	Northing	Easting	Elevation (MSL)
S16	10-11	S	PH Unit 19	Red	4	11-12	150	1000	D	62	747799.155	8152314.604	259.547
		D		Yellow	3		150		C	22	747799.155	8152314.604	232.377
	11-12	S		Blue	2		100		D	63	747748.826	8152350.942	259.866
		D		Green	1		100		C	23	747748.826	8152350.942	232.696
S17	12-13	S	PH Unit 19	Red	4	12-13	150	750	D	64	747698.843	8152387.293	259.612
		D		Yellow	3		150		C	24	747698.843	8152387.293	232.442
	13-14	S		Blue	2		100		D	65	747648.471	8152423.584	259.705
		D		Green	1		100		C	25	747648.471	8152423.584	232.535
S18	14-15	S	PH Unit 19	Red	4	14-15	150	750	D	66	747598.238	8152459.904	259.524
		D		Yellow	3		150		C	26	747598.238	8152459.904	232.354
	15-16	S		Blue	2		100		D	67	747548.010	8152496.251	259.345
		D		Green	1		100		C	27	747548.010	8152496.251	232.175
S19	16-17	S	PH Unit 19	Red	4	16-17	150	500	D	68	747497.645	8152532.546	259.622
		D		Yellow	3		150		C	28	747497.645	8152532.546	232.452
	17-18	S		Blue	2		100		D	71	747447.224	8152568.918	259.927
		D		Green	1		100		C	29	747447.224	8152568.918	232.757
S20	18-19	S	PH Unit 19	Red	4	18-19	150	500	D	72	747397.018	8152605.211	259.781
		D		Yellow	3		150		C	30	747397.018	8152605.211	232.611
	19-20	S		Blue	2		100		D	73	747346.707	8152641.527	259.779
		D		Green	1		100		C	31	747346.707	8152641.527	232.609

Table B.2. Approximate global positioning system coordinates of autonomous nodes deployed in 2008 by array. Array_Node is a concatenation of the array name and autonomous node number, which incremented with increasing distance from the Washington shore toward Oregon. Array name is a concatenation of "A" for autonomous, a single digit indicating the successive array number from Arlington, Oregon, downstream to Oak Point, Washington, and "CR" for Columbia River.

Array_Node	Array Function	Latitude in Decimal Deg. (neg. is south)	Longitude in Decimal Deg. (neg. is west)	Approximate Depth (m)
A1CR351_01	JDA Forebay Entrance	45.731319	-120.677188	36.6
A1CR351_02		45.730279	-120.675845	41.1
A1CR351_03		45.729167	-120.674787	30.5
A1CR351_04		45.728181	-120.673703	34.7
A1CR351_05		45.727194	-120.672516	36.0
A1CR351_06		45.726136	-120.671329	34.1
A1CR351_07		45.725114	-120.670038	40.8
A1CR351_08		45.724074	-120.668877	23.2
A2CR346_01	JDA Tailwater Egress	45.690151	-120.785139	22.6
A2CR346_02		45.689271	-120.784493	17.0
A2CR346_03		45.688517	-120.783898	15.8
A2CR346_04		45.687690	-120.783303	11.7
A3CR312_01	TDA Forebay Entrance & JDA Primary	45.634858	-121.106748	7.5
A3CR312_02		45.634300	-121.105223	18.0
A3CR312_03		45.633795	-121.103775	28.0
A3CR312_04		45.633381	-121.102328	20.4
A3CR312_05		45.633075	-121.101062	12.8
A4CR237_01	BON Forebay Entrance & JDA Secondary; TDA Primary	45.652628	-121.914020	19.8
A4CR237_02		45.652196	-121.913659	28.2
A4CR237_03		45.651764	-121.913299	22.9
A4CR237_04		45.651405	-121.912939	16.4
A5CR203_01	JDA Tertiary; TDA Secondary; BON Primary	45.558905	-122.333054	6.0
A5CR203_02		45.549664	-122.316765	12.8
A5CR203_03		45.544965	-122.288452	15.9
A5CR203_04		45.544139	-122.288503	18.1
A5CR203_05		45.543406	-122.288460	19.4
A5CR203_06		45.542718	-122.288513	20.8
A5CR203_07		45.547699	-122.342397	9.8
A5CR203_08		45.550893	-122.345255	10.0
A5CR203_09		45.553001	-122.348805	8.3
A6CR192_01	TDA Tertiary; BON Secondary	45.575009	-122.435287	11.1

Table B.2. (contd)

Array_Node	Array Function	Latitude in Decimal Deg. (neg. is south)	Longitude in Decimal Deg. (neg. is west)	Approximate Depth (m)
A6CR192_02		45.568794	-122.420568	21.9
A6CR192_03		45.567852	-122.420311	19.8
A6CR192_04		45.566947	-122.420055	17.2
A6CR192_05		45.565824	-122.419696	10.4
A6CR192_06		45.564955	-122.419440	11.5
A7CR086_01	BON Tertiary	46.185928	-123.180278	21.3
A7CR086_02		46.184991	-123.179601	20.8
A7CR086_03		46.184127	-123.179132	15.8
A7CR086_04		46.183370	-123.178715	20.6

Appendix C

Tag-Life Plots

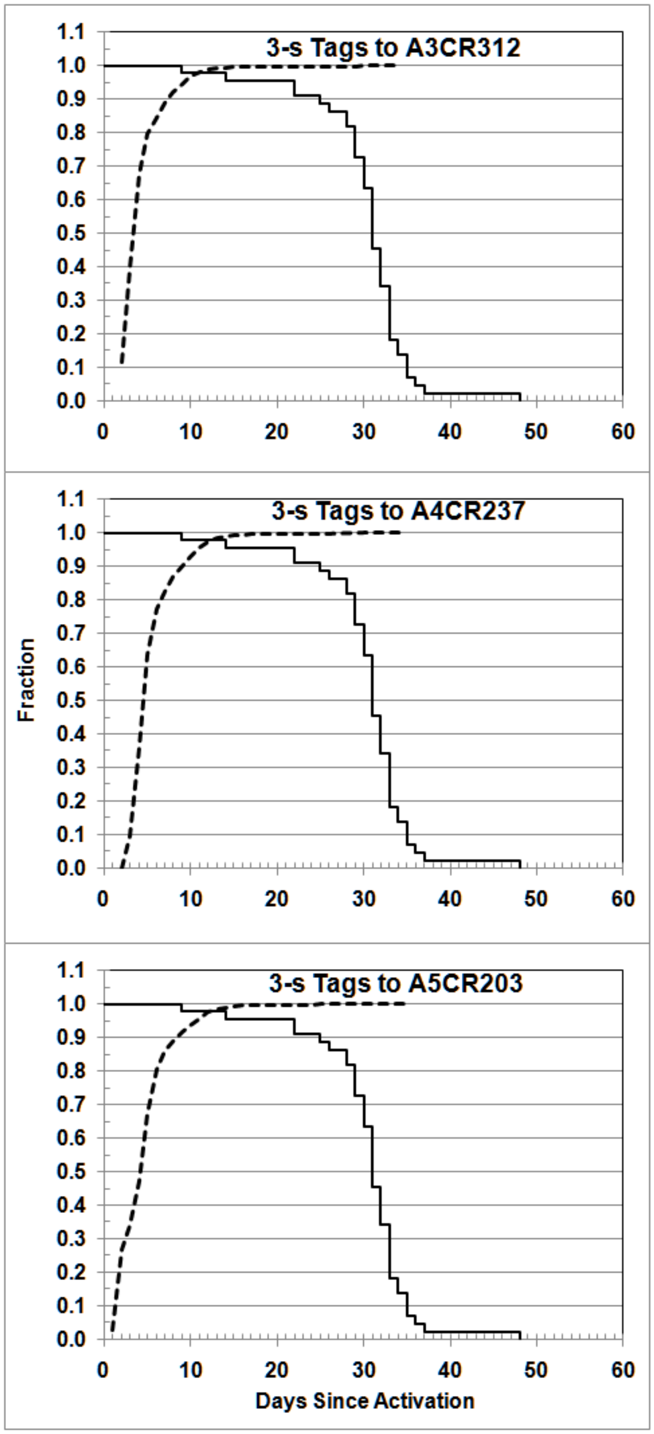

Figure C.1. Fraction of tag-life study tags transmitting (solid lines) and the cumulative fraction of tagged yearling Chinook salmon smolts arriving at three John Day Dam survival-detection arrays (dashed lines) as a function of days since tag activation. Arrays included A3CR312 (the John Day Dam primary array in The Dalles Dam forebay), A4CR237 (the secondary in the Bonneville Dam forebay), and A5CR203 (the tertiary in the Bonneville Dam tailwater).

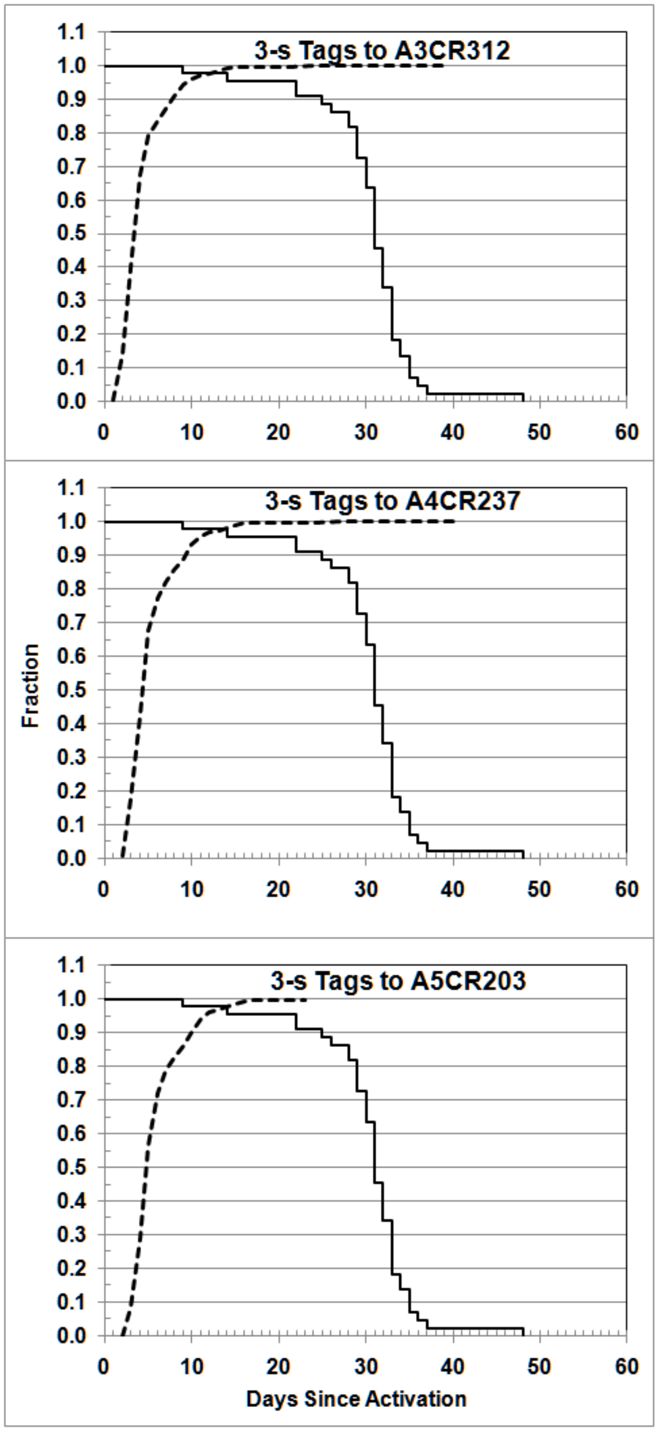

Figure C.2. Fraction of tag-life study tags transmitting (solid lines) and the cumulative fraction of tagged steelhead smolts arriving at three John Day Dam survival-detection arrays (dashed lines) as a function of days since tag activation. Arrays included A3CR312 (the John Day Dam primary array in The Dalles Dam forebay), A4CR237 (the secondary in the Bonneville Dam forebay), and A5CR203 (the tertiary in the Bonneville Dam tailwater).

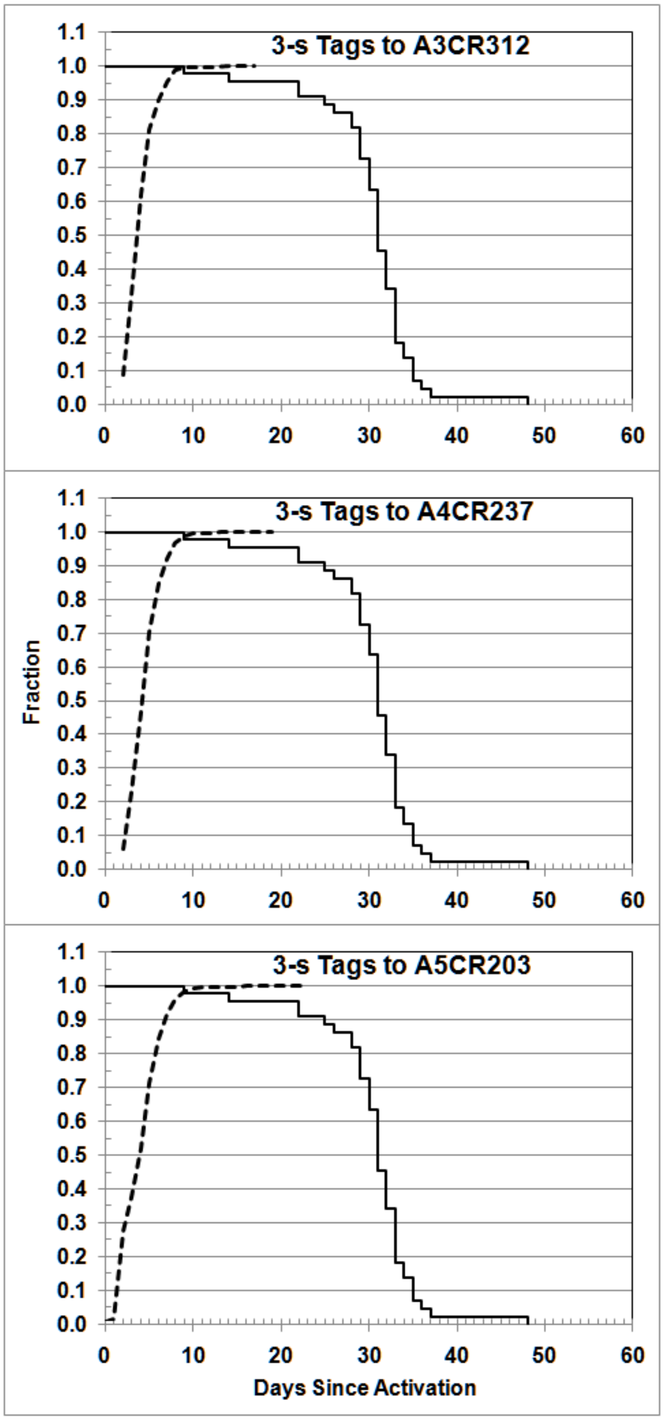

Figure C.3. Fraction of tag-life study tags transmitting (solid lines) and the cumulative fraction of tagged subyearling Chinook salmon smolts arriving at three John Day Dam survival-detection arrays (dashed lines) as a function of days since tag activation. Arrays included A3CR312 (the John Day Dam primary array in The Dalles Dam forebay), A4CR237 (the secondary in the Bonneville Dam forebay), and A5CR203 (the tertiary in the Bonneville Dam tailwater).

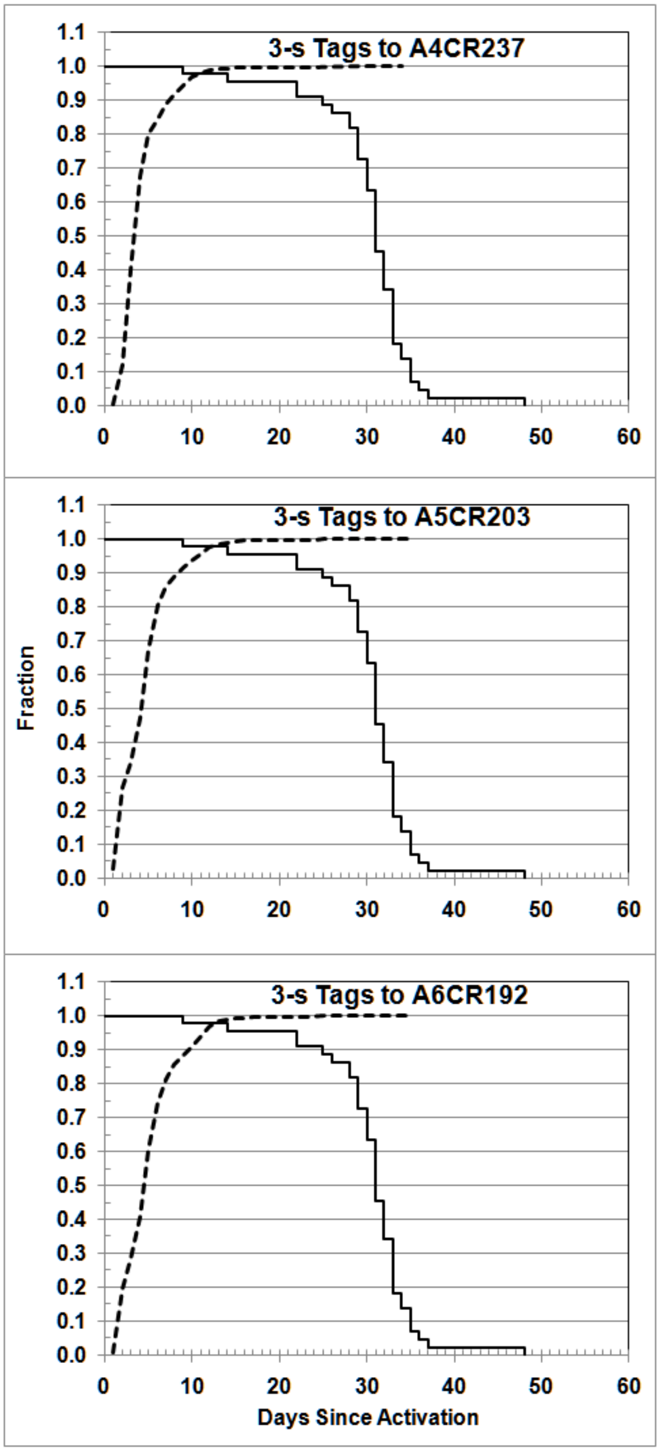

Figure C.4. Fraction of tag-life study tags transmitting (solid lines) and the cumulative fraction of tagged yearling Chinook salmon smolts arriving at three survival-detection arrays at The Dalles Dam (dashed lines) as a function of days since tag activation. Arrays included A4CR237 (The Dalles Dam primary array in the Bonneville Dam forebay), A5CR203 (the secondary in the Bonneville Dam tailwater), and A6CR192 (the tertiary in the Bonneville Dam tailwater).

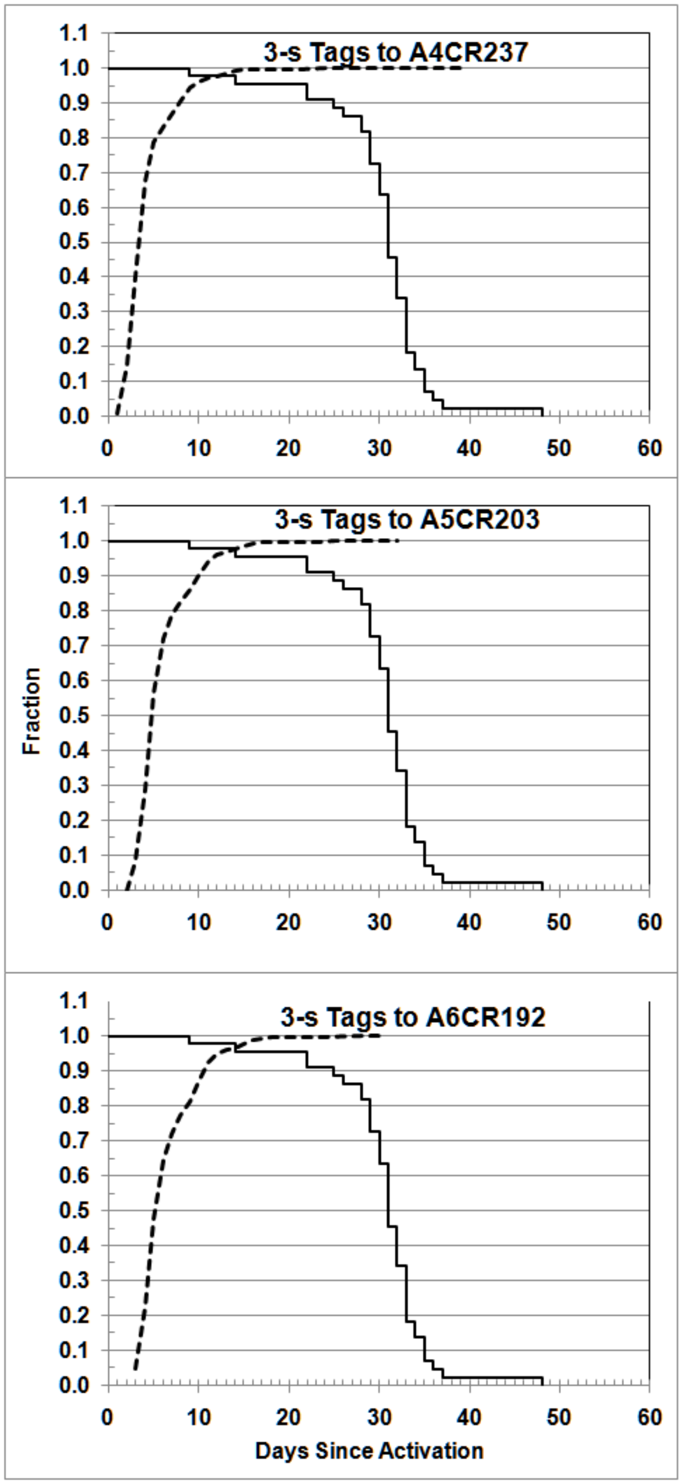

Figure C.5. Fraction of tag-life study tags transmitting (solid lines) and the cumulative fraction of tagged steelhead smolts arriving at three survival-detection arrays at The Dalles Dam (dashed lines) as a function of days since tag activation. Arrays included A4CR237 (The Dalles Dam primary array in the Bonneville Dam forebay), A5CR203 (the secondary in the Bonneville Dam tailwater), and A6CR192 (the tertiary in the Bonneville Dam tailwater).

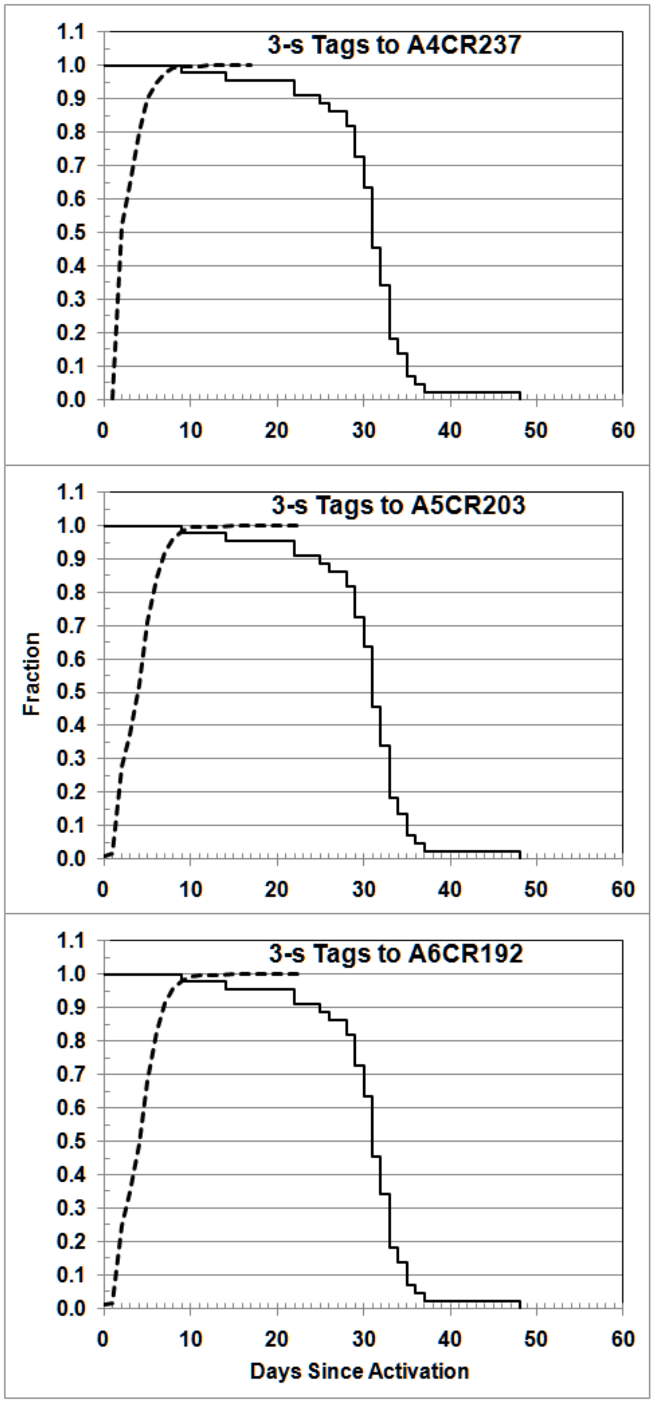

Figure C.6. Fraction of tag-life study tags transmitting (solid lines) and the cumulative fraction of tagged subyearling Chinook salmon smolts arriving at three survival-detection arrays at The Dalles Dam (dashed lines) as a function of days since tag activation. Arrays included A4CR237 (The Dalles Dam primary array in the Bonneville Dam forebay), A5CR203 (the secondary in the Bonneville Dam tailwater), and A6CR192 (the tertiary in the Bonneville Dam tailwater).

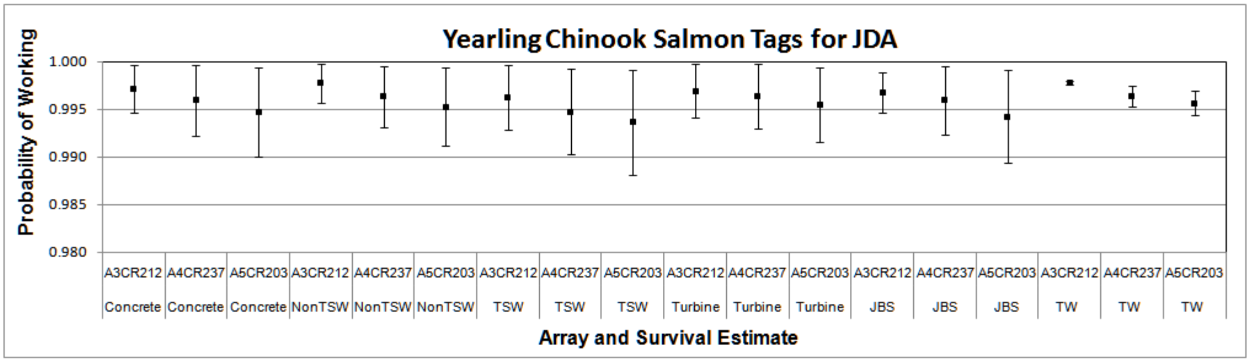

Figure C.7. Plot of the probability of a tag implanted in yearling Chinook salmon smolts working by the time fish arrived at survival-detection arrays for John Day Dam by array and survival estimate. Fish passing all dam-passage routes indicated below the array name on the x axis were released at Arlington, Oregon, except for those indicated by TW, which were released in the John Day tailrace.

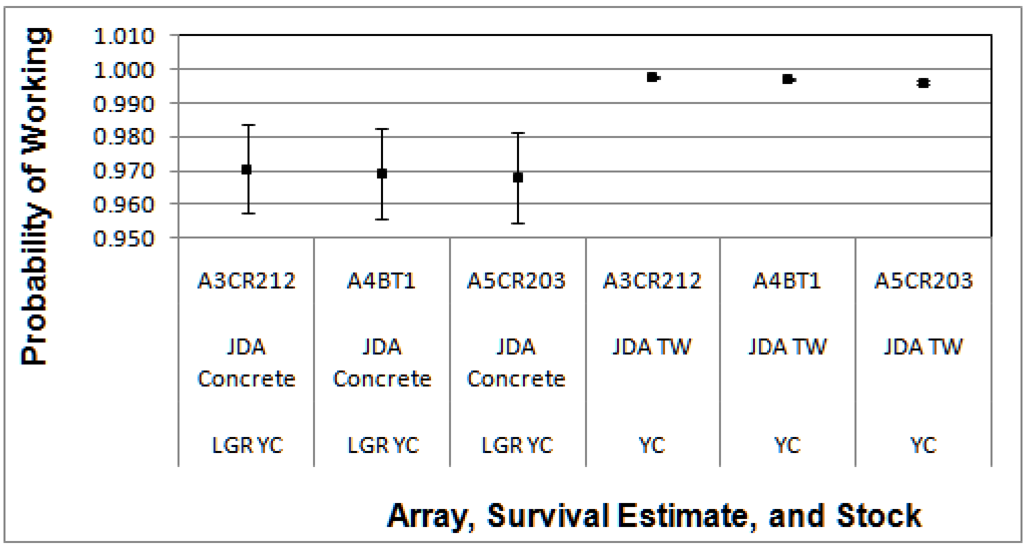

Figure C.8. Plot of the probability of a tag implanted in yearling Chinook salmon smolts released in the Lower Granite Dam tailrace (LGR YC) or in the John Day Tailwater (JDA TW) working by the time fish arrived at survival-detection arrays for John Day Dam by array, survival estimate, and stock. Array abbreviations are as follows: A3CR312 = The Dalles Dam forebay (primary), A4CR237 = Bonneville Dam forebay array (secondary), A4BT1 = Bonneville Dam tailwater 1 (tertiary).

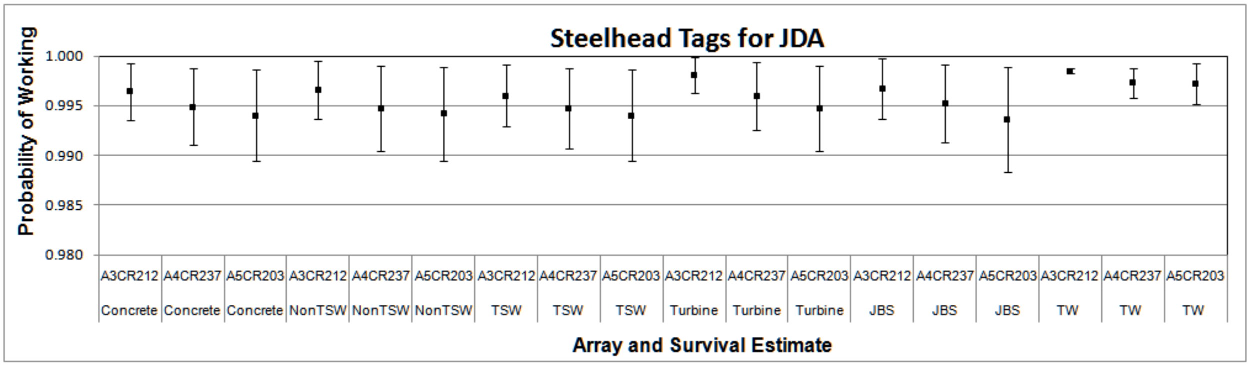

Figure C.9. Plot of the probability of a tag implanted in steelhead smolts working by the time fish arrived at survival-detection arrays for John Day Dam by array and survival estimate. Fish passing all dam-passage routes indicated below the array name on the x axis were released at Arlington, Oregon, except for those indicated by TW, which were released in the John Day tailrace.

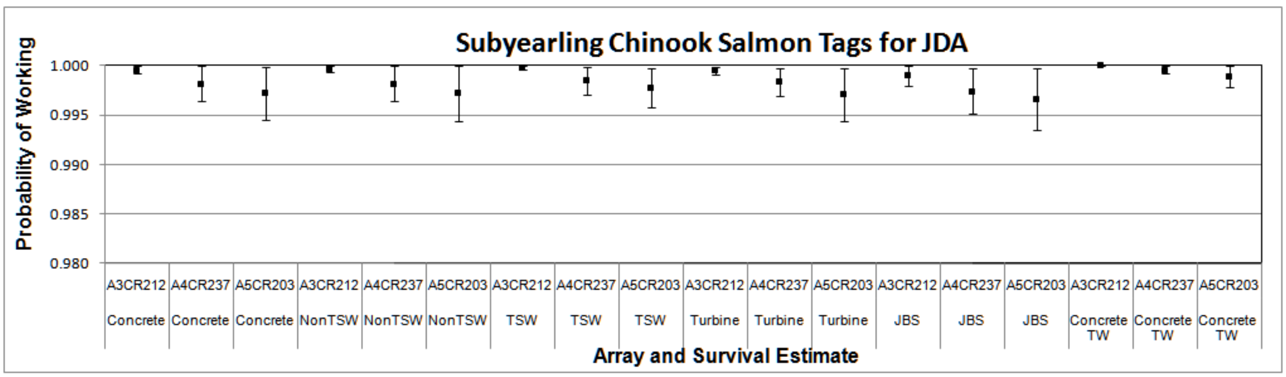

Figure C.10. Plot of the probability of a tag implanted in subyearling Chinook salmon smolts working by the time fish arrived at survival-detection arrays for John Day Dam by array and survival estimate. Fish passing all dam-passage routes indicated below the array name on the x axis were released at Arlington, Oregon, except for those indicated by TW, which were released in the John Day tailrace.

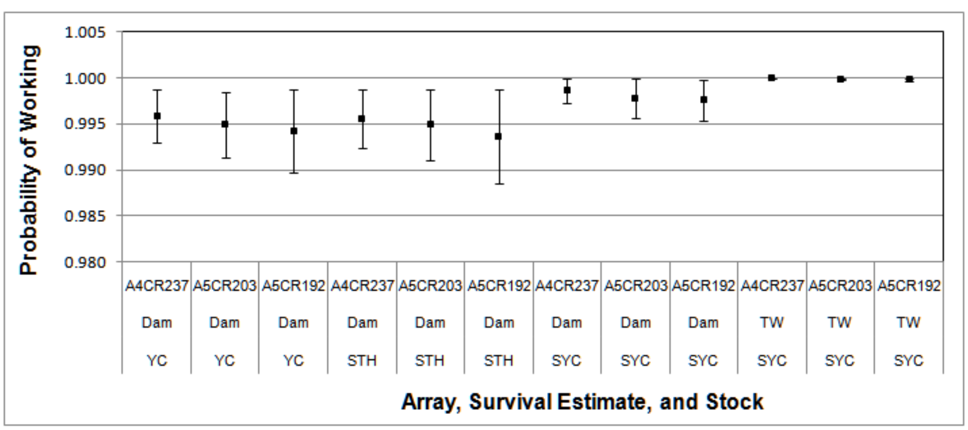

Figure C.11. Plot of the probability of a tag implanted in yearling Chinook salmon smolts released near Arlington, Oregon (Dam) or in the John Day tailwater (TW) working by the time fish arrived at survival-detection arrays for The Dalles Dam by array, survival estimate, and stock

Appendix D

Survival and Detection Probabilities for Single- and Paired-Releases without Tag-Life Corrections

Table D.1. List of Excel files on an accompanying compact disc[(a)]

File	Description
Appendix D1.xls	Yearling Chinook Single and Paired Release Survival and Detection Probabilities without Tag-Life Corrections
Appendix D2.xls	Steelhead Single and Paired Release Survival and Detection Probabilities without Tag-Life Corrections
Appendix D3.xls	Subyearling Chinook Single and Paired Release Survival and Detection Probabilities without Tag-Life Corrections

(a) A compact disc accompanying the report has nine files: A Portable Document Format (PDF) file of this report, three Excel files with non-tag-life-corrected survival and detection probabilities, and five Excel files with tagging, release, virtual release, capture-history, and dam operations data.

Table D.2. Variable names and definitions in Appendix D.xls files

Variable	Definition
S	Survival probabilities
CI	Confidence interval
Lambda	The product of survival and detection probabilities for the third array
N-Wt Mean	The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.
Capture History Headings	Headings of columns 2 through 9 on detection histories have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (The Dalles Dam forebay array, Bonneville [BON] forebay array, and BON tailwater1 array, respectively).
Virtual Releases	Smolts detected and regrouped to form virtual releases at the dam-face array except for the forebay survival (regrouped at the John Day Dam forebay array).

Appendix E

Tag-Life-Corrected John Day Concrete-Passage and Route-Specific Survival Rates for John Day Dam Yearling Chinook Salmon

Table E.1. Detection histories for yearling Chinook salmon smolts detected and regrouped to form virtual releases at John Day Dam in spring for estimating dam survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was not significant (P = 0.3880).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/03	38	0	1	0	9	0	6	4	58
5/04-5/05	83	0	5	0	31	0	16	10	145
5/06-5/07	118	0	27	0	39	0	30	17	231
5/08-5/09	86	2	11	0	34	0	16	8	157
5/10-5/11	89	0	21	0	28	0	31	13	182
5/12-5/13	108	0	14	0	45	0	20	9	196
5/14-5/15	70	0	15	0	26	1	19	17	148
5/16-5/17	53	0	42	0	22	0	43	11	171
5/18-5/19	48	0	55	0	39	0	63	15	220
5/20-5/21	32	0	37	0	36	0	63	4	172
5/22-5/23	28	2	35	1	33	2	50	14	165
5/24-5/25	42	0	35	0	37	0	58	6	178
5/26-5/27	35	0	60	0	43	0	60	6	204
5/28-5/29	23	0	47	0	19	0	55	10	154
Pooled	853	4	405	1	441	3	530	144	2381

Table E.2. Tag-life-corrected, single-release estimates of dam survival (S) and detection probabilities for yearling Chinook salmon smolts in virtual releases at John Day Dam based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/03	0.934	0.065	0.964	0.069	1.000	0.065	1.000	0.069	0.863	0.094
5/04-5/05	0.951	0.052	0.956	0.035	1.000	0.052	1.000	0.035	0.900	0.052
5/06-5/07	0.933	0.036	0.948	0.032	1.000	0.036	1.000	0.032	0.892	0.044
5/08-5/09	0.954	0.035	0.962	0.032	0.986	0.035	1.000	0.032	0.875	0.054
5/10-5/11	0.930	0.038	0.917	0.042	1.000	0.038	1.000	0.042	0.884	0.050
5/12-5/13	0.955	0.029	0.941	0.034	1.000	0.029	1.000	0.034	0.910	0.043
5/14-5/15	0.894	0.050	0.946	0.039	0.984	0.050	1.000	0.039	0.864	0.060
5/16-5/17	0.937	0.037	0.963	0.029	1.000	0.037	1.000	0.029	0.760	0.067
5/18-5/19	0.937	0.032	0.942	0.032	0.995	0.032	1.000	0.032	0.810	0.055
5/20-5/21	0.977	0.023	0.983	0.020	1.000	0.023	1.000	0.020	0.770	0.064
5/22-5/23	0.930	0.040	0.968	0.030	0.953	0.040	0.992	0.030	0.838	0.060
5/24-5/25	0.969	0.027	0.903	0.045	1.000	0.027	0.983	0.045	0.772	0.067
5/26-5/27	0.971	0.023	0.956	0.029	1.000	0.023	0.993	0.029	0.793	0.058
5/28-5/29	0.935	0.039	0.919	0.048	1.000	0.039	0.953	0.048	0.802	0.070
Pooled	0.944	0.011	0.946	0.010	0.994	0.011	0.995	0.010	0.836	0.016

Table E.3. Detection histories for yearling Chinook salmon smolts released in the upper John Day Dam tailwater as reference releases for dam survival and non-TSW survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was not significant (P = 0.3880).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/03	60	0	0	0	6	0	4	2	72
5/04-5/05	51	0	0	0	4	0	4	0	59
5/06-5/07	51	0	0	0	7	0	4	1	63
5/08-5/09	54	0	0	0	8	0	4	2	68
5/10-5/11	69	0	1	0	7	1	7	1	86
5/12-5/13	49	0	0	0	6	0	4	0	59
5/14-5/15	61	2	0	0	8	0	3	0	74
5/16-5/17	64	0	0	0	16	0	6	1	87
5/18-5/19	61	0	0	0	11	0	5	2	79
5/20-5/21	44	0	0	0	8	0	3	1	56
5/22-5/23	52	0	0	0	10	0	6	1	69
5/24-5/25	45	0	0	0	15	0	5	2	67
5/26-5/27	54	0	0	0	23	0	4	2	83
5/28-5/29	42	0	3	0	12	0	1	0	58
Pooled	757	2	4	0	141	1	60	15	980

Table E.4. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for yearling Chinook salmon smolts in reference releases for dam and non-TSW survival. Releases were in the upper John Day Dam tailwater. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/03	0.973	0.038	0.954	0.060	1.000	0.038	1.000	0.060	0.909	0.069
5/04-5/05	1.000	0.011	0.932	0.064	1.000	0.011	1.000	0.064	0.928	0.069
5/06-5/07	0.984	0.031	0.938	0.061	1.000	0.031	1.000	0.061	0.881	0.084
5/08-5/09	0.971	0.040	0.940	0.058	1.000	0.040	1.000	0.058	0.870	0.083
5/10-5/11	0.989	0.023	0.918	0.059	0.987	0.023	0.986	0.059	0.896	0.068
5/12-5/13	1.000	0.011	0.932	0.064	1.000	0.011	1.000	0.064	0.891	0.083
5/14-5/15	1.000	0.010	0.960	0.045	0.973	0.010	1.000	0.045	0.887	0.074
5/16-5/17	0.989	0.022	0.930	0.054	1.000	0.022	1.000	0.054	0.800	0.088
5/18-5/19	0.975	0.035	0.935	0.055	1.000	0.035	1.000	0.055	0.847	0.083
5/20-5/21	0.982	0.035	0.946	0.060	1.000	0.035	1.000	0.060	0.846	0.098
5/22-5/23	0.986	0.028	0.912	0.067	1.000	0.028	1.000	0.067	0.839	0.092
5/24-5/25	0.970	0.041	0.923	0.065	1.000	0.041	1.000	0.065	0.750	0.110
5/26-5/27	0.976	0.033	0.951	0.047	1.000	0.033	1.000	0.047	0.702	0.102
5/28-5/29	1.000	0.012	1.000	0.027	1.000	0.012	0.936	0.027	0.788	0.109
Pooled	0.987	0.008	0.940	0.015	0.997	0.008	0.995	0.015	0.843	0.024

Table E.5. Tag-life-corrected, paired-release estimates of dam survival (S) for yearling Chinook salmon smolts in virtual releases from the forebay to the upper John Day Dam tailwater

Paired Release	S to Upper Tailwater	1/2 95% CI
5/02-5/03	0.960	0.077
5/04-5/05	0.951	0.053
5/06-5/07	0.948	0.047
5/08-5/09	0.982	0.055
5/10-5/11	0.940	0.044
5/12-5/13	0.955	0.031
5/14-5/15	0.894	0.051
5/16-5/17	0.947	0.043
5/18-5/19	0.962	0.048
5/20-5/21	0.995	0.042
5/22-5/23	0.943	0.049
5/24-5/25	0.998	0.050
5/26-5/27	0.995	0.041
5/28-5/29	0.935	0.040
Pooled	0.957	0.013

Table E.6. Detection histories for yearling Chinook salmon smolts detected and regrouped to form virtual releases at non-TSW spill bays in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/03	27	0	1	0	8	0	4	2	42
5/04-5/05	35	0	2	0	17	0	11	3	68
5/06-5/07	53	0	11	0	20	0	13	5	102
5/08-5/09	34	0	4	0	18	0	8	2	66
5/10-5/11	49	0	13	0	14	0	14	6	96
5/12-5/13	65	0	9	0	26	0	12	4	116
5/14-5/15	25	0	8	0	7	0	5	7	52
5/16-5/17	28	0	19	0	11	0	16	4	78
5/18-5/19	34	0	37	0	23	0	39	8	141
5/20-5/21	19	0	17	0	19	0	32	3	90
5/22-5/23	19	1	21	0	22	0	28	7	98
5/24-5/25	32	0	25	0	24	0	34	6	121
5/26-5/27	17	0	29	0	24	0	34	5	109
5/28-5/29	8	0	28	0	11	0	25	4	76
Pooled	445	1	224	0	244	0	275	66	1255

Table E.7. Tag-life-corrected, single-release estimates of non-TSW spill bay passage survival (S) and detection probabilities for yearling Chinook salmon smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/03	0.955	0.065	0.995	0.053	1.000	0.065	1.000	0.053	0.846	0.113
5/04-5/05	0.976	0.059	0.939	0.058	1.000	0.059	1.000	0.058	0.836	0.093
5/06-5/07	0.956	0.043	0.951	0.044	1.000	0.043	1.000	0.044	0.865	0.072
5/08-5/09	0.974	0.042	0.958	0.053	1.000	0.042	1.000	0.053	0.869	0.085
5/10-5/11	0.938	0.048	0.911	0.059	1.000	0.048	1.000	0.059	0.878	0.071
5/12-5/13	0.967	0.033	0.938	0.045	1.000	0.033	1.000	0.045	0.896	0.059
5/14-5/15	0.887	0.087	0.933	0.073	0.977	0.087	1.000	0.073	0.861	0.104
5/16-5/17	0.949	0.049	0.973	0.037	1.000	0.049	1.000	0.037	0.764	0.098
5/18-5/19	0.944	0.038	0.955	0.035	1.000	0.038	1.000	0.035	0.820	0.067
5/20-5/21	0.967	0.037	1.000	0.000	1.000	0.037	1.000	0.000	0.805	0.083
5/22-5/23	0.941	0.048	0.959	0.043	0.977	0.048	0.986	0.043	0.829	0.080
5/24-5/25	0.951	0.039	0.961	0.038	1.000	0.039	0.977	0.038	0.787	0.077
5/26-5/27	0.954	0.039	0.962	0.037	1.000	0.039	1.000	0.037	0.710	0.089
5/28-5/29	0.947	0.050	0.949	0.054	1.000	0.050	0.981	0.054	0.761	0.102
Pooled	0.951	0.013	0.955	0.012	0.997	0.013	0.996	0.012	0.821	0.022
N-Wt Mean	0.951	0.009	0.955	0.011						

Table E.8. Tag-life-corrected, paired-release estimates of survival (S) for yearling Chinook salmon smolts in virtual releases at non-TSW spill bays to the upper John Day Dam tailwater. Treatment virtual release data were from Tables E.6 and E.7, and reference release data were from Table E.4.

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/03	0.982	0.077
5/04-5/05	0.976	0.060
5/06-5/07	0.972	0.053
5/08-5/09	1.003	0.060
5/10-5/11	0.948	0.054
5/12-5/13	0.967	0.035
5/14-5/15	0.887	0.087
5/16-5/17	0.960	0.054
5/18-5/19	0.969	0.052
5/20-5/21	0.985	0.051
5/22-5/23	0.955	0.056
5/24-5/25	0.980	0.057
5/26-5/27	0.978	0.052
5/28-5/29	0.947	0.051
N-Wt Mean	0.966	0.011

Table E.9. Detection histories for yearling Chinook salmon smolts detected and regrouped to form virtual releases at TSW spill bays in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0001).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/05	44	0	3	0	10	0	4	5	66
5/06-5/09	56	0	10	0	17	0	17	8	108
5/10-5/13	49	0	10	0	24	0	16	3	102
5/14-5/17	54	0	20	0	22	0	27	9	132
5/18-5/21	5	0	7	0	9	0	13	3	37
5/22-5/25	7	0	4	1	10	0	10	2	34
5/26-5/29	17	0	18	0	12	0	31	1	79
Pooled	232	0	72	1	104	0	118	31	558

Table E.10. Tag-life-corrected, single-release estimates of TSW survival (S) and detection probabilities for yearling Chinook salmon smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/05	0.985	0.021	0.944	0.044	1.000	0.021	1.000	0.044	0.917	0.049
5/06-5/09	0.977	0.026	0.939	0.042	1.000	0.026	1.000	0.042	0.876	0.059
5/10-5/13	0.994	0.013	0.924	0.044	0.993	0.013	0.992	0.044	0.894	0.053
5/14-5/17	0.995	0.012	0.943	0.036	0.987	0.012	1.000	0.036	0.841	0.058
5/18-5/21	0.978	0.025	0.939	0.041	1.000	0.025	1.000	0.041	0.847	0.063
5/22-5/25	0.978	0.025	0.917	0.047	1.000	0.025	1.000	0.047	0.795	0.072
5/26-5/29	1.000	0.023	0.974	0.033	1.000	0.023	0.970	0.033	0.737	0.076
Pooled	0.987	0.008	0.940	0.015	0.997	0.008	0.995	0.015	0.843	0.024
N-Wt Mean	0.987	0.007	0.940	0.013						

Table E.11. Detection histories for yearling Chinook salmon smolts in TSW reference releases in the upper John Day Dam tailwater based on three downstream arrays. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P = 0.0096).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/05	111	0	0	0	10	0	8	2	131
5/06-5/09	105	0	0	0	15	0	8	3	131
5/10-5/13	118	0	1	0	13	1	11	1	145
5/14-5/17	125	2	0	0	24	0	9	1	161
5/18-5/21	105	0	0	0	19	0	8	3	135
5/22-5/25	97	0	0	0	25	0	11	3	136
5/26-5/29	96	0	3	0	35	0	5	2	141
Pooled	757	2	4	0	141	1	60	15	980

Table E.12. Tag-life-corrected, single-release survival estimates for yearling Chinook salmon smolts in TSW reference releases based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/05	0.985	0.021	0.944	0.044	1.000	0.021	1.000	0.044	0.917	0.049
5/06-5/09	0.977	0.026	0.939	0.042	1.000	0.026	1.000	0.042	0.876	0.059
5/10-5/13	0.994	0.013	0.924	0.044	0.993	0.013	0.992	0.044	0.894	0.053
5/14-5/17	0.995	0.012	0.943	0.036	0.987	0.012	1.000	0.036	0.841	0.058
5/18-5/21	0.978	0.025	0.939	0.041	1.000	0.025	1.000	0.041	0.847	0.063
5/22-5/25	0.978	0.025	0.917	0.047	1.000	0.025	1.000	0.047	0.795	0.072
5/26-5/29	1.000	0.023	0.974	0.033	1.000	0.023	0.970	0.033	0.737	0.076
Pooled	0.987	0.008	0.940	0.015	0.997	0.008	0.995	0.015	0.843	0.024
N-Wt Mean	0.987	0.007	0.940	0.013						

Table E.13. Tag-life-corrected, paired-release estimates of TSW spill bay (15 and 16) passage survival (S) for yearling Chinook salmon smolts

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/05	0.956	0.071
5/06-5/09	0.952	0.057
5/10-5/13	0.979	0.036
5/14-5/17	0.938	0.045
5/18-5/21	0.940	0.093
5/22-5/25	0.966	0.085
5/26-5/29	0.987	0.033
Pooled	0.961	0.022
N-Wt Mean	0.961	0.020

Table E.14. Detection histories for yearling Chinook salmon smolts detected and regrouped to form virtual releases for John Day Dam turbines in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.001).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/06	10	0	0	0	6	0	3	6	25
5/07-5/12	19	0	3	0	6	0	3	6	37
5/13-5/18	7	0	5	0	5	1	6	5	29
5/19-5/24	7	0	11	0	7	1	19	7	52
5/25-5/29	8	0	18	0	4	0	9	6	45
Pooled	51	0	37	0	28	2	40	30	188

Table E.15. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for yearling Chinook salmon smolts in virtual releases at John Day Dam turbines based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	0.771	0.172	0.895	0.138	1.000	0.172	1.000	0.138	0.825	0.181
5/07-5/12	0.843	0.120	0.938	0.087	1.000	0.120	1.000	0.087	0.865	0.126
5/13-5/18	0.835	0.140	0.826	0.155	0.950	0.140	1.000	0.155	0.900	0.132
5/19-5/24	0.866	0.093	0.955	0.062	0.977	0.093	1.000	0.062	0.698	0.137
5/25-5/29	0.867	0.099	0.903	0.096	1.000	0.099	0.938	0.096	0.909	0.098
Pooled	0.844	0.053	0.914	0.045	0.986	0.053	0.983	0.045	0.825	0.063
N-Wt Mean	0.844	0.031	0.911	0.042						

Table E.16. Detection histories for yearling Chinook salmon smolts released in the upper John Day Dam tailwater as reference releases for turbine survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P = 0.0040).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/06	131	0	0	0	10	0	9	2	152
5/07-5/12	177	0	1	0	22	1	17	4	222
5/13-5/18	173	2	0	0	32	0	11	2	220
5/19-5/24	157	0	0	0	37	0	16	5	215
5/25-5/29	119	0	3	0	40	0	7	2	171
Pooled	757	2	4	0	141	1	60	15	980

Table E.17. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for yearling Chinook salmon smolts in turbine reference releases in the upper John Day Dam tailwater based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	0.987	0.018	0.946	0.04	1.000	0.018	1.000	0.04	0.9295	0.042
5/07-5/12	0.982	0.017	0.923	0.036	0.995	0.017	0.994	0.036	0.8851	0.044
5/13-5/18	0.992	0.013	0.949	0.029	0.990	0.013	1.000	0.029	0.8453	0.049
5/19-5/24	0.977	0.02	0.924	0.036	1.000	0.02	1.000	0.036	0.8093	0.055
5/25-5/29	1.000	0.02	0.967	0.031	1.000	0.02	0.975	0.031	0.752	0.068
Pooled	0.987	0.008	0.940	0.015	0.997	0.008	0.995	0.015	0.843	0.024
N-Wt Mean	0.987	0.008	0.94	0.016						

Table E.18. Tag-life-corrected, paired-release estimates of turbine-passage survival (S) for yearling Chinook salmon smolts in virtual releases into John Day Dam turbines to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/06	0.781	0.174
5/07-5/12	0.859	0.123
5/13-5/18	0.842	0.141
5/19-5/24	0.887	0.097
5/25-5/29	0.867	0.101
Pooled	0.855	0.054
N-Wt Mean	0.855	0.034

Table E.19. Detection histories for yearling Chinook salmon smolts detected and regrouped to form virtual releases for the John Day Dam JBS in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/07	30	0	6	0	7	0	5	5	53
5/08-5/11	37	2	6	0	7	0	7	1	60
5/12-5/15	20	0	6	0	10	0	3	7	46
5/16-5/19	13	0	12	0	9	0	20	2	56
5/20-5/23	9	1	20	0	16	1	29	2	78
5/24-5/29	16	0	22	0	16	0	33	0	87
Pooled	125	3	72	0	65	1	97	17	380

Table E.20. Tag-life-corrected, single-release estimates of JBS passage survival (S) and detection probabilities for yearling Chinook salmon smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/07	0.915	0.080	0.947	0.070	1.000	0.080	1.000	0.070	0.981	0.043
5/08-5/11	0.988	0.033	0.967	0.048	0.965	0.033	1.000	0.048	0.861	0.090
5/12-5/15	0.849	0.104	0.974	0.050	1.000	0.104	1.000	0.050	0.844	0.116
5/16-5/19	0.984	0.035	0.926	0.070	0.980	0.035	1.000	0.070	0.863	0.094
5/20-5/23	0.989	0.025	0.960	0.045	0.960	0.025	1.000	0.045	0.771	0.096
5/24-5/29	1.000	0.009	0.875	0.070	1.000	0.009	0.968	0.070	0.824	0.087
Pooled	0.965	0.020	0.935	0.026	0.982	0.020	0.993	0.026	0.848	0.038
N-Wt Mean	0.963	0.044	0.937	0.032						

Table E.21. Detection histories for yearling Chinook salmon smolts released in the upper John Day Dam tailwater as reference releases for JBS passage survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P = 0.0090).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/07	162	0	0	0	17	0	12	3	194
5/08-5/11	123	0	1	0	15	1	11	3	154
5/12-5/15	110	2	0	0	14	0	7	0	133
5/16-5/19	125	0	0	0	27	0	11	3	166
5/20-5/23	96	0	0	0	18	0	9	2	125
5/24-5/29	141	0	3	0	50	0	10	4	208
Pooled	757	2	4	0	141	1	60	15	980

Table E.22. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for yearling Chinook salmon smolts in JBS reference releases in the upper John Day Dam tailwater based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/07	0.985	0.017	0.942	0.036	1.000	0.017	1.000	0.036	0.906	0.043
5/08-5/11	0.981	0.022	0.928	0.042	0.993	0.022	0.992	0.042	0.885	0.053
5/12-5/15	1.000	0.008	0.947	0.038	0.985	0.008	1.000	0.038	0.889	0.055
5/16-5/19	0.982	0.020	0.933	0.039	1.000	0.020	1.000	0.039	0.822	0.061
5/20-5/23	0.984	0.022	0.927	0.046	1.000	0.022	1.000	0.046	0.842	0.067
5/24-5/29	0.991	0.019	0.958	0.030	1.000	0.019	0.979	0.030	0.741	0.063
Pooled	0.987	0.008	0.940	0.015	0.997	0.008	0.995	0.015	0.843	0.024
N-Wt Mean	0.987	0.005	0.940	0.010						

Table E.23. Tag-life-corrected, paired-release estimates of JBS-passage survival (S) for yearling Chinook salmon smolts in virtual releases from the JBS to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/07	0.929	0.083
5/08-5/11	1.007	0.040
5/12-5/15	0.849	0.104
5/16-5/19	1.002	0.041
5/20-5/23	1.005	0.034
5/24-5/29	1.009	0.021
Pooled	0.977	0.022
N-Wt Mean	0.976	0.045

Appendix F

Tag-Life-Corrected Survival Rates for Yearling Chinook at The Dalles Dam

Table F.1. Detection histories for yearling Chinook salmon smolts detected and regrouped to form virtual releases at The Dalles Dam in spring for estimating dam survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (BON_FB, BTW1, and BTW2). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/4/2008	71	6	2	1	19	0	1	10	110
5/5/2008	57	3	1	1	27	0	3	10	102
5/6/2008	70	4	8	0	27	2	3	11	125
5/7/2008	73	4	9	1	22	2	4	15	130
5/8/2008	51	6	20	2	20	1	7	14	121
5/9/2008	66	7	9	2	22	2	4	13	125
5/10/2008	84	8	10	2	23	1	5	5	138
5/11/2008	57	3	13	0	14	1	8	13	109
5/12/2008	70	8	13	2	26	0	3	18	140
5/13/2008	71	2	11	1	38	0	4	13	140
5/14/2008	48	8	10	1	15	4	4	13	103
5/15/2008	53	7	9	1	21	3	4	6	104
5/16/2008	49	13	16	3	20	2	10	7	120
5/17/2008	27	6	29	4	11	2	17	13	109
5/18/2008	37	6	28	4	18	5	26	23	147
5/19/2008	25	5	38	5	24	3	22	14	136
5/20/2008	31	3	21	5	21	6	30	21	138
5/21/2008	14	6	18	5	19	4	32	17	115
5/22/2008	17	4	17	5	32	3	28	14	120
5/23/2008	22	2	22	3	21	7	22	12	111
5/24/2008	17	8	11	6	30	2	25	15	114
5/25/2008	25	3	20	8	15	3	14	16	104
5/26/2008	18	4	32	6	21	4	22	21	128
5/27/2008	25	5	36	9	28	4	25	21	153
5/28/2008	13	4	30	7	17	1	20	21	113
5/29/2008	17	4	44	11	17	2	34	18	147
Pooled	1108	139	477	95	568	64	377	374	3202

Table F.2. Tag-life-corrected, single-release estimates of dam survival (S) and detection probabilities for yearling Chinook salmon smolts in virtual releases at The Dalles Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/4/2008	0.972	0.049	0.945	0.047	1.000	0.049	0.938	0.047	0.968	0.036
5/5/2008	0.956	0.054	0.949	0.047	1.000	0.054	0.966	0.047	0.955	0.044
5/6/2008	0.956	0.047	0.972	0.036	1.000	0.047	0.942	0.036	0.899	0.057
5/7/2008	0.937	0.045	0.953	0.043	1.000	0.045	0.941	0.043	0.881	0.062
5/8/2008	0.960	0.042	0.944	0.059	1.000	0.042	0.910	0.059	0.725	0.089
5/9/2008	0.953	0.043	0.944	0.047	1.000	0.043	0.907	0.047	0.870	0.065
5/10/2008	0.974	0.028	0.987	0.026	1.000	0.028	0.922	0.026	0.877	0.058
5/11/2008	0.938	0.046	0.953	0.048	0.990	0.046	0.947	0.048	0.772	0.086
5/12/2008	0.894	0.051	0.971	0.036	1.000	0.051	0.923	0.036	0.857	0.065
5/13/2008	0.937	0.041	0.965	0.033	1.000	0.041	0.982	0.033	0.879	0.057
5/14/2008	0.923	0.052	0.965	0.055	1.000	0.052	0.840	0.055	0.818	0.086
5/15/2008	0.963	0.037	0.988	0.037	1.000	0.037	0.881	0.037	0.851	0.075
5/16/2008	0.959	0.036	1.000	0.000	1.000	0.036	0.827	0.000	0.731	0.081
5/17/2008	0.955	0.039	0.978	0.100	1.000	0.039	0.826	0.100	0.452	0.106
5/18/2008	0.954	0.034	0.934	0.082	1.000	0.034	0.833	0.082	0.506	0.094
5/19/2008	0.964	0.032	0.969	0.081	1.000	0.032	0.860	0.081	0.449	0.093
5/20/2008	0.921	0.045	0.952	0.079	1.000	0.045	0.853	0.079	0.504	0.096
5/21/2008	0.957	0.037	0.983	0.128	1.000	0.037	0.768	0.128	0.398	0.105
5/22/2008	0.969	0.032	0.925	0.080	0.990	0.032	0.875	0.080	0.522	0.101
5/23/2008	0.947	0.042	1.000	0.056	1.000	0.042	0.830	0.056	0.496	0.097
5/24/2008	0.932	0.047	0.949	0.086	0.989	0.047	0.825	0.086	0.566	0.107
5/25/2008	0.925	0.052	0.885	0.093	0.988	0.052	0.870	0.093	0.540	0.113
5/26/2008	0.930	0.044	0.942	0.102	1.000	0.044	0.830	0.102	0.419	0.100
5/27/2008	0.949	0.035	0.919	0.082	0.992	0.035	0.855	0.082	0.465	0.092
5/28/2008	0.952	0.042	0.868	0.113	0.977	0.042	0.857	0.113	0.375	0.106
5/29/2008	0.957	0.043	0.957	0.111	0.941	0.043	0.850	0.111	0.304	0.085
Pooled	0.947	0.010	0.940	0.012	0.995	0.010	0.892	0.012	0.663	0.018
N-Wt Mean	0.947	0.007	0.954	0.012						

Appendix G

Tag-Life-Corrected Survival Rates for Lower Granite Dam Yearling Chinook at John Day Dam

Table G.1. Detection histories for yearling Chinook salmon smolts released at Lower Granite Dam and detected and regrouped to form virtual releases at John Day Dam in spring for estimating dam survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (A3CR311, A4CR236, and A5CR203, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.01).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/04-5/11	20	0	9	0	10	0	11	7	57
5/12-5/13	75	0	23	0	36	0	59	13	206
5/14-5/15	78	1	34	0	29	1	39	24	206
5/16-5/17	48	0	71	0	32	0	99	27	277
5/18-5/19	48	0	95	0	58	0	176	32	409
5/20-5/21	32	0	86	0	45	0	168	28	359
5/22-5/23	39	1	60	1	60	1	143	60	365
5/24-5/25	100	0	174	0	129	0	302	64	769
5/26-5/27	20	1	56	0	29	0	100	24	230
5/28-5/29	8	0	41	0	8	0	55	34	146
Pooled	468	3	649	1	436	2	1152	313	3024

Table G.2. Tag-life-corrected, single-release estimates of dam survival (S) and detection probabilities for yearling Chinook salmon smolts released at Lower Granite Dam and regrouped to form virtual releases at John Day Dam based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/04-5/11	0.905	0.089	0.962	0.054	1.000	0.089	1.000	0.054	0.876	0.094
5/12-5/13	0.967	0.044	0.927	0.038	1.000	0.044	0.993	0.038	0.770	0.062
5/14-5/15	0.919	0.052	0.959	0.030	0.983	0.052	0.993	0.030	0.835	0.055
5/16-5/17	0.938	0.045	0.964	0.025	0.996	0.045	0.994	0.025	0.747	0.055
5/18-5/19	0.953	0.032	0.960	0.020	1.000	0.032	1.000	0.020	0.783	0.043
5/20-5/21	0.951	0.034	0.953	0.023	1.000	0.034	1.000	0.023	0.728	0.049
5/22-5/23	0.867	0.045	0.938	0.028	0.983	0.045	0.990	0.028	0.727	0.052
5/24-5/25	0.941	0.032	0.943	0.017	0.999	0.032	0.994	0.017	0.772	0.032
5/26-5/27	0.914	0.046	0.938	0.035	1.000	0.046	0.974	0.035	0.813	0.056
5/28-5/29	0.795	0.074	1.000	0.044	1.000	0.074	0.864	0.044	0.757	0.079
Pooled	0.925	0.027	0.949	0.009	0.996	0.027	0.989	0.009	0.770	0.016
N-Wt Mean	0.925	0.026	0.951	0.010						

Table G.3. Detection histories for yearling Chinook salmon smolts released in the upper John Day Dam tailwater as reference releases for virtual releases of yearling Chinook salmon from Lower Granite Dam. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was not significant (P = 0.1630).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/04-5/11	225	0	1	0	26	1	19	4	276
5/12-5/13	49	0	0	0	6	0	4	0	59
5/14-5/15	61	2	0	0	8	0	3	0	74
5/16-5/17	64	0	0	0	16	0	6	1	87
5/18-5/19	61	0	0	0	11	0	5	2	79
5/20-5/21	44	0	0	0	8	0	3	1	56
5/22-5/23	52	0	0	0	10	0	6	1	69
5/24-5/25	45	0	0	0	15	0	5	2	67
5/26-5/27	54	0	0	0	23	0	4	2	83
5/28-5/29	42	0	3	0	12	0	1	0	58
Pooled	697	2	4	0	135	1	56	13	908

Table G.4. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for yearling Chinook salmon smolts in reference releases for dam and non-TSW survival. Releases were in the upper John Day Dam tailwater. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/04-5/11	0.986	0.014	0.931	0.030	0.996	0.014	0.996	0.030	0.893	0.038
5/12-5/13	1.000	0.011	0.932	0.064	1.000	0.011	1.000	0.064	0.891	0.083
5/14-5/15	1.000	0.010	0.960	0.045	0.973	0.010	1.000	0.045	0.887	0.074
5/16-5/17	0.989	0.022	0.930	0.054	1.000	0.022	1.000	0.054	0.800	0.088
5/18-5/19	0.975	0.035	0.935	0.055	1.000	0.035	1.000	0.055	0.847	0.083
5/20-5/21	0.982	0.035	0.946	0.060	1.000	0.035	1.000	0.060	0.846	0.098
5/22-5/23	0.986	0.028	0.912	0.067	1.000	0.028	1.000	0.067	0.839	0.092
5/24-5/25	0.970	0.041	0.923	0.065	1.000	0.041	1.000	0.065	0.750	0.110
5/26-5/27	0.976	0.033	0.951	0.047	1.000	0.033	1.000	0.047	0.702	0.102
5/28-5/29	1.000	0.012	1.000	0.027	1.000	0.012	0.936	0.027	0.788	0.109
Pooled	0.988	0.008	0.939	0.016	0.996	0.008	0.994	0.016	0.8377	0.025

Table G.5. Tag-life-corrected, paired-release estimates of dam survival (S) for yearling Chinook salmon smolts released from Lower Granite Dam, regrouped in virtual releases, and traveling from the forebay to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
5/04-5/11	0.918	0.092
5/12-5/13	0.967	0.045
5/14-5/15	0.919	0.053
5/16-5/17	0.949	0.050
5/18-5/19	0.978	0.048
5/20-5/21	0.968	0.049
5/22-5/23	0.880	0.052
5/24-5/25	0.970	0.052
5/26-5/27	0.936	0.057
5/28-5/29	0.795	0.074
Pooled	0.936	0.029
N-Wt Mean	0.938	0.028

Appendix H

Tag-Life-Corrected Survival Rates for Steelhead at John Day Dam

Table H.1. Detection histories for steelhead smolts detected and regrouped to form virtual releases at John Day Dam in spring for estimating dam survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with ≤ 5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/03	38	0	0	0	17	0	3	4	62
5/04-5/05	89	0	4	0	45	0	5	10	153
5/06-5/07	77	0	13	0	47	0	16	5	158
5/08-5/09	144	2	39	0	43	2	22	5	257
5/10-5/11	72	0	25	0	44	0	21	6	168
5/12-5/13	85	0	11	0	54	0	26	15	191
5/14-5/15	49	3	19	0	42	1	30	13	157
5/16-5/17	35	0	27	0	27	0	44	9	142
5/18-5/19	29	0	41	0	37	0	86	11	204
5/20-5/21	19	0	26	0	39	0	65	6	155
5/22-5/23	16	0	23	0	51	1	77	8	176
5/24-5/25	23	0	34	0	41	0	64	5	167
5/26-5/27	28	0	32	0	37	0	80	9	186
5/28-5/29	18	0	24	0	33	0	77	4	156
Pooled	722	5	318	0	557	4	616	110	2332

Table H.2. Tag-life-corrected, single-release estimates of dam survival (S) and detection probabilities for steelhead smolts in virtual releases at John Day Dam based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/03	0.951	0.062	1.000	0.000	1.000	0.062	1.000	0.000	0.932	0.065
5/04-5/05	0.957	0.040	1.000	0.000	1.000	0.040	1.000	0.000	0.887	0.052
5/06-5/07	0.979	0.030	0.968	0.028	1.000	0.030	1.000	0.028	0.902	0.049
5/08-5/09	0.994	0.015	0.981	0.022	0.976	0.015	1.000	0.022	0.921	0.034
5/10-5/11	0.967	0.028	0.970	0.027	1.000	0.028	1.000	0.027	0.898	0.047
5/12-5/13	0.922	0.038	0.921	0.040	1.000	0.038	1.000	0.040	0.914	0.043
5/14-5/15	0.926	0.042	0.943	0.038	0.964	0.042	1.000	0.038	0.884	0.054
5/16-5/17	0.938	0.040	0.947	0.038	1.000	0.040	1.000	0.038	0.856	0.061
5/18-5/19	0.951	0.030	0.943	0.033	0.995	0.030	1.000	0.033	0.814	0.056
5/20-5/21	0.961	0.030	0.947	0.036	1.000	0.030	1.000	0.036	0.759	0.071
5/22-5/23	0.967	0.027	0.952	0.032	0.982	0.027	1.000	0.032	0.828	0.058
5/24-5/25	0.970	0.026	0.963	0.029	1.000	0.026	1.000	0.029	0.814	0.061
5/26-5/27	0.952	0.031	0.956	0.031	1.000	0.031	0.993	0.031	0.816	0.059
5/28-5/29	0.975	0.025	0.981	0.035	1.000	0.025	0.912	0.035	0.765	0.071
Pooled	0.959	0.010	0.960	0.009	0.993	0.010	0.994	0.009	0.856	0.015
N-Wt Mean	0.959	0.011	0.960	0.011						

Table H.3. Detection histories for steelhead smolts released in the upper John Day Dam tailwater as reference releases for estimating dam passage survival and TSW passage survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with ≤ 5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/03	60	0	0	0	6	0	4	2	72
5/04-5/05	54	0	0	0	4	0	1	0	59
5/06-5/07	48	0	0	0	9	0	6	0	63
5/08-5/09	50	3	0	0	8	0	5	1	67
5/10-5/11	68	0	0	0	8	0	8	2	86
5/12-5/13	46	0	0	0	6	0	1	4	57
5/14-5/15	54	1	1	0	5	0	7	2	70
5/16-5/17	61	0	0	0	14	0	4	6	85
5/18-5/19	51	0	0	0	19	0	5	6	81
5/20-5/21	43	0	0	0	12	0	2	0	57
5/22-5/23	49	3	1	0	18	0	2	1	74
5/24-5/25	52	0	0	0	12	0	2	3	69
5/26-5/27	60	0	0	0	13	0	5	0	78
5/28-5/29	41	0	3	0	12	0	4	1	61
Pooled	737	7	5	0	146	0	56	28	979

Table H.4. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for steelhead smolts in reference releases for dam passage survival and TSW passage survival. Releases were in the upper John Day Dam tailwater. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/03	0.974	0.038	0.960	0.061	1.000	0.038	1.000	0.061	0.913	0.070
5/04-5/05	1.000	0.011	0.983	0.033	1.000	0.011	1.000	0.033	0.932	0.065
5/06-5/07	1.000	0.011	0.905	0.073	1.000	0.011	1.000	0.073	0.842	0.095
5/08-5/09	0.989	0.030	0.921	0.067	0.951	0.030	1.000	0.067	0.869	0.085
5/10-5/11	0.977	0.032	0.905	0.063	1.000	0.032	1.000	0.063	0.895	0.069
5/12-5/13	0.930	0.066	0.981	0.037	1.000	0.066	1.000	0.037	0.885	0.087
5/14-5/15	0.973	0.039	0.897	0.074	0.984	0.039	0.982	0.074	0.917	0.070
5/16-5/17	0.929	0.054	0.949	0.048	1.000	0.054	1.000	0.048	0.814	0.088
5/18-5/19	0.926	0.057	0.933	0.056	1.000	0.057	1.000	0.056	0.729	0.104
5/20-5/21	1.000	0.012	0.965	0.048	1.000	0.012	1.000	0.048	0.782	0.109
5/22-5/23	0.988	0.026	0.976	0.040	0.958	0.026	0.981	0.040	0.743	0.102
5/24-5/25	0.957	0.048	0.970	0.041	1.000	0.048	1.000	0.041	0.814	0.096
5/26-5/27	1.000	0.000	0.936	0.054	1.000	0.000	1.000	0.054	0.822	0.088
5/28-5/29	1.000	0.023	0.946	0.067	1.000	0.023	0.932	0.067	0.766	0.112
Pooled	0.973	0.010	0.943	0.015	0.992	0.010	0.993	0.015	0.836	0.024
N-Wt Mean	0.973	0.015	0.943	0.015						

Table H.5. Tag-life-corrected, paired-release estimates of dam survival (S) for steelhead smolts in virtual releases from the John Day Dam face to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/03	0.977	0.074
5/04-5/05	0.957	0.042
5/06-5/07	0.979	0.032
5/08-5/09	1.005	0.034
5/10-5/11	0.990	0.043
5/12-5/13	0.991	0.082
5/14-5/15	0.951	0.058
5/16-5/17	1.009	0.073
5/18-5/19	1.028	0.071
5/20-5/21	0.961	0.032
5/22-5/23	0.979	0.038
5/24-5/25	1.014	0.058
5/26-5/27	0.952	0.031
5/28-5/29	0.975	0.033
Pooled	0.986	0.015
N-Wt Mean	0.986	0.019

Table H.6. Detection histories for steelhead smolts detected and regrouped to form virtual releases at non-TSW spill bays in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/05	46	0	1	0	19	0	2	5	73
5/06-5/09	30	0	8	0	18	1	6	2	65
5/10-5/13	30	0	8	0	24	0	13	3	78
5/14-5/17	11	0	9	0	14	0	9	5	48
5/18-5/21	12	0	19	0	25	0	46	7	109
5/22-5/25	15	0	18	0	27	0	38	5	103
5/26-5/29	11	0	17	0	19	0	55	2	104
Pooled	155	0	80	0	146	1	169	29	580

Table H.7. Tag-life-corrected, single-release estimates of non-TSW spill bay passage survival (S) and detection probabilities for steelhead smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/05	0.951	0.059	1.000	0.011	1.000	0.059	1.000	0.011	0.927	0.062
5/06-5/09	0.991	0.031	0.955	0.054	0.967	0.031	1.000	0.054	0.969	0.045
5/10-5/13	0.964	0.043	0.934	0.056	1.000	0.043	1.000	0.056	0.928	0.060
5/14-5/17	0.917	0.078	0.977	0.045	0.977	0.078	1.000	0.045	0.907	0.087
5/18-5/21	0.936	0.046	0.922	0.052	1.000	0.046	1.000	0.052	0.798	0.081
5/22-5/25	0.962	0.037	0.959	0.039	0.990	0.037	1.000	0.039	0.811	0.079
5/26-5/29	0.981	0.026	0.966	0.038	1.000	0.026	0.954	0.038	0.884	0.065
Pooled	0.959	0.018	0.957	0.018	0.992	0.018	0.991	0.018	0.879	0.028
N-Wt Mean	0.959	0.017	0.956	0.019						

Table H.8. Detection histories for steelhead smolts released in the upper John Day Dam tailwater as reference releases for fish passing non-TSW spill bays in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/05	85	0	7	0	25	0	12	2	131
5/06-5/09	55	2	24	0	30	1	17	1	130
5/10-5/13	69	0	8	0	38	0	22	6	143
5/14-5/17	35	0	25	1	33	0	53	8	155
5/18-5/21	18	0	25	0	32	0	57	6	138
5/22-5/25	29	0	26	1	32	1	49	5	143
5/26-5/29	14	0	30	0	30	0	64	1	139
Pooled	305	2	145	2	220	2	274	29	979

Table H.9. Tag-life-corrected, paired-release estimates of survival (S) for steelhead smolts in reference releases in the upper John Day Dam tailwater for fish passing non-TSW bays in spring. The N-Wt mean and confidence interval (weighted by numbers of fish in releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/05	0.986	0.021	0.971	0.038	1.000	0.021	1.000	0.038	0.922	0.048
5/06-5/09	0.995	0.015	0.913	0.049	0.975	0.015	1.000	0.049	0.856	0.063
5/10-5/13	0.958	0.033	0.935	0.042	1.000	0.033	1.000	0.042	0.891	0.054
5/14-5/17	0.949	0.035	0.926	0.043	0.993	0.035	0.992	0.043	0.860	0.059
5/18-5/21	0.957	0.034	0.947	0.038	1.000	0.034	1.000	0.038	0.752	0.076
5/22-5/25	0.973	0.027	0.973	0.029	0.978	0.027	0.991	0.029	0.777	0.071
5/26-5/29	1.000	0.014	0.939	0.042	1.000	0.014	0.971	0.042	0.798	0.069
Pooled	0.973	0.010	0.943	0.015	0.992	0.010	0.993	0.015	0.836	0.024
N-Wt Mean	0.973	0.015	0.943	0.016						

Table H.10. Tag-life-corrected, paired-release estimates of dam survival (S) for steelhead smolts in virtual releases from non-TSW spill bays to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/05	0.965	0.063
5/06-5/09	0.996	0.035
5/10-5/13	1.006	0.057
5/14-5/17	0.967	0.090
5/18-5/21	0.979	0.059
5/22-5/25	0.988	0.047
5/26-5/29	0.981	0.030
Pooled	0.985	0.021
N-Wt Mean	0.985	0.023

Table H.11. Detection histories for steelhead smolts detected and regrouped to form virtual releases at TSW spill bays in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/03	11	0	0	0	5	0	2	2	20
5/04-5/05	45	0	2	0	24	0	3	2	76
5/06-5/07	43	0	8	0	32	0	11	1	95
5/08-5/09	85	1	24	0	24	1	11	1	147
5/10-5/11	48	0	12	0	26	0	9	4	99
5/12-5/13	53	0	7	0	25	0	14	11	110
5/14-5/15	31	2	8	0	23	1	16	5	86
5/16-5/17	25	0	16	0	17	0	30	5	93
5/18-5/19	17	0	18	0	10	0	32	4	81
5/20-5/21	10	0	8	0	21	0	25	1	65
5/22-5/23	3	0	7	0	20	0	29	3	62
5/24-5/25	12	0	14	0	13	0	27	3	69
5/26-5/27	16	0	18	0	22	0	38	5	99
5/28-5/29	7	0	11	0	9	0	28	0	55
Pooled	406	3	153	0	271	2	275	47	1157

Table H.12. Tag-life-corrected, single-release estimates of TSW survival (S) and detection probabilities for steelhead smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/03	0.914	0.133	1.000	0.021	1.000	0.133	1.000	0.021	0.944	0.106
5/04-5/05	1.000	0.005	0.988	0.026	1.000	0.005	1.000	0.026	0.836	0.085
5/06-5/07	1.000	0.002	0.980	0.029	1.000	0.002	1.000	0.029	0.895	0.064
5/08-5/09	0.998	0.014	0.998	0.015	0.987	0.014	1.000	0.015	0.905	0.047
5/10-5/11	0.961	0.039	0.979	0.029	1.000	0.039	1.000	0.029	0.893	0.063
5/12-5/13	0.900	0.056	0.909	0.057	1.000	0.056	1.000	0.057	0.923	0.055
5/14-5/15	0.943	0.050	0.962	0.043	0.962	0.050	1.000	0.043	0.898	0.067
5/16-5/17	0.948	0.046	0.943	0.048	1.000	0.046	1.000	0.048	0.878	0.070
5/18-5/19	0.964	0.041	0.948	0.050	0.987	0.041	1.000	0.050	0.824	0.087
5/20-5/21	0.985	0.030	0.954	0.052	1.000	0.030	1.000	0.052	0.836	0.093
5/22-5/23	0.968	0.044	0.967	0.046	0.983	0.044	1.000	0.046	0.810	0.101
5/24-5/25	0.957	0.048	0.970	0.041	1.000	0.048	1.000	0.041	0.891	0.076
5/26-5/27	0.950	0.043	0.950	0.046	1.000	0.043	0.986	0.046	0.796	0.084
5/28-5/29	1.000	0.012	0.962	0.065	1.000	0.012	0.946	0.065	0.700	0.127
Pooled	0.965	0.013	0.964	0.011	0.994	0.013	0.997	0.011	0.863	0.021
N-Wt Mean	0.965	0.017	0.963	0.013						

Table H.13. Tag-life-corrected, paired-release estimates of TSW spill bay (15 and 16) passage survival (S) for steelhead smolts

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/03	0.938	0.142
5/04-5/05	1.000	0.013
5/06-5/07	1.000	0.011
5/08-5/09	1.009	0.033
5/10-5/11	0.984	0.051
5/12-5/13	0.968	0.092
5/14-5/15	0.969	0.064
5/16-5/17	1.020	0.078
5/18-5/19	1.041	0.078
5/20-5/21	0.985	0.032
5/22-5/23	0.980	0.052
5/24-5/25	1.000	0.071
5/26-5/27	0.950	0.043
5/28-5/29	1.000	0.025
Pooled	0.992	0.017
N-Wt Mean	0.992	0.023

Table H.14. Detection histories for steelhead smolts detected and regrouped to form virtual releases for John Day Dam turbines in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P = 0.041).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/15	7	0	3	0	5	0	3	8	26
5/16-5/29	2	0	8	0	6	0	14	10	40
Pooled	9	0	11	0	11	0	17	18	66

Table H.15. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for steelhead smolts in virtual releases at John Day Dam turbines based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/15	0.696	0.178	0.950	0.107	1.000	0.178	1.000	0.107	0.824	0.181
5/16-5/29	0.750	0.134	0.933	0.089	1.000	0.134	1.000	0.089	0.571	0.183
Pooled	0.729	0.108	0.940	0.069	1.000	0.108	1.000	0.069	0.668	0.138
N-Wt Mean	0.729	0.052	0.940	0.016						

Table H.16. Detection histories for steelhead smolts released in the upper John Day Dam tailwater as reference releases for turbine survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/15	380	4	1	0	46	0	32	11	474
5/16-5/29	357	3	4	0	100	0	24	17	505
Pooled	737	7	5	0	146	0	56	28	979

Table H.17. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for steelhead smolts in turbine reference releases in the upper John Day Dam tailwater based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/15	0.978	0.014	0.933	0.024	0.991	0.014	0.997	0.024	0.8939	0.029
5/16-5/29	0.969	0.016	0.953	0.019	0.994	0.016	0.989	0.019	0.7819	0.038
Pooled	0.973	0.01	0.943	0.015	0.992	0.01	0.993	0.015	0.836	0.024
N-Wt Mean	0.973	0.008	0.943	0.019						

Table H.18. Tag-life-corrected, paired-release estimates of turbine-passage survival (S) for steelhead smolts in virtual releases into John Day Dam turbines to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/15	0.712	0.183
5/16-5/29	0.774	0.139
Pooled	0.749	0.111
N-Wt Mean	0.749	0.062

Table H.19. Detection histories for steelhead smolts detected and regrouped to form virtual releases for the John Day Dam JBS in spring. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/04	15	0	0	0	7	0	1	1	24
5/05-5/06	13	0	2	0	6	0	3	2	26
5/07-5/08	28	0	4	0	10	0	0	1	43
5/09-5/10	39	1	9	0	9	0	9	2	69
5/11-5/12	7	0	2	0	12	0	4	0	25
5/13-5/14	10	0	3	0	8	0	5	1	27
5/15-5/16	12	1	10	0	8	0	10	3	44
5/17-5/18	3	0	3	0	6	0	17	1	30
5/19-5/20	2	0	12	0	14	0	23	1	52
5/21-5/22	5	0	11	0	15	0	25	0	56
5/23-5/24	6	0	6	0	13	1	19	1	46
5/25-5/26	8	0	5	0	3	0	10	0	26
5/27-5/29	4	0	7	0	18	0	29	3	61
Pooled	152	2	74	0	129	1	155	16	529

Table H.20. Tag-life-corrected, single-release estimates of JBS passage survival (S) and detection probabilities for steelhead smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/04	0.978	0.082	1.000	0.018	1.000	0.082	1.000	0.018	0.958	0.083
5/05-5/06	0.940	0.108	0.917	0.111	1.000	0.108	1.000	0.111	0.911	0.120
5/07-5/08	0.982	0.045	1.000	0.000	1.000	0.045	1.000	0.000	0.959	0.065
5/09-5/10	0.993	0.030	0.942	0.058	0.969	0.030	1.000	0.058	0.906	0.071
5/11-5/12	1.000	0.017	0.963	0.077	1.000	0.017	1.000	0.077	0.833	0.149
5/13-5/14	0.963	0.071	0.962	0.074	1.000	0.071	1.000	0.074	0.920	0.106
5/15-5/16	0.935	0.075	0.901	0.093	0.973	0.075	1.000	0.093	0.785	0.133
5/17-5/18	0.968	0.064	0.897	0.111	1.000	0.064	1.000	0.111	0.846	0.139
5/19-5/20	0.981	0.037	0.980	0.038	1.000	0.037	1.000	0.038	0.760	0.118
5/21-5/22	1.000	0.000	0.929	0.067	1.000	0.000	1.000	0.067	0.770	0.115
5/23-5/24	0.979	0.042	1.000	0.000	0.978	0.042	1.000	0.000	0.778	0.122
5/25-5/26	1.000	0.017	0.962	0.074	1.000	0.017	1.000	0.074	0.802	0.157
5/27-5/29	0.952	0.054	0.989	0.055	1.000	0.054	0.907	0.055	0.751	0.118
Pooled	0.975	0.015	0.958	0.018	0.992	0.015	0.990	0.018	0.835	0.033
N-Wt Mean	0.975	0.012	0.958	0.020						

Table H.21. Detection histories for steelhead smolts released in the upper John Day Dam tailwater as reference releases for JBS passage survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P = 0.0090).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/04	81	0	0	0	9	0	4	2	96
5/05-5/06	52	0	0	0	3	0	1	0	56
5/07-5/08	55	3	0	0	10	0	9	1	78
5/09-5/10	61	0	0	0	10	0	7	0	78
5/11-5/12	52	0	0	0	6	0	3	4	65
5/13-5/14	54	0	0	0	6	0	3	3	66
5/15-5/16	65	1	1	0	8	0	6	4	85
5/17-5/18	42	0	0	0	14	0	4	4	64
5/19-5/20	51	0	0	0	18	0	5	5	79
5/21-5/22	48	0	1	0	16	0	3	0	68
5/23-5/24	48	3	0	0	19	0	2	3	75
5/25-5/26	58	0	0	0	8	0	3	1	70
5/27-5/29	70	0	3	0	19	0	6	1	99
Pooled	737	7	5	0	146	0	56	28	979

Table H.22. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for steelhead smolts in JBS reference releases in the upper John Day Dam tailwater based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/04	0.981	0.029	0.970	0.046	1.000	0.029	1.000	0.046	0.903	0.062
5/05-5/06	1.000	0.012	0.982	0.035	1.000	0.012	1.000	0.035	0.946	0.060
5/07-5/08	0.993	0.026	0.878	0.074	0.956	0.026	1.000	0.074	0.853	0.084
5/09-5/10	1.000	0.000	0.911	0.064	1.000	0.000	1.000	0.064	0.859	0.081
5/11-5/12	0.939	0.058	0.951	0.054	1.000	0.058	1.000	0.054	0.897	0.078
5/13-5/14	0.955	0.050	0.952	0.053	1.000	0.050	1.000	0.053	0.900	0.076
5/15-5/16	0.954	0.045	0.927	0.058	0.987	0.045	0.985	0.058	0.893	0.071
5/17-5/18	0.938	0.059	0.933	0.063	1.000	0.059	1.000	0.063	0.750	0.113
5/19-5/20	0.937	0.054	0.932	0.057	1.000	0.054	1.000	0.057	0.739	0.104
5/21-5/22	1.000	0.011	0.961	0.050	1.000	0.011	0.980	0.050	0.750	0.106
5/23-5/24	0.962	0.044	0.971	0.040	0.957	0.044	1.000	0.040	0.729	0.104
5/25-5/26	0.986	0.028	0.957	0.048	1.000	0.028	1.000	0.048	0.879	0.079
5/27-5/29	1.000	0.017	0.946	0.049	1.000	0.017	0.959	0.049	0.782	0.085
Pooled	0.973	0.010	0.943	0.015	0.992	0.010	0.993	0.015	0.836	0.024
N-Wt Mean	0.973	0.014	0.943	0.015						

Table H.23. Tag-life-corrected, paired-release estimates of JBS-passage survival (S) for steelhead smolts in virtual releases from the JBS to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/04	0.997	0.088
5/05-5/06	0.940	0.109
5/07-5/08	0.989	0.052
5/09-5/10	0.993	0.030
5/11-5/12	1.066	0.069
5/13-5/14	1.009	0.091
5/15-5/16	0.980	0.091
5/17-5/18	1.033	0.095
5/19-5/20	1.047	0.072
5/21-5/22	1.000	0.011
5/23-5/24	1.018	0.064
5/25-5/26	1.015	0.033
5/27-5/29	0.952	0.057
Pooled	1.002	0.019
N-Wt Mean	1.002	0.019

Appendix I

Tag-Life-Corrected Survival Rates for Steelhead at The Dalles Dam

Table I.1. Detection histories for steelhead smolts detected and regrouped to form virtual releases at The Dalles Dam in spring for estimating dam survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (BON_FB, BTW1, and BTW2, respectively). A chi-square test for homogeneity, excluding pooled estimates and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
05/03/2008	48	1	1	0	10	0	0	4	64
05/04/2008	52	6	1	0	15	2	1	4	81
05/05/2008	71	10	3	0	50	1	2	7	144
05/06/2008	45	0	7	0	26	0	1	3	82
05/07/2008	53	5	4	1	27	5	2	10	107
05/08/2008	40	4	33	2	24	3	5	15	126
05/09/2008	81	6	21	3	25	2	4	5	147
05/10/2008	96	5	11	2	37	1	5	11	168
05/11/2008	49	3	14	0	26	1	4	15	112
05/12/2008	52	4	18	0	34	3	6	10	127
05/13/2008	64	5	3	0	35	2	3	15	127
05/14/2008	32	1	10	1	25	0	9	11	89
05/15/2008	26	2	10	0	33	1	6	11	89
05/16/2008	40	3	16	5	28	2	24	12	130
05/17/2008	20	0	21	4	16	2	27	12	102
05/18/2008	19	3	20	3	16	1	29	22	113
05/19/2008	17	1	19	7	19	5	45	18	131
05/20/2008	14	5	20	5	28	8	33	21	134
05/21/2008	7	5	15	7	30	3	31	15	113
05/22/2008	7	4	10	7	32	4	37	17	118
05/23/2008	12	4	13	3	24	5	31	15	107
05/24/2008	20	2	14	5	33	7	39	12	132
05/25/2008	15	5	22	0	20	2	20	17	101
05/26/2008	16	1	25	1	22	3	37	20	125
05/27/2008	15	4	27	2	20	8	39	13	128
05/28/2008	11	0	19	7	13	6	47	15	118
05/29-6/01	14	3	15	7	24	8	51	22	144
Pooled	936	92	392	72	692	85	538	352	3159

Table I.2. Tag-life-corrected, single-release estimates of dam survival (S) and detection probabilities for steelhead smolts in virtual releases at The Dalles Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/3/2008	1.000	0.011	0.957	0.063	1.000	0.011	0.983	0.063	0.984	0.033
5/4/2008	0.989	0.051	1.000	0.008	1.000	0.051	0.885	0.008	0.962	0.043
5/5/2008	1.000	0.012	0.968	0.041	1.000	0.012	0.917	0.041	0.961	0.034
5/6/2008	1.000	0.000	0.964	0.041	1.000	0.000	1.000	0.041	0.898	0.066
5/7/2008	0.949	0.045	0.959	0.043	1.000	0.045	0.889	0.043	0.930	0.054
5/8/2008	0.934	0.046	0.975	0.059	1.000	0.046	0.901	0.059	0.628	0.094
5/9/2008	0.988	0.026	0.978	0.033	1.000	0.026	0.930	0.033	0.809	0.067
5/10/2008	0.975	0.027	0.955	0.034	0.994	0.027	0.957	0.034	0.893	0.050
5/11/2008	0.931	0.048	0.942	0.050	1.000	0.048	0.949	0.050	0.807	0.080
5/12/2008	0.946	0.040	0.991	0.032	1.000	0.040	0.925	0.032	0.782	0.077
5/13/2008	0.930	0.045	0.953	0.040	1.000	0.045	0.934	0.040	0.943	0.044
5/14/2008	0.944	0.048	0.921	0.060	1.000	0.048	0.983	0.060	0.750	0.097
5/15/2008	0.923	0.056	0.961	0.049	0.987	0.056	0.952	0.049	0.786	0.093
5/16/2008	0.947	0.039	0.942	0.054	1.000	0.039	0.932	0.054	0.631	0.091
5/17/2008	0.952	0.042	0.915	0.076	1.000	0.042	0.947	0.076	0.429	0.106
5/18/2008	0.921	0.050	0.900	0.093	1.000	0.050	0.897	0.093	0.416	0.105
5/19/2008	0.939	0.041	0.949	0.102	1.000	0.041	0.857	0.102	0.360	0.094
5/20/2008	0.963	0.032	0.965	0.111	1.000	0.032	0.764	0.111	0.442	0.100
5/21/2008	0.944	0.045	0.954	0.105	1.000	0.045	0.822	0.105	0.442	0.106
5/22/2008	0.968	0.033	0.908	0.102	0.989	0.033	0.830	0.102	0.454	0.105
5/23/2008	0.944	0.044	0.990	0.109	1.000	0.044	0.800	0.109	0.450	0.109
5/24/2008	0.985	0.021	0.954	0.078	1.000	0.021	0.855	0.078	0.500	0.095
5/25/2008	0.970	0.033	0.944	0.105	1.000	0.033	0.833	0.105	0.455	0.111
5/26/2008	0.936	0.043	0.945	0.084	1.000	0.043	0.905	0.084	0.380	0.095
5/27/2008	0.954	0.037	1.000	0.000	0.991	0.037	0.828	0.000	0.385	0.086
5/28/2008	0.959	0.041	0.996	0.154	0.938	0.041	0.800	0.154	0.267	0.091
05/29-6/01	0.988	0.033	0.947	0.121	0.922	0.033	0.776	0.121	0.366	0.093
Pooled	0.959	0.010	0.941	0.012	0.993	0.010	0.902	0.012	0.637	0.019
N-Wt Mean	0.959	0.009	0.957	0.010						

Appendix J

Tag-Life-Corrected Survival Rates at John Day Dam for John Day Dam Subyearling Chinook

Table J.1. Detection histories for subyearling Chinook salmon smolts detected and regrouped to form virtual releases at John Day Dam in summer for estimating dam survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with ≤ 5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/16-6/17	64	1	29	0	30	0	22	22	168
6/18-6/19	73	2	45	1	14	0	24	19	178
6/20-6/21	63	0	22	0	14	0	20	19	138
6/22-6/23	73	0	42	0	21	0	28	43	207
6/24-6/25	89	0	30	0	21	0	22	19	181
6/26-6/27	69	2	19	0	30	0	22	27	169
6/28-6/29	52	0	17	0	26	0	23	11	129
6/30-7/01	67	0	22	0	23	0	30	32	174
7/02-7/03	92	0	3	0	23	0	15	27	160
7/04-7/05	98	0	3	0	18	0	21	28	168
7/06-7/07	108	2	3	0	18	0	29	40	200
7/08-7/09	73	0	3	0	4	0	22	22	124
7/10-7/11	121	0	6	0	13	0	36	22	198
7/12-7/13	76	0	0	0	17	0	35	38	166
Pooled	1118	7	244	1	272	0	349	369	2360

Table J.2. Tag-life-corrected, single-release estimates of dam survival (S) and detection probabilities for subyearling Chinook salmon smolts in virtual releases at John Day Dam based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in each virtual release) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/16-6/17	0.870	0.051	0.921	0.045	0.993	0.051	0.974	0.045	0.840	0.063
6/18-6/19	0.894	0.045	0.955	0.033	0.980	0.045	1.000	0.033	0.857	0.056
6/20-6/21	0.863	0.058	0.917	0.050	1.000	0.058	1.000	0.050	0.881	0.061
6/22-6/23	0.793	0.055	0.910	0.044	1.000	0.055	1.000	0.044	0.881	0.053
6/24-6/25	0.895	0.045	0.965	0.029	1.000	0.045	0.992	0.029	0.841	0.058
6/26-6/27	0.843	0.055	0.928	0.047	0.985	0.055	1.000	0.047	0.893	0.053
6/28-6/29	0.915	0.048	0.950	0.040	1.000	0.048	1.000	0.040	0.841	0.068
6/30-7/01	0.817	0.058	0.928	0.045	1.000	0.058	1.000	0.045	0.880	0.056
7/02-7/03	0.832	0.058	0.940	0.040	1.000	0.058	1.000	0.040	0.904	0.052
7/04-7/05	0.834	0.056	0.907	0.048	1.000	0.056	1.000	0.048	0.882	0.056
7/06-7/07	0.801	0.055	0.925	0.041	0.987	0.055	0.992	0.041	0.858	0.057
7/08-7/09	0.823	0.067	0.892	0.060	1.000	0.067	1.000	0.060	0.759	0.088
7/10-7/11	0.889	0.044	0.904	0.044	1.000	0.044	1.000	0.044	0.875	0.052
7/12-7/13	0.771	0.064	0.838	0.064	1.000	0.064	0.989	0.064	0.868	0.064
Pooled	0.844	0.015	0.921	0.012	0.996	0.015	0.996	0.012	0.863	0.016
N-Wt Mean	0.844	0.023	0.920	0.016						

Table J.3. Detection histories for subyearling Chinook salmon smolts released in the upper John Day Dam tailwater as reference releases for estimating dam passage survival and non-TSW passage survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with ≤ 5 pooled detections, and totals, was not significant (P = 0.480).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/16-6/17	50	0	2	0	11	0	6	2	71
6/18-6/19	43	2	0	0	7	0	8	0	60
6/20-6/21	57	0	0	0	7	0	5	1	70
6/22-6/23	67	0	0	0	11	0	5	1	84
6/24-6/25	43	0	1	0	10	0	5	1	60
6/26-6/27	56	1	0	0	11	0	3	0	71
6/28-6/29	68	0	0	0	8	0	5	3	84
6/30-7/01	54	0	0	0	12	0	4	1	71
7/02-7/03	60	0	0	0	4	0	5	2	71
7/04-7/05	53	0	0	0	6	0	5	1	65
7/06-7/07	44	1	0	0	5	0	4	1	55
7/08-7/09	62	0	0	0	8	0	8	5	83
7/10-7/11	48	0	0	0	3	0	9	0	60
7/12-7/13	64	0	0	0	4	0	8	1	77
Pooled	769	4	3	0	107	0	80	19	982

Table J.4. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for subyearling Chinook salmon smolts in reference releases for dam-passage survival and non-TSW-passage survival. Releases were in the upper John Day Dam tailwater. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/16-6/17	0.972	0.038	0.919	0.068	1.000	0.038	0.962	0.068	0.820	0.096
6/18-6/19	1.000	0.011	0.867	0.086	0.967	0.011	1.000	0.086	0.865	0.093
6/20-6/21	0.986	0.028	0.928	0.061	1.000	0.028	1.000	0.061	0.892	0.077
6/22-6/23	0.988	0.023	0.940	0.051	1.000	0.023	1.000	0.051	0.860	0.077
6/24-6/25	0.983	0.032	0.920	0.072	1.000	0.032	0.977	0.072	0.815	0.106
6/26-6/27	1.000	0.010	0.961	0.047	0.986	0.010	1.000	0.047	0.839	0.088
6/28-6/29	0.964	0.040	0.938	0.052	1.000	0.040	1.000	0.052	0.896	0.069
6/30-7/01	0.986	0.027	0.943	0.054	1.000	0.027	1.000	0.054	0.818	0.093
7/02-7/03	0.972	0.038	0.928	0.061	1.000	0.038	1.000	0.061	0.938	0.059
7/04-7/05	0.985	0.030	0.922	0.066	1.000	0.030	1.000	0.066	0.898	0.077
7/06-7/07	0.983	0.035	0.925	0.071	0.980	0.035	1.000	0.071	0.900	0.083
7/08-7/09	0.940	0.051	0.897	0.067	1.000	0.051	1.000	0.067	0.886	0.074
7/10-7/11	1.000	0.011	0.850	0.090	1.000	0.011	1.000	0.090	0.941	0.064
7/12-7/13	0.988	0.025	0.895	0.069	1.000	0.025	1.000	0.069	0.941	0.056
Pooled	0.981	0.009	0.917	0.017	0.996	0.009	0.996	0.017	0.879	0.022

Table J.5. Tag-life-corrected, paired-release estimates of dam survival (S) for subyearling Chinook salmon smolts in virtual releases from the John Day Dam face to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
6/16-6/17	0.895	0.063
6/18-6/19	0.894	0.047
6/20-6/21	0.875	0.063
6/22-6/23	0.802	0.059
6/24-6/25	0.911	0.054
6/26-6/27	0.843	0.056
6/28-6/29	0.949	0.063
6/30-7/01	0.829	0.063
7/02-7/03	0.856	0.069
7/04-7/05	0.847	0.063
7/06-7/07	0.814	0.064
7/08-7/09	0.875	0.086
7/10-7/11	0.889	0.045
7/12-7/13	0.781	0.068
Pooled	0.861	0.017

Table J.6. Detection histories for subyearling Chinook salmon smolts detected and regrouped to form virtual releases at non-TSW spill bays in summer. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/16-6/17	29	1	24	0	15	0	13	13	95
6/18-6/19	38	1	26	1	11	0	16	7	100
6/20-6/21	24	0	6	0	6	0	3	7	46
6/22-6/23	34	0	19	0	9	0	14	33	109
6/24-6/25	46	0	17	0	11	0	13	14	101
6/26-6/27	43	1	11	0	18	0	9	17	99
6/28-6/29	26	0	10	0	13	0	13	5	67
6/30-7/01	29	0	9	0	9	0	13	19	79
7/02-7/03	40	0	1	0	14	0	8	10	73
7/04-7/05	49	0	3	0	7	0	11	16	86
7/06-7/07	37	1	0	0	8	0	8	20	74
7/08-7/09	27	0	1	0	0	0	11	14	53
7/10-7/11	51	0	2	0	8	0	19	10	90
7/12-7/13	27	0	0	0	8	0	15	11	61
Pooled	500	4	129	1	137	0	166	196	1133

Table J.7. Tag-life-corrected, single-release estimates of non-TSW spill bay passage survival (S) and detection probabilities for subyearling Chinook salmon smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/16-6/17	0.864	0.069	0.904	0.065	0.987	0.069	0.983	0.065	0.808	0.090
6/18-6/19	0.931	0.050	0.956	0.042	0.978	0.050	1.000	0.042	0.844	0.076
6/20-6/21	0.848	0.104	0.949	0.069	1.000	0.104	1.000	0.069	0.893	0.100
6/22-6/23	0.698	0.086	0.897	0.069	1.000	0.086	1.000	0.069	0.899	0.072
6/24-6/25	0.861	0.067	0.967	0.038	1.000	0.067	1.000	0.038	0.882	0.069
6/26-6/27	0.830	0.074	0.970	0.044	0.987	0.074	1.000	0.044	0.887	0.070
6/28-6/29	0.926	0.063	0.937	0.061	1.000	0.063	1.000	0.061	0.864	0.089
6/30-7/01	0.760	0.094	0.937	0.064	1.000	0.094	1.000	0.064	0.913	0.075
7/02-7/03	0.864	0.079	0.905	0.073	1.000	0.079	1.000	0.073	0.930	0.066
7/04-7/05	0.814	0.082	0.900	0.070	1.000	0.082	1.000	0.070	0.857	0.086
7/06-7/07	0.731	0.101	0.943	0.062	0.980	0.101	1.000	0.062	0.923	0.074
7/08-7/09	0.736	0.119	0.898	0.095	1.000	0.119	1.000	0.095	0.743	0.145
7/10-7/11	0.889	0.065	0.864	0.076	1.000	0.065	1.000	0.076	0.841	0.086
7/12-7/13	0.820	0.096	0.840	0.102	1.000	0.096	1.000	0.102	0.857	0.106
Pooled	0.828	0.022	0.921	0.018	0.994	0.022	0.999	0.018	0.869	0.023
N-Wt Mean	0.827	0.039	0.921	0.020						

Table J.8. Tag-life-corrected, paired-release estimates of survival (S) for subyearling Chinook salmon smolts in virtual releases from non-TSW spill bays to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
6/16-6/17	0.889	0.079
6/18-6/19	0.931	0.051
6/20-6/21	0.860	0.108
6/22-6/23	0.706	0.089
6/24-6/25	0.876	0.074
6/26-6/27	0.830	0.075
6/28-6/29	0.960	0.076
6/30-7/01	0.771	0.098
7/02-7/03	0.889	0.089
7/04-7/05	0.827	0.087
7/06-7/07	0.743	0.106
7/08-7/09	0.783	0.133
7/10-7/11	0.889	0.066
7/12-7/13	0.830	0.100
Pooled	0.844	0.024
N-Wt Mean	0.844	0.044

Table J.9. Detection histories for subyearling Chinook salmon smolts detected and regrouped to form virtual releases at TSW spill bays in summer. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/16-6/19	17	0	10	0	8	0	5	4	44
6/20-6/23	26	0	13	0	8	0	9	5	61
6/24-6/27	26	1	11	0	10	0	4	6	58
6/28-7/01	11	0	6	0	6	0	9	3	35
7/02-7/05	44	0	0	0	10	0	9	4	67
7/06-7/09	60	0	5	0	9	0	16	9	99
7/10-7/13	71	0	3	0	11	0	25	13	123
Pooled	255	1	48	0	62	0	77	44	487

Table J.10. Tag-life-corrected, single-release estimates of TSW survival (S) and detection probabilities for subyearling Chinook salmon smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/16-6/19	0.909	0.085	0.925	0.082	1.000	0.085	1.000	0.082	0.893	0.100
6/20-6/23	0.918	0.069	0.965	0.049	1.000	0.069	1.000	0.049	0.871	0.090
6/24-6/27	0.898	0.078	0.966	0.054	0.980	0.078	1.000	0.054	0.840	0.102
6/28-7/01	0.914	0.093	0.911	0.102	1.000	0.093	1.000	0.102	0.932	0.092
7/02-7/05	0.941	0.057	0.953	0.053	1.000	0.057	1.000	0.053	0.900	0.076
7/06-7/09	0.909	0.057	0.891	0.065	1.000	0.057	0.985	0.065	0.849	0.079
7/10-7/13	0.894	0.054	0.865	0.064	1.000	0.054	0.988	0.064	0.905	0.060
Pooled	0.910	0.025	0.916	0.026	0.998	0.025	0.994	0.026	0.882	0.032
N-Wt Mean	0.910	0.012	0.916	0.032						

Table J.11. Detection histories for subyearling Chinook salmon smolts released into the upper John Day Dam tailwater as reference releases for fish passing the John Day Dam TSW, turbines, and JBS in summer. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was not significant (P = 0.1010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/16-6/19	93	2	2	0	18	0	14	2	131
6/20-6/23	124	0	0	0	18	0	10	2	154
6/24-6/27	99	1	1	0	21	0	8	1	131
6/28-7/01	122	0	0	0	20	0	9	4	155
7/02-7/05	113	0	0	0	10	0	10	3	136
7/06-7/09	106	1	0	0	13	0	12	6	138
7/10-7/13	112	0	0	0	7	0	17	1	137
Pooled	769	4	3	0	107	0	80	19	982

Table J.12. Tag-life-corrected, single-release estimates of survival of upper tailwater releases of reference fish for TSW-, turbine-, and JBS-passed subyearling Chinook salmon in summer based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/16-6/19	0.987	0.021	0.893	0.055	0.983	0.021	0.979	0.055	0.841	0.067
6/20-6/23	0.987	0.018	0.934	0.039	1.000	0.018	1.000	0.039	0.874	0.055
6/24-6/27	0.993	0.015	0.942	0.042	0.992	0.015	0.990	0.042	0.829	0.068
6/28-7/01	0.974	0.025	0.941	0.038	1.000	0.025	1.000	0.038	0.860	0.057
7/02-7/05	0.978	0.025	0.925	0.045	1.000	0.025	1.000	0.045	0.919	0.048
7/06-7/09	0.957	0.034	0.908	0.049	0.992	0.034	1.000	0.049	0.892	0.056
7/10-7/13	0.993	0.014	0.875	0.056	1.000	0.014	1.000	0.056	0.941	0.042
Pooled	0.981	0.009	0.917	0.017	0.996	0.009	0.996	0.017	0.879	0.022

Table J.13. Tag-life-corrected, paired-release estimates of TSW spill bay (15 and 16) passage survival (S) for subyearling Chinook salmon smolts

Paired Release	S to Tailrace	1/2 95% CI
6/16-6/19	0.921	0.088
6/20-6/23	0.931	0.072
6/24-6/27	0.904	0.080
6/28-7/01	0.939	0.098
7/02-7/05	0.962	0.063
7/06-7/09	0.950	0.068
7/10-7/13	0.901	0.056
Pooled	0.928	0.027
N-Wt Mean	0.927	0.016

Table J.14. Detection histories for subyearling Chinook salmon smolts detected and regrouped to form virtual releases for John Day Dam turbines in summer. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/16-6/19	21	0	2	0	3	0	9	17	52
6/20-6/23	23	0	13	0	4	0	10	16	66
6/24-6/27	24	0	2	0	6	0	7	9	48
6/28-7/01	22	0	3	0	13	0	8	15	61
7/02-7/05	27	0	2	0	6	0	2	22	59
7/06-7/09	26	1	0	0	4	0	5	16	52
7/10-7/13	28	0	1	0	2	0	7	18	56
Pooled	171	1	23	0	38	0	48	113	394

Table J.15. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for subyearling Chinook salmon smolts in virtual releases at John Day Dam turbines based on three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/16-6/19	0.673	0.128	0.915	0.093	1.000	0.128	1.000	0.093	0.813	0.135
6/20-6/23	0.758	0.103	0.881	0.090	1.000	0.103	1.000	0.090	0.888	0.094
6/24-6/27	0.813	0.111	0.927	0.084	1.000	0.111	1.000	0.084	0.864	0.113
6/28-7/01	0.755	0.108	0.915	0.082	1.000	0.108	1.000	0.082	0.835	0.113
7/02-7/05	0.628	0.123	0.946	0.073	1.000	0.123	1.000	0.073	0.914	0.093
7/06-7/09	0.694	0.126	0.915	0.093	0.970	0.126	1.000	0.093	0.818	0.132
7/10-7/13	0.679	0.122	0.947	0.071	1.000	0.122	1.000	0.071	0.834	0.122
Pooled	0.714	0.045	0.919	0.032	0.996	0.045	1.000	0.032	0.854	0.043
N-Wt Mean	0.714	0.046	0.920	0.018						

Table J.16. Tag-life-corrected, paired-release estimates of turbine-passage survival (S) for subyearling Chinook salmon smolts in virtual releases into John Day Dam turbines to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
6/16-6/19	0.682	0.130
6/20-6/23	0.768	0.106
6/24-6/27	0.819	0.112
6/28-7/01	0.775	0.113
7/02-7/05	0.642	0.127
7/06-7/09	0.725	0.134
7/10-7/13	0.683	0.124
Pooled	0.728	0.046
N-Wt Mean	0.728	0.056

Table J.17. Detection histories for subyearling Chinook salmon smolts detected and regrouped to form virtual releases for the John Day Dam JBS in summer. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (TDA_FB, BON_FB, and BTW1, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant ($P < 0.0010$).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/16-6/19	32	1	12	0	7	0	3	0	55
6/20-6/23	29	0	13	0	8	0	12	1	63
6/24-6/27	19	0	8	0	6	0	11	0	44
6/28-7/01	31	0	11	0	8	0	10	1	61
7/02-7/05	30	0	0	0	4	0	6	3	43
7/06-7/09	31	0	0	0	1	0	11	3	46
7/10-7/13	20	0	0	0	1	0	5	8	34
Pooled	192	1	44	0	35	0	58	16	346

Table J.18. Tag-life-corrected, single-release estimates of JBS passage survival (S) and detection probabilities for subyearling Chinook salmon smolts in virtual releases at John Day Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/16-6/19	1.000	0.000	0.986	0.036	0.982	0.000	0.959	0.036	0.904	0.080
6/20-6/23	0.986	0.031	0.889	0.079	1.000	0.031	1.000	0.079	0.855	0.093
6/24-6/27	1.000	0.013	0.871	0.103	1.000	0.013	0.968	0.103	0.813	0.126
6/28-7/01	0.985	0.032	0.971	0.046	1.000	0.032	1.000	0.046	0.794	0.104
7/02-7/05	0.930	0.076	0.925	0.082	1.000	0.076	1.000	0.082	0.866	0.110
7/06-7/09	0.935	0.071	0.930	0.076	1.000	0.071	1.000	0.076	0.701	0.142
7/10-7/13	0.765	0.143	0.924	0.103	1.000	0.143	1.000	0.103	0.917	0.111
Pooled	0.955	0.022	0.930	0.028	0.997	0.022	0.988	0.028	0.832	0.042
N-Wt Mean	0.954	0.054	0.930	0.032						

Table J.19. Tag-life-corrected, paired-release estimates of JBS-passage survival (S) for subyearling Chinook salmon smolts in virtual releases from the JBS to the upper John Day Dam tailwater

Paired Release	S to Tailrace	1/2 95% CI
6/16-6/19	1.014	0.022
6/20-6/23	0.999	0.036
6/24-6/27	1.007	0.020
6/28-7/01	1.011	0.042
7/02-7/05	0.951	0.081
7/06-7/09	0.977	0.082
7/10-7/13	0.771	0.144
Pooled	0.973	0.024
N-Wt Mean	0.973	0.057

Appendix K

Tag-Life-Corrected Survival Rates at The Dalles Dam for Subyearling Chinook Salmon

Table K.1. Detection histories for subyearling Chinook salmon smolts detected and regrouped to form virtual releases at The Dalles Dam in summer for estimating dam survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (BON_FB, BTW1, and BTW2, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with ≤ 5 pooled detections, and totals, was significant (P < 0.0010).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
06/16-6/17	54	4	24	5	19	6	7	16	135
06/18/2008	43	6	20	7	23	4	10	12	125
06/19/2008	43	4	30	3	12	1	6	13	112
06/20/2008	46	2	21	2	8	0	2	10	91
06/21/2008	50	5	15	1	7	1	3	12	94
06/22/2008	43	3	25	2	13	0	6	13	105
06/23/2008	47	4	27	6	20	4	13	14	135
06/24/2008	48	10	24	2	10	1	7	12	114
06/25/2008	55	11	14	4	18	1	5	9	117
06/26/2008	40	5	12	3	16	2	9	11	98
06/27/2008	56	6	14	2	20	4	6	10	118
06/28/2008	34	5	13	2	19	1	4	14	92
06/29/2008	43	2	15	2	23	1	5	11	102
06/30/2008	37	5	16	3	14	0	9	4	88
07/01/2008	38	5	16	3	20	1	7	15	105
07/02/2008	70	5	9	0	14	2	5	13	118
07/03/2008	58	1	1	0	14	1	2	8	85
07/04/2008	76	3	1	0	18	1	1	11	111
07/05/2008	62	4	2	1	13	3	1	16	102
07/06/2008	60	5	3	0	14	0	0	12	94
07/07/2008	74	4	3	0	15	0	3	13	112
07/08/2008	69	11	3	0	4	1	1	17	106
07/09/2008	39	5	2	0	4	1	1	16	68
07/10/2008	69	5	2	2	12	0	1	21	112
07/11/2008	84	2	6	0	11	0	2	26	131
07/12/2008	72	0	2	0	7	0	1	18	100
07/13/2008	65	1	0	0	14	0	2	19	101
Pooled	1475	123	320	50	382	36	119	366	2871

Table K.2. Tag-life-corrected, single-release estimates of dam survival (S) and detection probabilities for subyearling Chinook salmon smolts in virtual releases at The Dalles Dam based on detections at three downstream arrays. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in each virtual release) is preferred over the pooled estimate when capture histories are not homogeneous.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
06/16-6/17	0.911	0.048	0.961	0.054	1.000	0.048	0.880	0.054	0.702	0.088
06/18/2008	0.957	0.038	0.924	0.067	0.953	0.038	0.868	0.067	0.687	0.093
06/19/2008	0.911	0.053	0.975	0.056	1.000	0.053	0.917	0.056	0.605	0.101
06/20/2008	0.945	0.047	0.930	0.060	1.000	0.047	0.964	0.060	0.702	0.102
06/21/2008	0.904	0.059	0.976	0.051	1.000	0.059	0.905	0.051	0.760	0.097
06/22/2008	0.906	0.056	0.966	0.050	1.000	0.056	0.949	0.050	0.644	0.101
06/23/2008	0.912	0.048	0.976	0.055	1.000	0.048	0.893	0.055	0.627	0.092
06/24/2008	0.940	0.044	0.990	0.063	1.000	0.044	0.841	0.063	0.652	0.099
06/25/2008	0.967	0.033	0.950	0.055	1.000	0.033	0.859	0.055	0.794	0.083
06/26/2008	0.929	0.058	0.965	0.064	0.976	0.058	0.889	0.064	0.728	0.100
06/27/2008	0.964	0.039	0.962	0.049	1.000	0.039	0.884	0.049	0.792	0.081
06/28/2008	0.892	0.064	0.950	0.062	1.000	0.064	0.898	0.062	0.757	0.100
06/29/2008	0.942	0.046	0.938	0.054	1.000	0.046	0.957	0.054	0.768	0.089
06/30/2008	0.979	0.031	0.972	0.058	1.000	0.031	0.911	0.058	0.672	0.106
07/01/2008	0.930	0.052	0.923	0.066	1.000	0.052	0.906	0.066	0.716	0.098
07/02/2008	0.934	0.046	0.965	0.041	1.000	0.046	0.923	0.041	0.858	0.069
07/03/2008	0.954	0.045	0.952	0.047	1.000	0.045	0.973	0.047	0.959	0.044
07/04/2008	0.928	0.048	0.972	0.033	1.000	0.048	0.959	0.033	0.979	0.029
07/05/2008	0.902	0.058	0.927	0.054	1.000	0.058	0.915	0.054	0.962	0.043
07/06/2008	0.916	0.056	0.956	0.045	0.988	0.056	0.937	0.045	0.961	0.043
07/07/2008	0.947	0.042	0.937	0.048	1.000	0.042	0.957	0.048	0.938	0.049
07/08/2008	0.915	0.053	0.925	0.056	1.000	0.053	0.859	0.056	0.948	0.050
07/09/2008	0.897	0.072	0.859	0.090	1.000	0.072	0.878	0.090	0.935	0.071
07/10/2008	0.875	0.061	0.911	0.057	1.000	0.061	0.942	0.057	0.965	0.040
07/11/2008	0.879	0.056	0.915	0.052	1.000	0.056	0.979	0.052	0.922	0.052
07/12/2008	0.900	0.059	0.911	0.059	1.000	0.059	1.000	0.059	0.963	0.041
07/13/2008	0.862	0.067	0.943	0.049	1.000	0.067	0.988	0.049	0.975	0.034
Pooled	0.920	0.010	0.943	0.010	0.996	0.010	0.922	0.010	0.813	0.016
N-Wt Mean	0.922	0.011	0.947	0.010						

Table K.3. Detection histories for subyearling Chinook salmon smolts released in the upper The Dalles Dam tailwater as reference releases for estimating The Dalles Dam passage survival. Headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival-detection arrays (BON_FB, BTW1, and BTW2, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with ≤ 5 pooled detections, and totals, was not significant (P = 0.480).

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
06/16-6/17	82	0	14	0	61	1	16	0	174
06/18/2008	37	3	5	0	31	1	8	2	87
06/19/2008	47	0	8	0	28	0	3	1	87
06/20/2008	47	0	3	0	28	0	7	0	85
06/21/2008	49	0	5	0	28	0	7	0	89
06/22/2008	41	0	3	0	38	0	5	0	87
06/23/2008	31	0	6	0	34	0	15	0	86
06/24/2008	42	0	8	0	32	0	4	1	87
06/25/2008	60	0	13	0	6	0	7	1	87
06/26/2008	47	2	9	0	20	1	7	1	87
06/27/2008	54	0	8	0	19	0	6	0	87
06/28/2008	61	0	5	0	13	0	7	1	87
06/29/2008	64	0	7	0	11	0	5	0	87
06/30/2008	56	0	7	0	20	0	4	0	87
07/01/2008	57	0	3	0	14	0	9	4	87
07/02/2008	47	0	1	0	7	0	6	0	61
07/03/2008	90	0	10	0	9	0	4	1	114
07/04/2008	74	0	5	0	3	0	5	0	87
07/05/2008	76	0	5	0	0	0	4	2	87
07/06/2008	65	6	6	1	3	0	6	0	87
07/07/2008	67	0	10	0	4	0	4	2	87
07/08/2008	40	0	3	0	2	0	6	0	51
07/09/2008	102	0	4	0	5	0	10	1	122
07/10/2008	73	0	7	0	4	0	6	0	90
07/11/2008	75	0	2	0	3	0	8	1	89
07/12/2008	81	0	0	0	1	0	4	4	90
07/13/2008	75	0	1	0	2	0	7	3	88
Pooled	1640	11	158	1	426	3	180	25	2444

Table K.4. Tag-life-corrected, single-release estimates of survival (S) and detection probabilities for subyearling Chinook salmon smolts in reference releases for dam passage survival. Releases were in the upper The Dalles Dam tailwater. Lambda is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt mean and confidence interval (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero and would overly weight high survival estimates.

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
06/16-6/17	1.000	0.000	0.969	0.059	0.994	0.000	0.854	0.059	0.569	0.080
06/18/2008	0.982	0.032	0.948	0.082	0.948	0.032	0.889	0.082	0.556	0.110
06/19/2008	0.989	0.022	1.000	0.000	1.000	0.022	0.872	0.000	0.640	0.100
06/20/2008	1.000	0.009	0.939	0.065	1.000	0.009	0.940	0.065	0.627	0.110
06/21/2008	1.000	0.009	0.954	0.066	1.000	0.009	0.907	0.066	0.636	0.100
06/22/2008	1.000	0.009	0.975	0.063	1.000	0.009	0.932	0.063	0.519	0.110
06/23/2008	1.000	0.009	0.902	0.112	1.000	0.009	0.838	0.112	0.477	0.120
06/24/2008	0.989	0.022	1.000	0.020	1.000	0.022	0.861	0.020	0.581	0.100
06/25/2008	0.989	0.022	0.936	0.061	1.000	0.022	0.822	0.061	0.911	0.070
06/26/2008	0.992	0.023	0.960	0.072	0.962	0.023	0.845	0.072	0.700	0.100
06/27/2008	1.000	0.009	0.963	0.061	1.000	0.009	0.871	0.061	0.740	0.100
06/28/2008	0.989	0.022	0.931	0.060	1.000	0.022	0.924	0.060	0.824	0.080
06/29/2008	1.000	0.009	0.956	0.051	1.000	0.009	0.901	0.051	0.853	0.080
06/30/2008	1.000	0.009	0.983	0.052	1.000	0.009	0.889	0.052	0.737	0.090
07/01/2008	0.954	0.044	0.900	0.068	1.000	0.044	0.950	0.068	0.803	0.090
07/02/2008	1.000	0.011	0.904	0.075	1.000	0.011	0.979	0.075	0.870	0.090
07/03/2008	0.991	0.017	0.974	0.035	1.000	0.017	0.900	0.035	0.909	0.050
07/04/2008	1.000	0.009	0.945	0.049	1.000	0.009	0.937	0.049	0.961	0.040
07/05/2008	0.977	0.032	0.953	0.045	1.000	0.032	0.938	0.045	1.000	0.010
07/06/2008	1.000	0.009	0.934	0.054	0.920	0.009	0.910	0.054	0.960	0.040
07/07/2008	0.977	0.032	0.960	0.046	1.000	0.032	0.870	0.046	0.944	0.050
07/08/2008	1.000	0.012	0.885	0.089	1.000	0.012	0.930	0.089	0.952	0.060
07/09/2008	0.992	0.016	0.919	0.049	1.000	0.016	0.962	0.049	0.953	0.040
07/10/2008	1.000	0.000	0.938	0.052	1.000	0.000	0.913	0.052	0.948	0.050
07/11/2008	0.989	0.022	0.910	0.060	1.000	0.022	0.974	0.060	0.962	0.040
07/12/2008	0.956	0.043	0.954	0.044	1.000	0.043	1.000	0.044	0.988	0.020
07/13/2008	0.966	0.038	0.918	0.058	1.000	0.038	0.987	0.058	0.974	0.030
Pooled	0.990	0.004	0.942	0.011	0.993	0.004	0.912	0.011	0.794	0.010
N-Wt Mean	0.990	0.005	0.947	0.011						

Table K.5. Tag-life-corrected, paired-release estimates of dam survival (S) for subyearling Chinook salmon smolts in virtual releases from the The Dalles Dam forebay entrance array to the upper end of the The Dalles Dam tailwater. Treatment virtual release data were from Tables K.1 and K.2, and reference release data were from Tables K.3 and K.4.

Paired Release	S to Tailrace	1/2 95% CI
06/16-6/17	0.911	0.048
06/18/2008	0.975	0.050
06/19/2008	0.921	0.057
06/20/2008	0.945	0.048
06/21/2008	0.904	0.060
06/22/2008	0.906	0.057
06/23/2008	0.912	0.049
06/24/2008	0.951	0.050
06/25/2008	0.977	0.040
06/26/2008	0.937	0.062
06/27/2008	0.964	0.040
06/28/2008	0.902	0.068
06/29/2008	0.942	0.047
06/30/2008	0.979	0.033
07/01/2008	0.975	0.071
07/02/2008	0.934	0.047
07/03/2008	0.962	0.048
07/04/2008	0.928	0.049
07/05/2008	0.923	0.066
07/06/2008	0.916	0.057
07/07/2008	0.969	0.053
07/08/2008	0.915	0.054
07/09/2008	0.905	0.074
07/10/2008	0.875	0.061
07/11/2008	0.889	0.060
07/12/2008	0.942	0.074
07/13/2008	0.892	0.078
Pooled	0.929	0.011
N-Wt Mean	0.931	0.013

Appendix L

Tables on Tagging, John Day Dam Tailwater Releases, John Day Dam Virtual Releases, John Day Dam Operations Data, and Capture History Data at John Day Dam or Downstream

Table L.1. List of comma-separated-variable files on an accompanying compact disc.[a] Variables in the first row of comma-separated-variable files are defined in Tables L.2 through L.6 below.

File	Description
Appendix L1.xls	John Day Dam virtual releases, reference releases, hourly dam operations data, and capture history data at John Day Dam or at the primary, secondary, and tertiary arrays downstreamA (all species)
Appendix L2.xls	Tagging, release, and capture history data for steelhead
Appendix L3.xls	Tagging, release, and capture history data for spring Chinook salmon released in the John Day Dam and The Dalles Dam pools
Appendix L4.xls	Tagging, release, and capture history data for fall Chinook salmon released in the John DayDam, The Dalles Dam, and Bonneville Dam pools
Appendix L5.xls	Tagging, release, and capture history data for spring Chinook salmon released in the Lower Granite Dam tailrace

[a] A compact disc accompanying the report has nine files: A Portable Document Format (PDF) file of this report, three Excel files with non-tag-life-corrected survival and detection probabilities, and five Excel files with tagging, release, virtual release, capture-history, and dam operations data.

Table L.2. Variable names and definitions in Appendix L1.xls

Variable	Definition
SEASON	Spring or Summer
TAGGER	Name of surgeon implanting tags
SP	Species name
SPP	PTAGIS species code
LENGTH	Fork length (mm)
WEIGHT	Fish weight (g)
MORT	0=Alive; > 0 = Dead
ACTAGCODE	Acoustic tag code
PRI	Pulse repetition interval of acoustic tag
PIT	PIT tag code
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
TDATETIME	Tagging date and time (mm/dd/yyyy hh:mm)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
REL_LOC	Release location
Rkm	Release river kilometer (km)
JDA_ARRAY	Regrouped at John Day Dam face array (1 = yes or 0 = no)
DATE	Date released (if REL_LOC=JDA_TW) or date of dam-face virtual release (if JDA_ARRAY=1). Routes are indicated by JROUTE, JSUB_ROUTE, or JHOLE below.
HOUR	Hour released (if REL_LOC=JDA_TW) or hour of dam-face virtual release (if JDA_ARRAY=1). Routes are indicated by JROUTE, JSUB_ROUTE, or JHOLE below.
A3CR312	Detected (1) or not detected (0) on The Dalles Dam forebay entrance array (primary survival-detection array)
A4CR237	Detected (1) or not detected (0) on the Bonneville Dam forebay entrance array (secondary survival-detection array)
A5CR203	Detected (1) or not detected (0) on the tertiary survival-detection array in the Bonneville Dam tailwater near Reed Island
A3CR312_TIME	Time of arrival at The Dalles Dam forebay entrance array
A4CR237_TIME	Time of arrival at the Bonneville Dam forebay entrance array
A5CR203_TIME	Time of arrival at the tertiary survival-detection array in the Bonneville Dam tailwater near Reed Island
JROUTE	Route of passage through John Day Dam (powerhouse or spillway)
JSUB_ROUTE	Sub-route of passage through John Day Dam (turbine, JBS, TSW, non-TSW)
JHOLE	Specific route of passage exiting the forebay (turbine = T01-T16; spill bay = S01-S20
J	Assigned pool of dates for virtual releases at John Day Dam for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with variable J above
J_TSW	Assigned pool of dates for virtual releases at John Day Dam TSW spill bays (spill bays 15 and 16 in 2008)
J_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TSW above

Table L.2. (contd)

Variable	Definition
J_NON_TSW	Assigned pool of dates for virtual releases at non-TSW spill bays at John Day Dam
J_NON_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_NON_TSW above
J_TUR	Assigned pool of dates for virtual releases at John Day Dam turbines
J_TUR_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TUR above
J_JBS	Assigned pool of dates for virtual releases at the John Day Dam JBS
J_JBS_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_JBS above
T1	Turbine 1 discharge (cfs × 1000)
T2	Turbine 2 discharge (cfs × 1000)
T3	Turbine 3 discharge (cfs × 1000)
T4	Turbine 4 discharge (cfs × 1000)
T5	Turbine 5 discharge (cfs × 1000)
T6	Turbine 6 discharge (cfs × 1000)
T7	Turbine 7 discharge (cfs × 1000)
T8	Turbine 8 discharge (cfs × 1000)
T9	Turbine 9 discharge (cfs × 1000)
T10	Turbine 10 discharge (cfs × 1000)
T11	Turbine 11 discharge (cfs × 1000)
T12	Turbine 12 discharge (cfs × 1000)
T13	Turbine 13 discharge (cfs × 1000)
T14	Turbine 14 discharge (cfs × 1000)
T15	Turbine 15 discharge (cfs × 1000)
T16	Turbine 16 discharge (cfs × 1000)
SB1	Spill bay 1 discharge (cfs × 1000)
SB2	Spill bay 2 discharge (cfs × 1000)
SB3	Spill bay 3 discharge (cfs × 1000)
SB4	Spill bay 4 discharge (cfs × 1000)
SB5	Spill bay 5 discharge (cfs × 1000)
SB6	Spill bay 6 discharge (cfs × 1000)
SB7	Spill bay 7 discharge (cfs × 1000)
SB8	Spill bay 8 discharge (cfs × 1000)
SB9	Spill bay 9 discharge (cfs × 1000)
SB10	Spill bay 10 discharge (cfs × 1000)
SB11	Spill bay 11 discharge (cfs × 1000)
SB12	Spill bay 12 discharge (cfs × 1000)
SB13	Spill bay 13 discharge (cfs × 1000)
SB14	Spill bay 14 discharge (cfs × 1000)

Table L.2. (contd)

Variable	Definition
SB15	Spill bay 15 discharge (cfs × 1000) – TSW route in 2008
SB16	Spill bay 16 discharge (cfs × 1000) – TSW route in 2008
SB17	Spill bay 17 discharge (cfs × 1000)
SB18	Spill bay 18 discharge (cfs × 1000)
SB19	Spill bay 19 discharge (cfs × 1000)
SB20	Spill bay 20 discharge (cfs × 1000)
JDA_Q	John Day Dam project discharge (cfs × 1000)
PH_Q	John Day Dam powerhouse discharge (cfs × 1000)
SPILL_Q	John Day Dam spill discharge (cfs × 1000)
TSW_Q	TSW discharge (cfs × 1000)
NON_TSW_Q	Non-TSW discharge (cfs × 1000)
P_SPILL	Percent spill at John Day Dam

Table L.3. Variable names and definitions in Appendix L2.xls

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (SPR_STH = steelhead)
REL_LOC	Release location (ARLINGTON=Arlington, OR; JDA_TW = upper end of the John Day Dam tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive integrated transponder tag code
ACTAGCODE	Acoustic tag code
A1CR351	Detection indicator for the John Day Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the John Day Dam-face array (1 = detected; 0 = not detected; blank = missing)
A2CR339	Detection indicator for the John Day Dam tailwater array (1 = detected; 0 = not detected; blank = missing)
A3CR312	Detection indicator for The Dalles Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
A4CR237	Detection indicator for the Bonneville Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Dam Powerhouse 2 dam-face array (1 = detected; 0 = not detected; blank = missing)
BSPILL_ARRAY	Detection indicator for the Bonneville Dam spillway array (1 = detected; 0 = not detected; blank = missing)
A5CR203	Detection indicator for the first Bonneville Dam tailwater array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6CR192	Detection indicator for the second Bonneville Dam tailwater array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7CR086	Detection indicator for the third Bonneville Dam tailwater array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1CR351_TIME	Date and time of arrival at the John Day Dam forebay entrance array
JDATETIME	Date and time of arrival at the John Day Dam-face array
A2CR339_TIME	Date and time of arrival at the John Day Dam tailwater array
A3CR312_TIME	Date and time of arrival at The Dalles Dam forebay entrance array
A4CR237_TIME	Date and time of arrival at the Bonneville Dam forebay entrance array
B2DATETIME	Date and time of last detection on the Bonneville Dam Powerhouse 2 array
BSDATETIME	Date and time of last detection on the Bonneville Dam spillway array
A5CR203_TIME	Date and time of arrival at the first Bonneville Dam tailwater array at Reed Island
A6CR192_TIME	Date and time of arrival at the second Bonneville Dam tailwater array at Lady Island
A7CR086_TIME	Date and time of arrival at the third Bonneville Dam tailwater array at Oak Point
JROUTE	Route of passage through John Day Dam (powerhouse or spillway)
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill), non-TSW (spill), turbine, JBS]

Table L.3. (contd)

Variable Name	Definition
JHOLE	Specific route of passage (spill bays S1-S20; turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (spill bays = SB1-SB18; Turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at John Day Dam for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with variable J above
J_NON_TSW	Assigned pool of dates for virtual releases at non-TSW spill bays at John Day Dam
J_NON_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_NON_TSW above
J_TSW	Assigned pool of dates for virtual releases at John Day Dam TSW spill bays (spill bays 15 and 16 in 2008)
J_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TSW above
J_TUR	Assigned pool of dates for virtual releases at John Day Dam turbines
J_TUR_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TUR above
J_JBS	Assigned pool of dates for virtual releases at the John Day Dam JBS
J_JBS_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_JBS above
T_FB	Assigned pool of dates for virtual releases at The Dalles Dam forebay entrance array
B_FB	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TUR above
B2	Assigned pool of dates for virtual releases at Bonneville Dam Powerhouse 2
B2CC	Assigned pool of dates for virtual releases at the Bonneville Dam B2CC
B2_JBS	Assigned pool of dates for virtual releases at the Bonneville Dam B2 JBS
B2_TUR	Assigned pool of dates for virtual releases at Bonneville Dam B2 turbines
BSPILL	Assigned pool of dates for virtual releases at the Bonneville Dam spillway
BS_END	Assigned pool of dates for virtual releases at end bays (1-3 and 16-18) at the Bonneville Dam spillway
BS_MID	Assigned pool of dates for virtual releases at middle spill bays at the Bonneville Dam spillway

Table L.4. Variable names and definitions in Appendix L3.xls

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (SPR_CHN = spring Chinook salmon)
REL_LOC	Release location (ARLINGTON=Arlington, OR; JDA_TW = upper end of the John Day Dam tailwater; BON_T = the upper end of the Bonneville Dam tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive integrated transponder tag code
ACTAGCODE	Acoustic tag code
A1CR351	Detection indicator for the John Day Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the John Day Dam-face array (1 = detected; 0 = not detected; blank = missing)
A2CR339	Detection indicator for the John Day Dam tailwater array (1 = detected; 0 = not detected; blank = missing)
A3CR312	Detection indicator for The Dalles Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
A4CR237	Detection indicator for the Bonneville Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Dam Powerhouse 2 dam-face array (1 = detected; 0 = not detected; blank = missing)
BSPILL_ARRAY	Detection indicator for the Bonneville Dam spillway array (1 = detected; 0 = not detected; blank = missing)
A5CR203	Detection indicator for the first Bonneville Dam tailwater array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6CR192	Detection indicator for the second Bonneville Dam tailwater array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7CR086	Detection indicator for the third Bonneville Dam tailwater array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1CR351_TIME	Date and time of arrival at the John Day Dam forebay entrance array
JDATETIME	Date and time of arrival at the John Day Dam-face array
A2CR339_TIME	Date and time of arrival at the John Day Dam tailwater array
A3CR312_TIME	Date and time of arrival at The Dalles Dam forebay entrance array
A4CR237_TIME	Date and time of arrival at the Bonneville Dam forebay entrance array
B2DATETIME	Date and time of last detection on the Bonneville Dam Powerhouse 2 array
BSDATETIME	Date and time of last detection on the Bonneville Dam spillway array
A5CR203_TIME	Date and time of arrival at the first Bonneville Dam tailwater array at Reed Island
A6CR192_TIME	Date and time of arrival at the second Bonneville Dam tailwater array at Lady Island
A7CR086_TIME	Date and time of arrival at the third Bonneville Dam tailwater array at Oak Point
JROUTE	Route of passage through John Day Dam (powerhouse or spillway)
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill) , non-TSW (spill), Turbine, JBS]

Table L.4. (contd)

Variable Name	Definition
JHOLE	Specific route of passage (spill bays S1-S20; Turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; Turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (spill bays = SB1-SB18; Turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at John Day Dam for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with variable J above
J_NON_TSW	Assigned pool of dates for virtual releases at non-TSW spill bays at John Day Dam
J_NON_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_NON_TSW above
J_TSW	Assigned pool of dates for virtual releases at John Day Dam TSW spill bays (spill bays 15 and 16 in 2008)
J_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TSW above
J_TUR	Assigned pool of dates for virtual releases at John Day Dam turbines
J_TUR_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TUR above
J_JBS	Assigned pool of dates for virtual releases at the John Day Dam JBS
J_JBS_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_JBS above
T_FB	Assigned pool of dates for virtual releases at The Dalles Dam forebay entrance array
B_FB	Assigned pool of dates for virtual releases at the Bonneville Dam forebay entrance array for estimating Bonneville Dam survival
B_FB_TW	Assigned pool of date for reference releases for pairing with B_FB above
B2	Assigned pool of dates for virtual releases at Bonneville Dam Powerhouse 2
B2_TW	Assigned pool of dates for reference releases for pairing with B2 above
B2CC	Assigned pool of dates for virtual releases at the Bonneville Dam B2CC
B2CC_TW	Assigned pool of dates for reference releases for pairing with B2 above
B2CC_R	Assigned pool of dates for releases directly into the B2CC
B2CC_R_TW	Assigned pool of dates for reference releases in the Bonneville Dam tailwater for pairing with B2CC_R
B2_JBS	Assigned pool of dates for virtual releases at the Bonneville Dam B2 JBS
B2_JBS_TW	Assigned pool of dates for reference releases in the Bonneville Dam tailwater for pairing with B2_JBS above
B2_TUR	Assigned pool of dates for virtual releases at Bonneville Dam B2 Turbines
B2_TUR_TW	Assigned pool of dates for reference releases in the Bonneville Dam tailwater for pairing with B2_TUR above
BSPILL	Assigned pool of dates for virtual releases at the Bonneville Dam spillway

Table L.4. (contd)

Variable Name	Definition
BSPILL_TW	Assigned pool of dates for references releases in the Bonneville Dam tailwater for pairing with BSPILL above
BS_END	Assigned pool of dates for virtual releases at end bays (1-3 and 16-18) at the Bonneville Dam spillway
BS_END_TW	Assigned pool of dates for references releases in the Bonneville Dam tailwater for pairing with BS_END above
BS_MID	Assigned pool of dates for virtual releases at middle spill bays at the Bonneville Dam spillway
BS_MID_TW	Assigned pool of dates for references releases in the Bonneville Dam tailwater for pairing with BS_MID above

Table L.5. Variable names and definitions in Appendix L4.xls

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (FALL_CHN = fall Chinook salmon)
REL_LOC	Release location (ARLINGTON=Arlington, OR; JDA_TW = upper end of the John Day Dam tailwater; TDA_TW = the upper end of The Dalles Dam tailwater; BON_T = the upper end of the Bonneville Dam tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive integrated transponder tag code
ACTAGCODE	Acoustic tag code
A1CR351	Detection indicator for the John Day Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the John Day Dam-face array (1 = detected; 0 = not detected; blank = missing)
A2CR339	Detection indicator for the John Day Dam tailwater array (1 = detected; 0 = not detected; blank = missing)
A3CR312	Detection indicator for The Dalles Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
A4CR237	Detection indicator for the Bonneville Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Dam Powerhouse 2 dam-face array (1 = detected; 0 = not detected; blank = missing)
BSPILL_ARRAY	Detection indicator for the Bonneville Dam spillway array (1 = detected; 0 = not detected; blank = missing)
A5CR203	Detection indicator for the first Bonneville Dam tailwater array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6CR192	Detection indicator for the second Bonneville Dam tailwater array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7CR086	Detection indicator for the third Bonneville Dam tailwater array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1CR351_TIME	Date and time of arrival at the John Day Dam forebay entrance array
JDATETIME	Date and time of arrival at the John Day Dam-face array
A2CR339_TIME	Date and time of arrival at the John Day Dam tailwater array
A3CR312_TIME	Date and time of arrival at The Dalles Dam forebay entrance array
A4CR237_TIME	Date and time of arrival at the Bonneville Dam forebay entrance array
B2DATETIME	Date and time of last detection on the Bonneville Dam Powerhouse 2 array
BSDATETIME	Date and time of last detection on the Bonneville Dam spillway array
A5CR203_TIME	Date and time of arrival at the first Bonneville Dam tailwater array at Reed Island
A6CR192_TIME	Date and time of arrival at the second Bonneville Dam tailwater array at Lady Island
A7CR086_TIME	Date and time of arrival at the third Bonneville Dam tailwater array at Oak Point
JROUTE	Route of passage through John Day Dam (powerhouse or spillway)

Table L.5. (contd)

Variable Name	Definition
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill), non-TSW (spill), turbine, JBS]
JHOLE	Specific route of passage (spill bays S1-S20; Turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (spill bays = SB1-SB18; turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at John Day Dam for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with variable J above
J_NON_TSW	Assigned pool of dates for virtual releases at non-TSW spill bays at John Day Dam
J_NON_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_NON_TSW above
J_TSW	Assigned pool of dates for virtual releases at John Day Dam TSW spill bays (spill bays 15 and 16 in 2008)
J_TSW_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TSW above
J_TUR	Assigned pool of dates for virtual releases at John Day Dam turbines
J_TUR_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_TUR above
J_JBS	Assigned pool of dates for virtual releases at the John Day Dam JBS
J_JBS_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with J_JBS above
T_FB	Assigned pool of dates for virtual releases at The Dalles Dam forebay entrance array
T_FB	Assigned pool of dates for reference releases in the upper tailwater of The Dalles Dam
B_FB	Assigned pool of dates for virtual releases at the Bonneville Dam forebay entrance array for estimating Bonneville Dam survival
B_FB_TW	Assigned pool of date for reference releases for pairing with B_FB above
B2	Assigned pool of dates for virtual releases at Bonneville Dam Powerhouse 2
B2_TW	Assigned pool of dates for reference releases for pairing with B2 above
B2CC	Assigned pool of dates for virtual releases at the Bonneville Dam B2CC
B2CC_TW	Assigned pool of dates for reference releases for pairing with B2 above
B2CC_R	Assigned pool of dates for releases directly into the B2CC
B2CC_R_TW	Assigned pool of dates for reference releases in the Bonneville Dam tailwater for pairing with B2CC_R
B2_JBS	Assigned pool of dates for virtual releases at the Bonneville Dam B2 JBS
B2_JBS_TW	Assigned pool of dates for reference releases in the Bonneville Dam tailwater for pairing with B2_JBS above
B2_TUR	Assigned pool of dates for virtual releases at Bonneville Dam B2 Turbines
B2_TUR_TW	Assigned pool of dates for reference releases in the Bonneville Dam tailwater for pairing with B2_TUR above

Table L.5. (contd)

Variable Name	Definition
BSPILL	Assigned pool of dates for virtual releases at the Bonneville Dam spillway
BSPILL_TW	Assigned pool of dates for references releases in the Bonneville Dam tailwater for pairing with BSPILL above
BS_END	Assigned pool of dates for virtual releases at end bays (1-3 and 16-18) at the Bonneville Dam spillway
BS_END_TW	Assigned pool of dates for references releases in the Bonneville Dam tailwater for pairing with BS_END above
BS_MID	Assigned pool of dates for virtual releases at middle spill bays at the Bonneville Dam spillway
BS_MID_TW	Assigned pool of dates for references releases in the Bonneville Dam tailwater for pairing with BS_MID above

Table L.6. Variable Names and definitions in Appendix L5.xls

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (SPR_CHN = spring Chinook salmon)
REL_LOC	Release Location (LGR=Lower Granite Tailwater; JDA_TW = upper end of the John Day Dam tailwater; BON_T = the upper end of the Bonneville Dam tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive integrated transponder tag code
ACTAGCODE	Acoustic tag code
A1CR351	Detection indicator for the John Day Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the John Day Dam-face array (1 = detected; 0 = not detected; blank = missing)
A2CR339	Detection indicator for the John Day Dam tailwater array (1 = detected; 0 = not detected; blank = missing)
A3CR312	Detection indicator for The Dalles Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
A4CR237	Detection indicator for the Bonneville Dam forebay entrance array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Dam Powerhouse 2 dam-face array (1 = detected; 0 = not detected; blank = missing)
BSPILL_ARRAY	Detection indicator for the Bonneville Dam spillway array (1 = detected; 0 = not detected; blank = missing)
A5CR203	Detection indicator for the first Bonneville Dam tailwater array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6CR192	Detection indicator for the second Bonneville Dam tailwater array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7CR086	Detection indicator for the third Bonneville Dam tailwater array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1CR351_TIME	Date and time of arrival at the John Day Dam forebay entrance array
JDATETIME	Date and time of arrival at the John Day Dam-face array
A2CR339_TIME	Date and time of arrival at the John Day Dam tailwater array
A3CR312_TIME	Date and time of arrival at The Dalles Dam forebay entrance array
A4CR237_TIME	Date and time of arrival at the Bonneville Dam forebay entrance array
B2DATETIME	Date and time of last detection on the Bonneville Dam Powerhouse 2 array
BSDATETIME	Date and time of last detection on the Bonneville Dam spillway array
A5CR203_TIME	Date and time of arrival at the first Bonneville Dam tailwater array at Reed Island
A6CR192_TIME	Date and time of arrival at the second Bonneville Dam tailwater array at Lady Island
A7CR086_TIME	Date and time of arrival at the third Bonneville Dam tailwater array at Oak Point
JROUTE	Route of passage through John Day Dam (powerhouse or spillway)
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill), non-TSW (spill), turbine, JBS]

Table L.6. (contd)

Variable Name	Definition
JHOLE	Specific route of passage (spill bays S1-S20; Turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; Turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (spill bays = SB1-SB18; turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at John Day Dam for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper John Day Dam tailwater for pairing with variable J above
B_FB	Assigned pool of dates for virtual releases at the Bonneville Dam forebay entrance array for estimating Bonneville Dam survival
B_FB_TW	Assigned pool of date for reference releases for pairing with B_FB above

Appendix M

Burnham Test 2 and 3 Tables

Table M.1. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for spring Chinook salmon smolts passing John Day Dam. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/03	NC	NC
5/04-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	0.8409	0.5186
5/10-5/11	NC	NC
5/12-5/13	NC	NC
5/14-5/15	0.8661	0.2784
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	0.3077	0.3823
5/24-5/25	NC	NC
5/26-5/27	NC	NC
5/28-5/29	NC	NC
Pooled	0.2843	0.2626

Table M.2. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for spring Chinook salmon smolts passing John Day Dam tailwater. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/03	NC	NC
5/04-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	NC	NC
5/10-5/11	0.9872	0.1039
5/12-5/13	NC	NC
5/14-5/15	NC	0.7859
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	NC	NC
5/24-5/25	NC	NC
5/26-5/27	NC	NC
5/28-5/29	NC	NC
Pooled	0.9868	0.3362

Table M.3. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for spring Chinook salmon smolts passing the John Day Dam powerhouse. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	0.7216	0.6359
5/10-5/11	NC	NC
5/12-5/13	NC	NC
5/14-5/15	0.8000	0.4000
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	0.175	0.4945
5/24-5/25	NC	NC
5/26-5/29	NC	NC
Pooled	0.1328	0.2362

Table M.4. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for spring Chinook salmon smolts passing the John Day Dam turbines. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/06	NC	NC
5/07-5/12	NC	NC
5/13-5/18	NC	0.4615
5/19-5/24	0.5769	0.5333
5/25-5/29	NC	NC
Pooled	0.4694	0.1343

Table M.5. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for spring Chinook salmon smolts passing the John Day Dam JBS. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/07	NC	NC
5/08-5/11	0.7805	0.7159
5/12-5/15	NC	NC
5/16-5/19	NC	NC
5/20-5/23	0.3247	0.4843
5/24-5/29	NC	NC
Pooled	0.2805	0.3938

Table M.6. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for spring Chinook salmon smolts passing the John Day Dam spillway. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/03	NC	NC
5/04-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	NC	NC
5/10-5/11	NC	NC
5/12-5/13	NC	NC
5/14-5/15	NC	NC
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	0.4505	0.5000
5/24-5/25	NC	NC
5/26-5/27	NC	NC
5/28-5/29	NC	NC
Pooled	0.3485	0.6608

Table M.7. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for spring Chinook salmon smolts passing the John Day Dam TSW bays (15 and 16) in 2008. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/05	NC	NC
5/06-5/09	NC	NC
5/10-5/13	NC	NC
5/14-5/17	NC	NC
5/18-5/21	NC	NC
5/22-5/25	0.2273	NC
5/26-5/29	NC	NC
Pooled	0.1785	NC

Table M.8. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for steelhead smolts passing John Day Dam. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/03	NC	NC
5/04-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	0.473	0.195
5/10-5/11	NC	NC
5/12-5/13	NC	NC
5/14-5/15	0.4771	0.2985
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	0.7473	0.7647
5/24-5/25	NC	NC
5/26-5/27	NC	NC
5/28-5/29	NC	NC
Pooled	0.1365	0.2607

Table M.9. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for steelhead smolts passing John Day Dam tailwater. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual	P-Values from Fisher's Exact Test	
Release Date	Test 2.2	Test 3.1
5/02-5/03	NC	NC
5/04-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	NC	0.6509
5/10-5/11	NC	NC
5/12-5/13	NC	NC
5/14-5/15	0.9836	0.9167
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	0.9577	0.4037
5/24-5/25	NC	NC
5/26-5/27	NC	NC
5/28-5/29	NC	NC
Pooled	0.9614	0.284

Table M.10. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for steelhead smolts passing the John Day Dam powerhouse. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual	P-Values from Fisher's Exact Test	
Release Date	Test 2.2	Test 3.1
5/02-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	0.8413	0.8302
5/11-5/12	NC	NC
5/13-5/14	NC	NC
5/15-5/16	0.6471	0.5909
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	0.7692	0.7000
5/25-5/26	NC	NC
5/27-5/29	0.2937	NC
Pooled	0.4762	0.4015

Table M.11. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for steelhead smolts passing the John Day Dam turbines. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/15	NC	NC
5/16-5/29	NC	NC
Pooled	NC	NC

Table M.12. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for steelhead smolts passing the John Day Dam JBS. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	0.8448	0.8163
5/11-5/12	NC	NC
5/13-5/14	NC	NC
5/15-5/16	0.6774	0.619
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	0.7692	0.7000
5/25-5/26	NC	NC
5/27-5/29	NC	NC
Pooled	0.4981	0.4054

Table M.13. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for steelhead smolts passing the John Day Dam spillway. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/03	NC	NC
5/04-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	0.5466	0.1464
5/10-5/11	NC	NC
5/12-5/13	NC	NC
5/14-5/15	0.5874	0.4023
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	NC	NC
5/24-5/25	NC	NC
5/26-5/27	NC	NC
5/28-5/29	NC	NC
Pooled	0.2786	0.2937

Table M.14. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for steelhead smolts passing the John Day Dam TSW Bays (15 and 16) in 2008. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/03	NC	NC
5/04-5/05	NC	NC
5/06-5/07	NC	NC
5/08-5/09	0.675	0.3522
5/10-5/11	NC	NC
5/12-5/13	NC	NC
5/14-5/15	0.6699	0.4331
5/16-5/17	NC	NC
5/18-5/19	NC	NC
5/20-5/21	NC	NC
5/22-5/23	NC	NC
5/24-5/25	NC	NC
5/26-5/27	NC	NC
5/28-5/29	NC	NC
Pooled	0.3625	0.3469

Table M.15. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for fall Chinook salmon smolts passing John Day Dam. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/16-6/17	0.7661	0.6842
6/18-6/19	0.4492	0.7086
6/20-6/21	NC	NC
6/22-6/23	NC	NC
6/24-6/25	NC	NC
6/26-6/27	0.7073	0.4921
6/28-6/29	NC	NC
6/30-7/01	NC	NC
7/02-7/03	NC	NC
7/04-7/05	NC	NC
7/06-7/07	0.9546	0.7376
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
Pooled	0.3859	0.2188

Table M.16. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for fall Chinook salmon smolts passing John Day Dam tailwater. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/16-6/17	NC	NC
6/18-6/19	NC	0.7466
6/20-6/21	NC	NC
6/22-6/23	NC	NC
6/24-6/25	NC	NC
6/26-6/27	NC	0.8382
6/28-6/29	NC	NC
6/30-7/01	NC	NC
7/02-7/03	NC	NC
7/04-7/05	NC	NC
7/06-7/07	NC	0.9000
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
Pooled	0.9865	0.5948

Table M.17. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for fall Chinook salmon smolts passing the John Day Dam powerhouse. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/16-6/17	NC	NC
6/18-6/19	0.7317	0.9667
6/20-6/21	NC	NC
6/22-6/23	NC	NC
6/24-6/25	NC	NC
6/26-6/27	NC	NC
6/28-6/29	NC	NC
6/30-7/01	NC	NC
7/02-7/03	NC	NC
7/04-7/05	NC	NC
7/06-7/07	NC	0.907
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
Pooled	0.752	0.6941

Table M.18. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for fall Chinook salmon smolts passing the John Day Dam turbines. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/16-6/17	NC	NC
6/18-6/19	NC	NC
6/20-6/21	NC	NC
6/22-6/23	NC	NC
6/24-6/25	NC	NC
6/26-6/27	NC	NC
6/28-6/29	NC	NC
6/30-7/01	NC	NC
7/02-7/03	NC	NC
7/04-7/05	NC	NC
7/06-7/07	NC	0.871
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
Pooled	0.9013	0.819

Table M.19. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for fall Chinook salmon smolts passing the John Day Dam JBS. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/16-6/17	0.7692	0.825
6/18-6/19	NC	NC
6/20-6/21	NC	NC
6/22-6/23	NC	NC
6/24-6/25	NC	NC
6/26-6/27	NC	NC
6/28-6/29	NC	NC
6/30-7/01	NC	NC
7/02-7/03	NC	NC
7/04-7/05	NC	NC
7/06-7/07	NC	NC
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
Pooled	0.8382	0.8465

Table M.20. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for fall Chinook salmon smolts passing the John Day Dam spillway. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/16-6/17	0.7011	0.6557
6/18-6/19	0.4724	0.7797
6/20-6/21	NC	NC
6/22-6/23	NC	NC
6/24-6/25	NC	NC
6/26-6/27	0.6679	0.5102
6/28-6/29	NC	NC
6/30-7/01	NC	NC
7/02-7/03	NC	NC
7/04-7/05	NC	NC
7/06-7/07	0.9659	0.8353
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
Pooled	0.4021	0.3117

Table M.21. Burnham et al. (1987) Test 2 and Test 3 P-values for goodness-of-fit to the single release-recapture data for fall Chinook salmon smolts passing through the John Day Dam TSW bays (15 and 16) in 2008. Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells with NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10 indicated a violation of model assumptions.

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/16-6/17	NC	NC
6/18-6/19	NC	NC
6/20-6/21	NC	NC
6/22-6/23	NC	NC
6/24-6/25	0.7708	0.7297
6/26-6/27	NC	NC
6/28-6/29	NC	NC
6/30-7/01	NC	NC
7/02-7/03	NC	NC
7/04-7/05	NC	NC
7/06-7/07	NC	NC
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
Pooled	0.8689	0.805

Reference

Burnham KP, DR Anderson, GC White, C Brownie, and KH Pollock. 1987. "Design and Analysis Methods for Fish Survival Estimates Based on Release-Recapture." *American Fisheries Society Monograph* No. 5.

Appendix N

Time-of-Arrival Plots for Treatment and Reference Releases of Fish Used for Paired-Release Survival Estimation

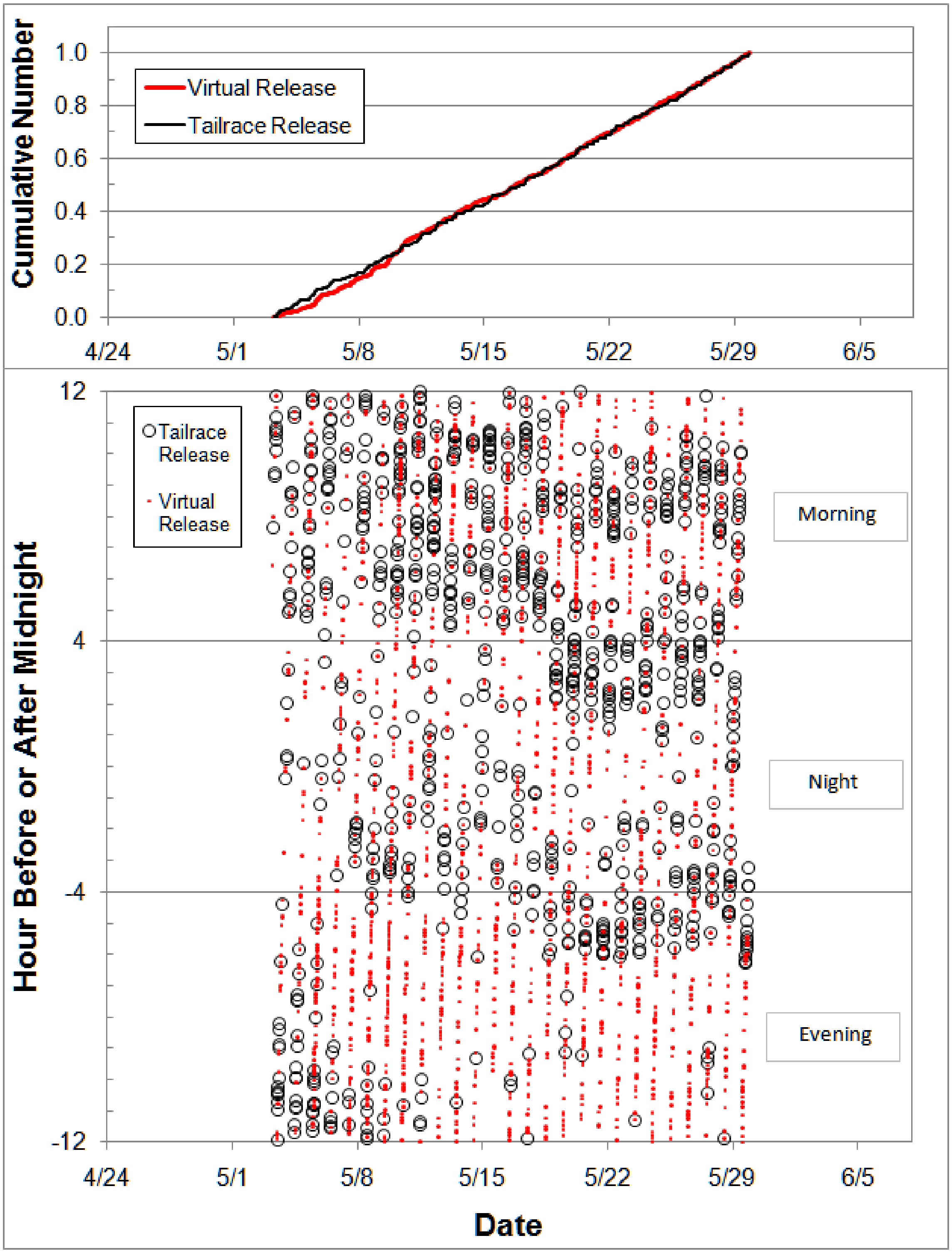

Figure N.1. Cumulative frequency of arrivals of tagged steelhead smolts from virtual releases at John Day Dam and references releases in the John Day Dam tailrace (top) and a scatter plot of arrival hour of each released fish before or after midnight by date (bottom)

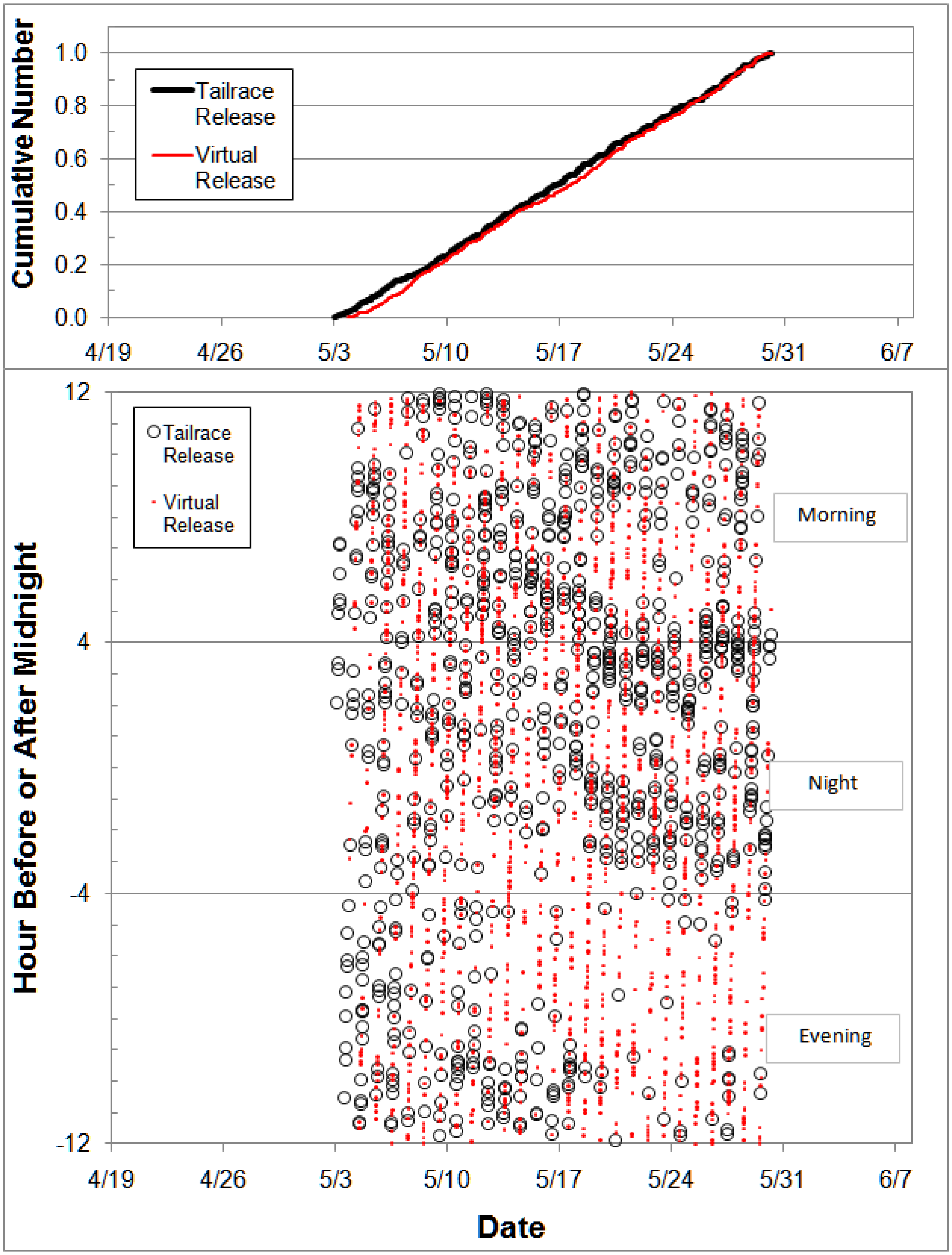

Figure N.2. Cumulative frequency of arrivals of tagged yearling Chinook salmon smolts from virtual releases at John Day Dam and references releases in the John Day Dam tailrace (top) and a scatter plot of arrival hour of each released fish before or after midnight by date (bottom)

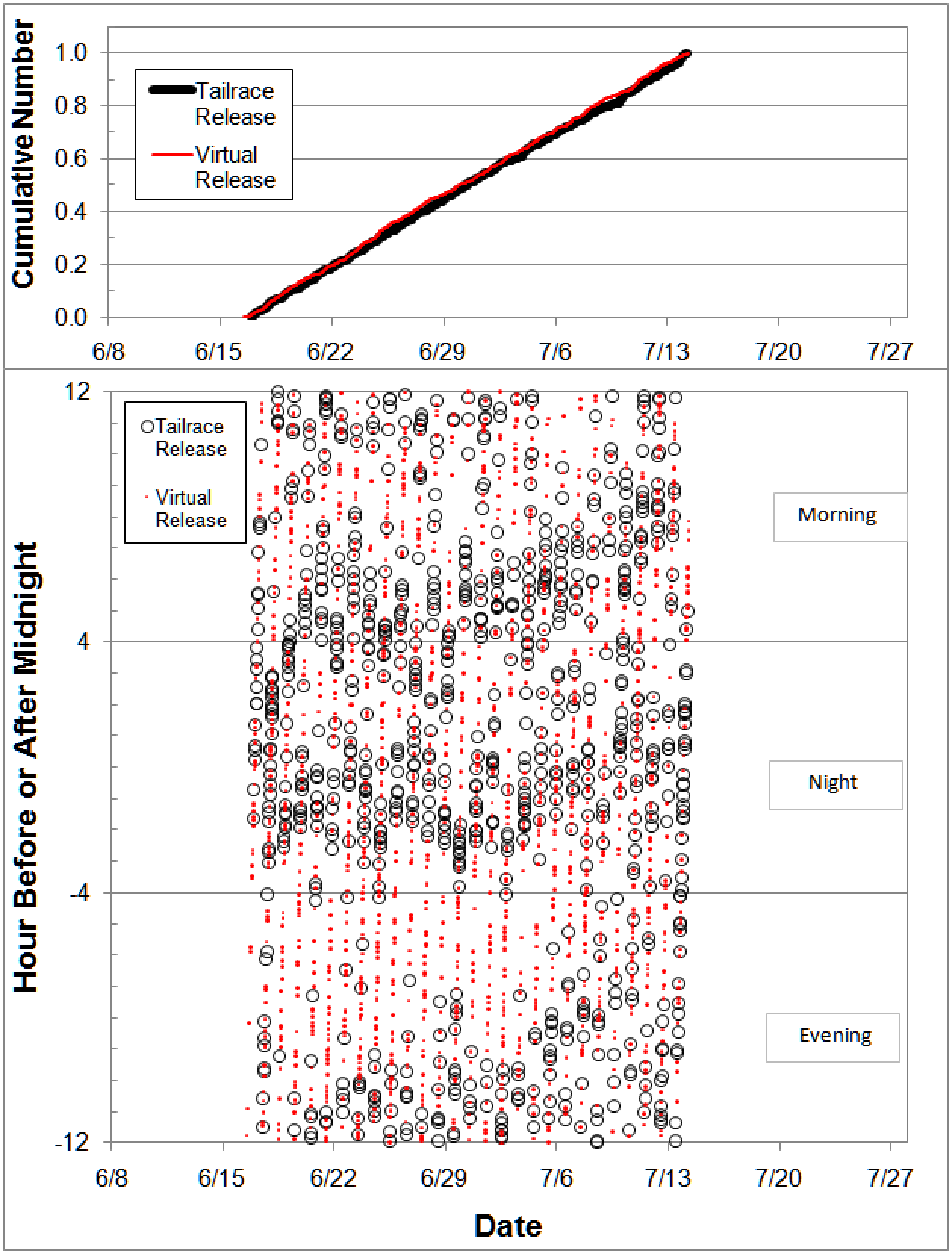

Figure N.3. Cumulative frequency of arrivals of tagged subyearling Chinook salmon smolts from virtual releases at John Day Dam and references releases in the John Day Dam tailrace (top) and a scatter plot of arrival hour of each released fish before or after midnight by date (bottom)

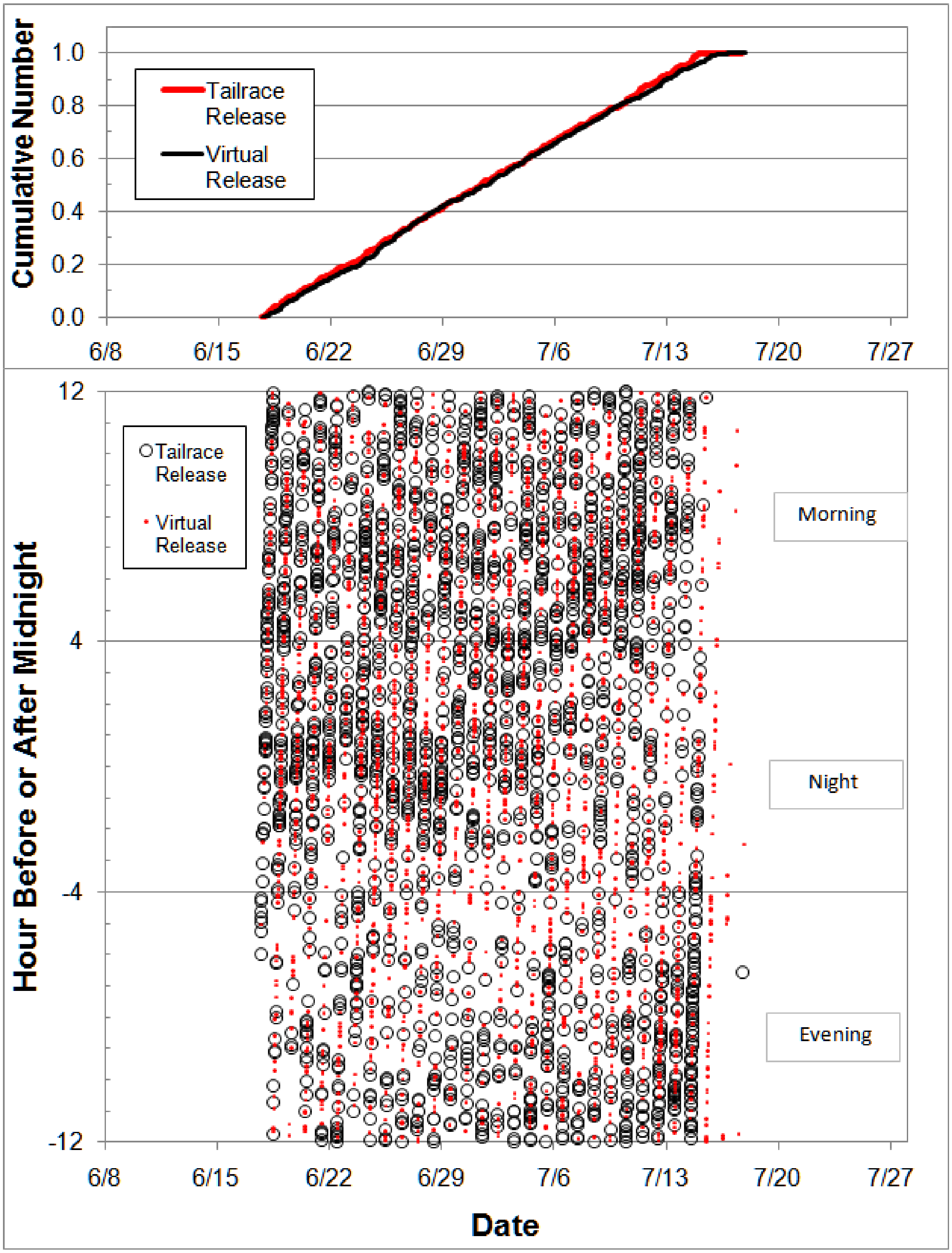

Figure N.4. Cumulative frequency of arrivals of tagged subyearling Chinook salmon smolts from virtual releases at The Dalles Dam and references releases in the The Dalles Dam tailrace (top) and a scatter plot of arrival hour of each released fish before or after midnight by date (bottom)

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