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Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival Proportions at John Day Dam, 2009

FINAL REPORT

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September 2011

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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, Sean Tackley, 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 the survival rate of juvenile salmonids migrating downstream through the Federal Columbia River Power System (FCRPS) continues to be a high priority for the USACE and the region. Many of these fish are from populations listed as threatened or endangered under the Endangered Species Act. Increasing survival rates is necessary to ensure sustainable salmon populations in the future and meet performance standards set forth in the 2008 Biological Opinion (BiOp) and 2008 Columbia Basin Fish Accords on operation of the FCRPS. The BiOp mandates that a 96% and 93% survival rate be achieved for spring and summer downstream migrating juvenile salmonids, respectively. At John Day Dam (JDA), 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, called a top-spill weir (TSW), and the dam as a 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 JDA to maximize the survival rate for juvenile salmonids.

This is the report of research for the acoustic telemetry evaluation of juvenile salmonids during 2009 at JDA. The study was conducted by the Pacific Northwest National Laboratory and the University of Washington for the U.S. Army Corps of Engineers (USACE) Portland District.

S.1 Objectives

The overall purpose of the acoustic-telemetry study at JDA during 2009 was to determine the best configuration and operation for JDA prior to conducting BiOp performance standard tests. The primary objective was to determine the best operation between 30% and 40% spill treatments. Route-specific, JDA forebay-to-TDA forebay, JDA-to-The Dalles Dam (TDA) forebay survival estimates, passage distribution, and timing/behavior metrics were used for comparison of 30% and 40% spill treatments. A secondary objective was to evaluate the performance of TSWs installed in spill bays 15 and 16 and to estimate fish survival rates and passage efficiencies under 30% and 40% spill-discharge treatments each season.

It was initially planned to conduct this study using a paired-release model to estimate survival. Prior to the start of the study, the decision was made to release fish only above JDA and use a single-release model to improve the chance of detecting a significant difference between the two spill treatments as well as passage distribution and timing metrics. The survival estimate for the single-release model was calculated from JDA to TDA forebay. The spill bays with TSWs installed and southernmost spill bays (spill bays 15–20) where closed during the 2009 summer study period because of excessive predation by gulls in the TSW outfall plume. The field study period began with fish releases on April 27 and ended on August 25, 2009, when at least 90% of the acoustic tags from the last release had died, as estimated from the 2009 tag-life study.

The study objectives and sub-objectives, applied separately to yearling Chinook salmon (CH1), steelhead (STH), and subyearling Chinook salmon (CH0) surgically implanted with acoustic tags at JDA during 2009, were to do the following:

1. Estimate survival rates[1] as follows:
    a. JDA-to-TDA forebay (from the dam face at JDA to TDA forebay array 2 km upstream of TDA) and route-specific estimates
    b. JDA forebay-to-TDA forebay (from the forebay array 2 km upstream of JDA to TDA forebay array 2 km upstream of TDA)
    c. JDA seasonal and day/night trends
    d. Association of JDA passage route and survival rates at TDA.
2. Estimate passage metrics and distributions as follows:
    a. Fish-passage efficiency (FPE), spill-passage efficiency (SPE), fish-guidance efficiency (FGE), TSW efficiency (TSWE), juvenile bypass system passage-efficiency (JBSE), spill-passage effectiveness (SPEF), and TSW effectiveness (TSWEF)
    b. Powerhouse horizontal distribution and the relationship between passage and discharge
    c. Spillway horizontal distribution
    d. Day/night trends in passage.
3. Characterize fish behavior as follows:
    a. Approach patterns and eventual passage routes
    b. Day/night behavior patterns
    c. Vertical distribution behavior patterns
    d. Travel times and forebay residence times.
4. Determine the effect of spill condition (30% versus 40% spill) on survival rates and passage efficiencies.

S.2 Methods

This study used the Juvenile Salmon Acoustic Telemetry System (JSATS). JSATS acoustic tags and passive integrated transponder (PIT) tags were surgically implanted in 3470 CH1 and 3471 STH in spring and in 3461 CH0 in summer 2009. Median lengths of tagged fish were: CH1 = 146 mm; STH = 212 mm; CH0 = 110 mm. Tagged CH1 and STH were released daily over a 29-day spring period (4/27 to 5/26/09) at Roosevelt, Washington. Similarly, CH0 implanted with acoustic transmitters were released in summer over a 29-day period (6/16 to 7/15/09) at Roosevelt, Washington (rkm 390).

To detect signals from fish tagged with JSATS acoustic transmitters for the JDA evaluation, six arrays of hydrophones were deployed. A dam-face cabled array was placed on the upstream side of JDA (rkm 349). Five arrays of autonomous receivers were deployed at river cross sections located 2 km upstream (rkm 351) and 2 km downstream (rkm 347) of JDA, 2 km upstream of TDA (rkm 311), 1.5 km upstream of Bonneville Dam (BON; rkm 236), and downstream of BON at Lady Island (rkm 192; Camas, Washington). The JDA forebay array was used to create a virtual release for fish known to have entered the forebay 2 km upstream of JDA to estimate forebay survival. The JDA dam-face array was used to

[1] See Section 2.1.3 for definitions.

create a virtual release for fish known to have passed the dam and to estimate JDA-to-TDA forebay and route-specific-passage survival rates based on three-dimensional (3D) and last-detection data. Time of last detection on the dam-face array minus the time of first detection on the forebay entrance array at JDA was used to estimate forebay residence time. TDA forebay array was the primary array for estimating the survival rate for tagged smolts passing through JDA. The BON forebay array was used as the secondary array for estimating the passage survival rate from JDA to TDA forebay. The first BON tailwater array near Lady Island was used as the tertiary array for estimating the product of survival and detection rates (λ) for tagged smolts passing through JDA.

Data from the receiving arrays were used to address the four main objectives. Single release-recapture methods using tagged fish regrouped at the JDA forebay array or at the dam-face array were applied to estimate the survival rates for each fish stock. (Paired-release estimates could not be made in 2009 because no tagged fish were released in the JDA tailrace.) Using the smolts known to have passed through a specific route at the dam, absolute survival rates from the dam entrance to TDA forebay array were estimated using a single release-recapture model. No tag-life corrections (after Townsend et al. 2006) were applied to the individual release Cormack-Jolly-Seber survival estimates because all fish passed the tertiary array before tag-life failure occurred. The route-specific passage data were used to estimate passage efficiencies and distributions. Fish behavior was assessed by 3D tracking of JSATS-tagged fish in the immediate forebay of JDA. The effects of spill condition (30% vs. 40% spill out of total project discharge) were statistically evaluated using the survival and passage efficiency data obtained within a randomized block design with 2-day treatments.

S.3 Results

S.3.1 Environmental Conditions

During the 2009 study period, mean daily project discharge was above the previous 10-year average in spring and early summer, but dropped below average during July. Forebay water temperatures were 1–2 degrees below the 10-year average most of spring and within 1 degree of the 10-year average most of summer, except for the last 1.5 weeks in July when they were 1–4 degrees above average. Run timing for the run-at-large of CH1 and STH both peaked in May 2009; 50% passed by May 17 and May 10, respectively. Run timing for the run-at-large of CH0 salmon peaked in late June 2009; 50% passed by July 1, 2009. Length frequency distributions of tagged and run-of-river juvenile salmon populations were very similar for all three runs in 2009.

S.3.2 JSATS Performance

The combined detection probability of the dam-faced array for each of three tagged fish runs was 96.3% for CH1, 95.6% for STH, and 97.9% for CH0. Detection probabilities for autonomous arrays were over 99% for arrays deployed upstream of TDA, 92 to 95% for the BON forebay array, 90 to 98% for the first tailwater reach below BON, and 92 to 95% for the second tailwater reach. For the BON forebay and tailrace arrays, detection probabilities were consistently higher for CH0 passing in summer (95 to 98%) than they were for CH1 (92%) and STH (90 to 92%) passing in spring 2009.

All acoustic tags in the tag-life study were active for the expected 23 days. Mean time to tag failure was 30 ± 1.0 (standard error) days. The range in time until tag failure was from 24 to 49 days. All stocks of fish passed the tertiary array before there were any tag failures due to battery life.

A major assumption of the survival models used in this study is that upstream detections do not affect downstream detection or survival probabilities. This assumption is assessed using Burnham Tests 2 and 3. For CH1, none of the results for Test 2 were significant, and out of 74 runs of Test 3, 6 (8%) were significant at $\alpha = 0.1$. For STH, 4 of 69 runs (6%) for Test 2 and 4 of 69 for Test 3 (6%) were significant. For CH0, 2 of 53 results (4%) for Test 2 were significant and, for Test 3, 2 of 53 (4%) were significant at $\alpha = 0.1$.

S.3.3 Survival Rates

For JDA as a whole, JDA-to-TDA forebay single-release estimates of survival rates were highest for CH1 (0.927) and STH (0.953) and lowest for CH0 (0.839) (Table S.1). The highest survival rates were at the juvenile bypass system (JBS; 0.975 for CH1, 0.966 for STH, and 0.908 for CH0). The TSW had the second highest route-specific survival rates in spring (0.951 for CH1 and 0.963 for STH; the TSW was not operated in summer during the CH0 migration). The lowest survival rates were observed at the turbine route. Generally, survival rates over successive 2-day periods for all three tagged populations tended to decrease slightly as the season progressed. Survival estimates for STH were generally higher during night than during day regardless of route of passage.

Table S.1. Single-Release Estimates of JDA-to-TDA Forebay (FB) and Route-Specific Survival During 2009

	CH1		STH		CH0	
Route	Single\Release	½ 95%CI	Single Release	½ 95%CI	Single Release	½ 95% CI
JDA-to-TDA FB	0.927	0.010	0.953	0.008	0.839	0.014
Non-TSW	0.913	0.014	0.936	0.016	0.847	0.016
TSW	0.951	0.014	0.963	0.010	--	--
Turbine	0.851	0.047	0.824	0.080	0.749	0.039
JBS	0.975	0.016	0.966	0.014	0.908	0.031
CI = confidence interval						

S.3.4 Effect of Spill Condition on Survival and Passage

During spring 2009, dam operators were able to meet spill treatment requirements for the first five of eight blocks in spring. Compared to spill treatments that occurred during the first five blocks that closely met prescribed treatments, a one-tailed paired t-test showed that survival rates for CH1 were significantly ($P = 0.0330$) higher during the 30% spill treatment than they were during the 40% spill treatment. The survival difference for STH was not significant for the 5 block test ($P = 0.1430$). During summer, the prescribed spill treatments were met reasonably well during the last seven blocks and very well during the last five blocks of the summer test. The TSWs and spill bays 17–20 were closed in summer and water was spilled only through spill bays 2–14. This operational change was the result of hydraulic patterns that developed below the TSW bays and spill bays 17–20 that aided predatory birds in their search for juvenile fish, reducing survival rates of juvenile salmon through the dam. Survival rates from JDA-to-TDA forebay for CH0 were about 84–85% for both the 30% and 40% spill treatments and were not statistically different for either the five (P=0.2916) or seven block (P=0.4535) groups. Spill- passage efficiency was higher under the 40% spill treatment than under the 30% spill treatment, but the opposite was true for all other fish-passage metrics (Table S.2).

Table S.2. Estimates of Survival from JDA to TDA Forebay, Passage Efficiencies and Effectiveness by Spill Condition During 2009. 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. The TSW was not operated during summer 2009.

	CH1		STH		CH0	
Metric	30%	40%	30%	40%	30%	40%
JDA-to-TDA FB	0.930	0.924	0.960	0.946	0.847	0.834
FPE	0.926	0.943	0.968	0.980	0.832	0.854
FGE	0.694	0.606	0.887	0.894	0.451	0.397
SPE	0.759	0.854	0.715	0.812	0.695	0.758
TSWE	0.315	0.226	0.485	0.518	--	--
JBSE	0.168	0.088	0.253	0.168	0.138	0.096
SEF	2.513	2.207	2.369	2.097	2.318	2.111
TSWEF	4.349	2.980	6.700	6.835	--	--

S.3.5 Passage Metrics and Distributions

Passage metrics were highest for STH and lowest for CH0 (Table S.3). Of total project passage, 7% CH1, 3% STH, and 15% CH0 passed through turbines. Passage generally was highest at the end units of the powerhouse (T1–3 and T14–16). For each run, regressions of number of tagged fish passing into each unit in spring on unit-specific discharge were significant (P < 0.0001) with discharge explaining a majority of the variation in passage into the powerhouse. Spillway horizontal distributions during spring were skewed with highest passage through the TSWs in spill bays 15 and 16. During summer, passage was fairly uniform at the open bays (S2–14). Total passage and spillway passage rates for CH1 and STH were higher during the day than they were at night, while passage rates for the powerhouse (JBS and turbines) were higher at night than during the day. For CH0, passage rates for the powerhouse, turbines, and JBS were higher at night than during the day; the opposite was true at the spillway.

Table S.3. Summary of Passage Efficiency and Effectiveness Data During 2009 at JDA. Confidence intervals are provided in corresponding tables in the main body of the report. The TSW was closed during the CH0 migration in summer 2009.

Metric	CH1	STH	CH0
FPE	0.934	0.974	0.845
SPE	0.806	0.763	0.732
FGE	0.662	0.890	0.422
TSWE	0.271	0.501	--
JBSE	0.128	0.211	0.113
SPEF	2.366	2.239	2.211
TSWEF	3.663	6.781	--

S.3.6 Fish Behavior

The approach of CH1 at JDA during 2009 was as follows: 40% at the powerhouse, 13% at the skeleton bays, and 47% at the spillway (Figure S.1a). Of the tagged CH1 first detected approaching the powerhouse or skeleton bays, 66% eventually moved north and passed at the spillway. Fish approaching at the spillway were more likely to pass through the dam at the spillway (46% of total approach) than at the powerhouse (1.6% of total approach).

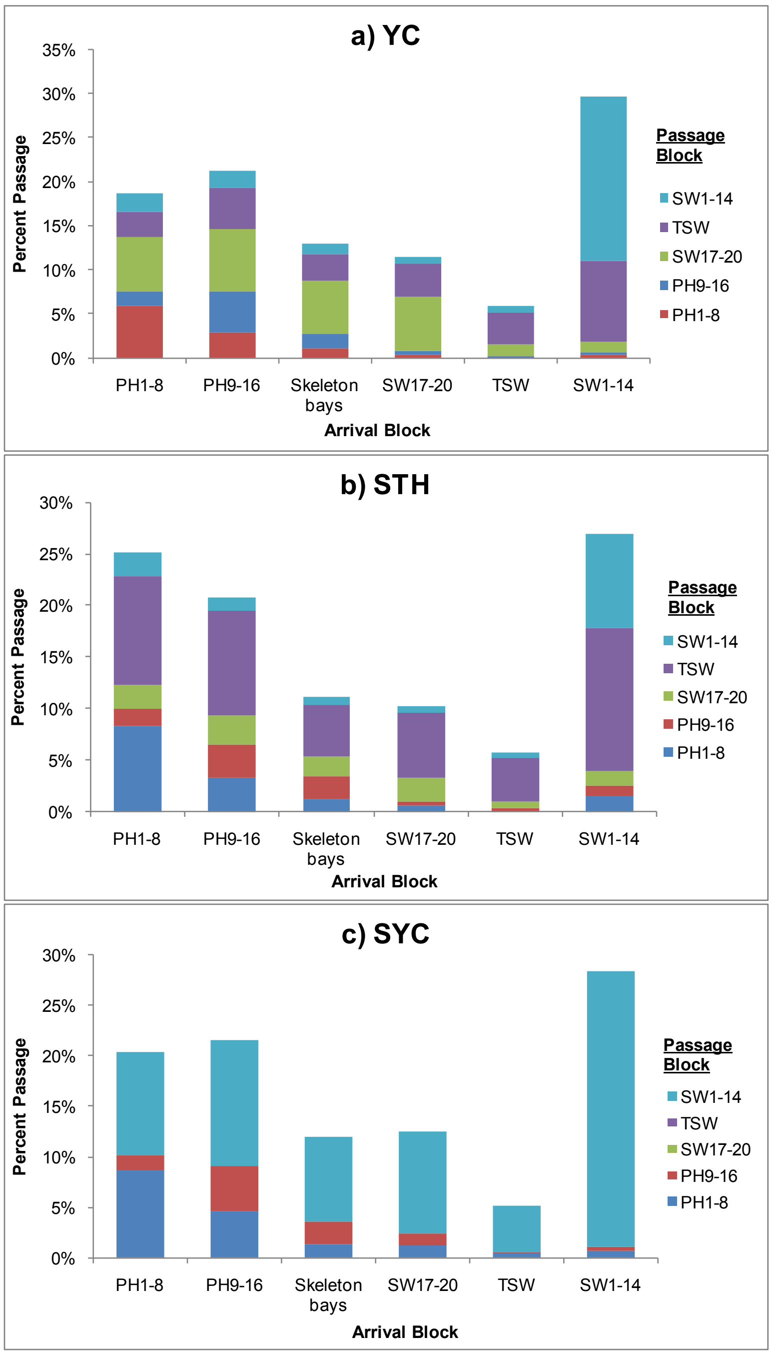

Figure S.1. Fish Behavior Expressed as Approach and Passage Patterns at the Forebay of JDA, 2009

The forebay approach pattern for STH was 46% at the powerhouse, 11% at the skeleton bays, and 43% at the spillway (Figure S.1b). Of the tagged STH first detected approaching the powerhouse or skeleton bays, 65% moved north and passed at the spillway. As with CH1, STH approaching at the spillway were more likely to pass through the dam at the spillway (39% of total approach) than at the powerhouse (3.8% of total approach).

For CH0, 42% approached in the forebay of the powerhouse, 12% at the skeleton bays, and 46% at the spillway forebay (Figure S.1c). Of the CH0 approaching at the powerhouse and skeleton bays, 58% ended up passing at the spillway even with the TSWs closed. On the other hand, few CH0 approaching the spillway moved south to pass at the powerhouse (4.1% of total approach).

On a day/night basis, tagged fish passing the powerhouse at night tended to approach at the powerhouse. However, during daytime fish approaching the powerhouse were more likely to migrate to the spillway and pass there rather than pass at the powerhouse. A similar pattern held for fish approaching the skeleton bay area. Upon approaching the spillway, tagged fish displayed a tendency to pass there during the day; this pattern was also evident at night.

Vertical distribution in the forebay was surface oriented with most tagged fish in the surface 5 to 7 m of the water column. Steelhead were the shallowest and CH0 the deepest of the three tagged populations. Fish approaching the powerhouse (within 75 m) tended to be about 5 m deeper than those approaching the spillway.

For the project as a whole, median residence times in the JDA forebay were 2.9 hours for CH1, 5.5 hours for STH, and 3.8 hours for CH0 (Table S.4). Residence times were shortest for fish passing at the TSW and longest for fish passing at the powerhouse.

Table S.4. Residence Times (hours) in the JDA Forebay (defined as the 2 km upstream of the dam)

	CH1		STH		CH0	
Route	Median	Mean	Median	Mean	Median	Mean
Project	2.9	4.8	5.5	8.9	3.8	7.2
JBS	4.0	5.8	7.5	10.2	3.8	8.2
Turbine	2.7	4.6	6.1	13.3	4.6	9.0
TSW	2.6	4.5	4.8	8.2	--	--
Spillway (non-TSW)	3.7	6.3	5.5	8.8	3.6	6.7

S.4 Conclusions

The main conclusions from the acoustic telemetry evaluation of survival rates, fish-passage efficiencies and distributions, fish behavior, and effects of spill condition for CH1 salmon, STH, and CH0 at JDA during 2009 are as follows.

- Survival Rates
  - For 2009, single-release estimates of JDA-to-TDA forebay- passage survival rates for CH1 (0.927 ± 0.010[1]) and STH (0.953 ± 0.008) did not meet the 96% performance standard set forth in the 2008 BiOp for yearling migrants. Estimates for CH0 (0.839 ± 0.014) are below the BiOp standard of 93% for subyearling migrants.
  - The passage route with the highest survival rate is the JBS (0.908 to 0.975) and, the turbines had the worst route survival (0.749 to 0.851).
- Passage Efficiencies and Distributions
  - Fish-passage metrics are generally highest for STH and lowest for CH0. Proportionately more CH0 than CH1 or STH pass the dam via turbines.
  - Fish-passage rates at individual turbine units are strongly, positively correlated with unit-specific discharge.
- Fish Behavior
  - Spill and TSW operations attracted downstream migrant juvenile salmonids to the spillway. 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, relatively few smolts approaching the spillway passed at the powerhouse.
  - Fish approaching (within 100 m of the concrete) the spillway have the shortest median residence time of all approach paths (4 to 20 minutes, depending on fish run). The longest residence time is for fish approaching the powerhouse and then passing through the dam at the spillway or vice versa (2 to 7 hours).
  - Downstream migrants are surface-oriented, being distributed in the upper portion of the water column (< 5–7 m) on approach to the dam.
- Effect of Spill Condition (30% versus 40% spill)
  - There is no statistically significant difference in fish performance between the two treatments when comparing the 30% versus 40% spill conditions over the entire study. Survival, however, was significantly higher at 30% spill for CH1 for the first five blocks when spill treatments were maintained accurately. Survival estimates, passage efficiencies, and fish behaviors are similar between the two spill conditions. The increase in spill discharge from 30% to 40% of total water discharge through the dam basically serves to pass incrementally more fish at non-TSW bays and incrementally fewer fish at the TSW bays.
- TSW Performance
  - In terms of fish collection, the TSWs perform well when they are operated. Using about 20 kcfs, the TSW bays passed half of the STH and a quarter of the CH1, respective to totals passing through JDA.

[1] ± ½ 95% confidence interval.

– As intended in the TSW design and operation, 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).

S.5 Recommendations

Based on the 2009 results, recommendations include the following:

- Assuming there would be no adverse impact on tailrace passage conditions, the TSWs should be moved closer to the powerhouse to maximize the collection of fish approaching the powerhouse and thereby minimize turbine passage.
- To date, there is only 1 year (2008) of TSW evaluation for CH0. Performance of the TSW during summer for CH0 should be addressed in future studies.
- After due diligence examination of tailrace hydraulics in a physical scale model, a comparison of 20% versus 40%, 10% versus 30%, or other spill treatment with a larger range might be considered for future studies.

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Advanced Telemetry Systems (ATS), Inc. manufactured the 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

2D	two-dimensional
3D	three-dimensional
A1CR351	John Day Dam forebay entrance array
A2CR346	John Day Dam tailwater egress array
A3CR311	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
A5CR192	First Bonneville tailwater array; John Day Dam tertiary survival-detection array; The Dalles Dam secondary survival-detection array
A6CR113	Second Bonneville Dam tailwater survival-detection array; The Dalles Dam tertiary survival-detection array
AT	acoustic telemetry
ATS	Advanced Telemetry Systems, Inc.
B2	(Bonneville) Powerhouse 2
BiOp	Biological Opinion
BON	Bonneville Dam
°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
DSP	digital signal-processing card
FCRPS	Federal Columbia River Power System
FPE	fish-passage efficiency
FGE	fish-guidance efficiency (in-turbine screens)
FPGA	field-programmable logic gate array
ft	foot(feet)
g	gram(s)
GPS	global positioning system
h	hour(s)
HA	hydroacoustic
JBS	juvenile bypass system
JBSE	juvenile bypass system-passage efficiency
JDA	John Day Dam

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
RT	radio telemetry
s	second(s)
SPE	spill-passage efficiency
SEF	spill-passage effectiveness
SFO	surface-flow outlet
SMF	Smolt Monitoring Facility (John Day Dam)
STH	steelhead
SW	spillway or spillway block
CH0	subyearling Chinook salmon
TDA	The Dalles Dam
TOA	time of arrival
TOAD	time of arrival difference
TSW	top-spill weir
TSWE	top-spill weir-passage efficiency
TSWEF	top-spill weir-passage effectiveness
µPa	micro-Pascal
µs	micro-seconds
USACE	U.S. Army Corps of Engineers
UW	University of Washington
WEL	Wells Dam
CH1	yearling Chinook salmon

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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. The BiOp mandates that a 96% and 93% survival rate be achieved for spring and summer downstream migrating juvenile salmonids, respectively. At John Day Dam (JDA), 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 determine the 1) best configuration and operation for JDA prior to conducting BiOp performance standard tests by evaluating fish passage and survival at 30% and 40% spill treatments and 2) the performance of the prototype SFO. The Portland District and regional fisheries managers will use the data to adaptively manage the configuration and operation of JDA to maximize the survival rate for juvenile salmonids.

This is the report of research for the acoustic telemetry evaluation of juvenile salmonids during 2009 at JDA (Figure 1.1). The study also provides estimates of passage survival rates for The Dalles Dam (TDA) from the forebay of TDA to the Bonneville Dam (BON) forebay. The study was conducted by the Pacific Northwest National Laboratory (PNNL) and the University of Washington (UW) for the USACE Portland District.

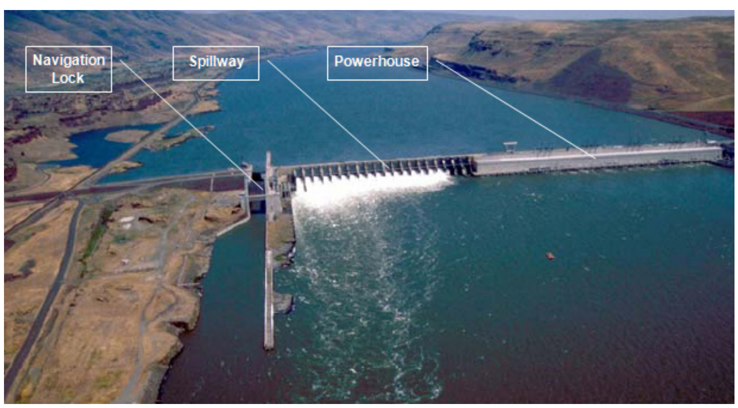

Figure 1.1. John Day Dam on the Columbia River

1.1 Previous Survival and Passage Studies

Radio telemetry was first used at JDA 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 (yearling Chinook salmon [CH1], steelhead [STH], and subyearling Chinook salmon [CH0]), estimates of survival rates tend to be higher at the spillway than at the powerhouse, with whole-dam estimates in between as determined in radio telemetry studies in 2000, 2002, and 2003 (Table 1.1). The differences in survival rates between the powerhouse and spillway were greater for CH1 and CH0 than for STH (Table 1.1). These data indicate that the BiOp performance standard would not be met under previous conditions.

Table 1.1. Radio-Telemetry Estimates of Survival Rates for Three Salmonid Stocks Passing Routes at JDA During 2000, 2002, and 2003 and Acoustic Telemetry Estimates During 2008. The ranges are for point estimates under different treatments. Point estimates ± ½ 95% confidence intervals were provided for 2008 because there were no significant differences between spill treatments.

Study Year (Passage Route)	CH1	STH	CH0	Reference
2000 (Dam)	93.7 to 98.6%	90.5 to 98.8%	---	Counihan et al. 2002b
2002 (Spillway)	99.3 to 100%	93.2 to 95.8%	98.5 to 100%	Counihan et al. 2006a
2002 (Powerhouse)	77.8 to 83.2%	89.9 to 93.0%	86.6 to 96.6%	Ibid
2002 (Dam)	92.9 to 96.3%	91.5 to 94.0%	92.8 to 99.2%	Ibid
2003 (Spillway)	93.4 to 93.9%	---	90.1 to 95.5%	Counihan et al. 2006b
2003 (Powerhouse)	76.4 to 82.0%	---	71.9 to 72.2%	Ibid
2003 (Dam)	92.2 to 94.0%	---	84.5 to 88.6%	Ibid
2008 (Concrete)	95.7 ± 1.3%	98.6 ± 1.7%	86.1 ± 1.7%	Weiland et al. 2009
2008 (Non-TSW Spillway)	96.6 ± 1.1%	98.5 ± 2.3%	84.4 ± 4.4%	Ibid
2008 (TSW Spill Bays)	96.1 ± 2.0%	99.2 ± 2.3%	92.7 ± 1.6%	Ibid
2008 (Turbine)	85.5 ± 3.4%	74.9 ± 6.2%	72.8 ± 5.6%	Ibid
2008 (JBS)	97.6 ± 4.5%	100.0 ± 1.9%	97.3 ± 5.7%	Ibid

At least six studies have estimated fish-passage efficiency and spill efficiency at JDA (Table 1.2). The radio and acoustic telemetry studies indicated that fish-passage efficiency ranged from 88% to 97% for STH, 82% to 93% for CH1, and from 70% to 84% for CH0. A hydroacoustic study in 2002 estimated a similar range of fish-passage efficiency for spring stocks but the estimate for CH0 (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) provide 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 JDA. 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 CH0 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 JDA. 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.

Table 1.2. Some Radio Telemetry (RT), Acoustic Telemetry (AT), and Hydroacoustic (HA) Estimates of Fish-Passage Efficiency and Spill-Passage Efficiency for JDA. See Section 2.6.1 for definitions of metrics. The ranges are for point estimates under different study treatments.

Study Year/Type	CH1	STH	CH0	Reference
Fish-Passage Efficiency				
1999 RT	82 to 88%	90 to 94%	---	Hansel et al. 2000
2000 RT	90 to 92%	91 to 93%	---	Beeman et al. 2003
2002 RT	84 to 85%	88 to 91%	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
2008 AT	91 to 93%	97 to 97%	82 to 84%	Weiland et al. 2009
Spill-Passage Efficiency				
1999 RT	53 to 66%	45 to 53%	---	Hansel et al. 2000
2000 RT	75 to 86%	61 to 79%	---	Beeman et al. 2003
2002 RT	48 to 57%	54 to 64%	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
2008 AT	76 to 77%	72 to 76%	66 to 71%	Weiland et al. 2009

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 top 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 JDA. 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 and to increase the fish-passage efficiency and passage survival rates of downstream-migrating juvenile salmonids at JDA.

The 2008 acoustic telemetry study showed that the survival rates of CH1 (96.1%), STH (99.6%), and CH0 (92.7%) were high through the TSWs and second only to rates for smolts passing through the JBS. Using about 20 kcfs, the TSW bays passed half of the STH, a quarter of the CH1, and a fifth of the CH0 of the respective total number of fishes passing JDA. 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.

The 2008 study also showed that there were no significant differences in survival rates between post-hoc 30% and 40% spill conditions at JDA. The only metric that showed a significant difference was spill-passage effectiveness, and it was significantly higher at 30% spill than it was at 40% spill for STH and for CH0. 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. 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. Because the 30% and 40% spill treatment conditions were largely unmet during the 2008 study period, the study was repeated during 2009.

1.3 Research Objectives

The overall purpose of the acoustic telemetry study at JDA during 2009 was to estimate fish survival rates and passage efficiencies under 30% and 40% spill-discharge treatments each season, and to evaluate the performance of TSWs installed in spill bays 15 and 16. The TSWs were not operated during the summer study because of excessive predation by gulls in the TSW outfall plume. Randomized block experimental designs were developed for spring and summer, and each 4-day block was designed to begin with one 2-day treatment randomly selected to be 30% or 40% spill discharge followed by the alternate treatment. The field study period began with fish releases on April 27 and ended on August 25, 2009, when 90% of the acoustic tags in fish had died, as estimated from the 2009 tag-life study.

The study objectives and sub-objectives, applied separately to acoustic-tagged CH1, STH, and CH0 at JDA during 2009, were to do the following:

1. Estimate survival rates[1] as follows:
   a. JDA-to-TDA forebay(from the dam face at JDA to TDA forebay array 2 km upstream of TDA) and route-specific estimates
   b. JDA forebay-to-TDA forebay (from the forebay array 2 km upstream of JDA to TDA forebay array 2 km upstream of TDA)
   c. JDA seasonal and day/night trends
   d. Association of JDA passage route and survival rates at TDA.
2. Estimate passage metrics and distributions as follows:
   a. Fish-passage efficiency (FPE), spill-passage efficiency (SPE), fish-guidance efficiency (FGE), TSW efficiency (TSWE), juvenile bypass system-passage efficiency (JBSE), spill effectiveness (SEF), and TSW effectiveness (TSWEF)
   b. Powerhouse horizontal distribution and the relationship between passage and discharge
   c. Spillway horizontal distribution
   d. Day/night trends in passage.
3. Characterize fish behavior as follows:
   a. Approach patterns and eventual passage routes
   b. Day/night behavior patterns

[1] See Section 2.1.3 for definitions.

c. Vertical distribution behavior patterns

d. Travel times and forebay residence times.

4. Determine the effect of spill condition (30% versus 40% spill) on survival rates and passage efficiencies.

1.4 Study Area

The study area for the acoustic telemetry evaluation of survival and passage at JDA during 2009 included 198 river kilometers (rkm) of the lower Columbia River from Roosevelt, Washington (rkm 390), where all tagged fish were released, to Lady Island (rkm 192) near Camas, Washington (Figure 1.2). JDA is located 41.4 km downstream of the fish release transect. JDA 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). The skeleton bays are in between the powerhouse turbine intakes and the spillway. Throughout this report, references are made to locations on the river that are varying distances apart, so a quick reference was created to clarify distances between locations (Table 1.3).

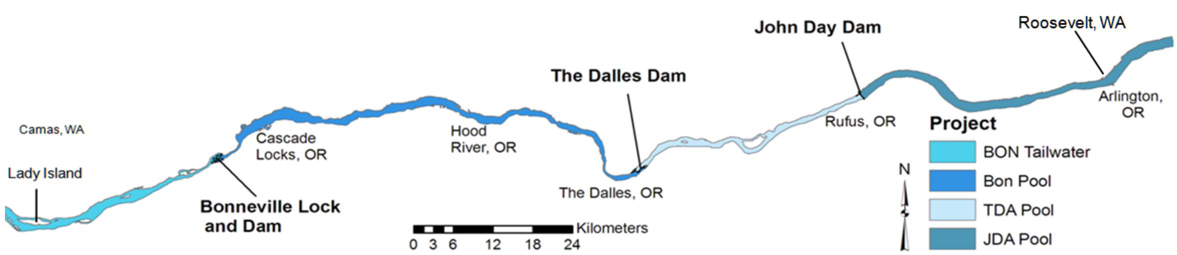

Figure 1.2. 2009 Study Area on the Columbia River from Roosevelt, Washington, to Camas, Washington

Table 1.3. Lookup Table to Determine Distances (km) Between Locations Referenced in this Study

Location	Study Function	Distance Upstream of Columbia River Mouth (km)	Roosevelt, WA	A1CR351	JDA	A2CR346	A3CR311	TDA	A4CR236	BON	A5CR192	A6CR113
			390	351	349	346	311	309	236	235	192	113
Roosevelt, WA	Release – Spr & Sum	390	0	39	41	44	79	81	154	155	198	277
A1CR351	Forebay virtual Release	351		0	2	5	40	42	115	116	159	238
JDA	Effects	349			0	3	38	40	113	114	157	236
A2CR346	Egress rates	346				0	35	37	110	111	154	233
A3CR311	JDA primary $\hat{S}$; Forebay virtual release	311					0	2	75	76	119	198
TDA	Effects	309						0	73	74	117	196
A4CR236	JDA secondary $\hat{S}$; TDA primary $\hat{S}$	236							0	1	44	123
BON	Effects	235								0	43	122
A5CR192	JDA tertiary (λ); TDA secondary $\hat{S}$	192									0	79
A6CR113	TDA tertiary (λ)	113										0

JDA has a juvenile bypass system (JBS) that uses intake screens to divert fish out of turbine intakes and convey them through the dam to the tailrace. Basically, fish are diverted by submerged traveling screens from the upper part of the powerhouse turbines into the gatewell slots. They then pass through one of two gatewell orifices per gatewell 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 Smolt Monitoring Facility (SMF) or to an outfall pipe discharging into the tailrace (Figure 1.3). At the SMF, fish are sampled as part of the regional Smolt Monitoring Program. Fish for the 2009 JDA acoustic-telemetry study were obtained from the SMF.

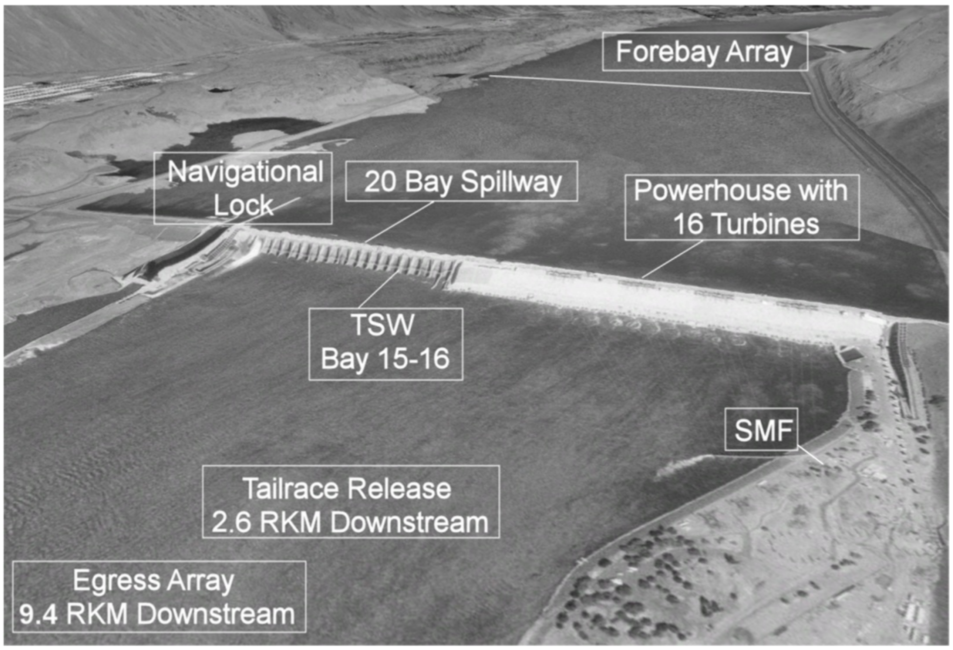

Figure 1.3. Aerial View of John Day Dam

At JDA, TSW SFOs were installed at spill bays 15 and 16. The TSWs are basically weirs formed by a stop log assembly that water flows over when the spill gates are raised (Figure 1.4). TSW discharge per bay is about 10,000 cfs. The TSWs create a flow field in the forebay that downstream migrants can discover and use to pass the dam instead of sounding through turbines. Spill at adjacent bays helps the tailrace egress conditions for fish in the TSW plume. (Overall design criteria are shown in Table 1.4).

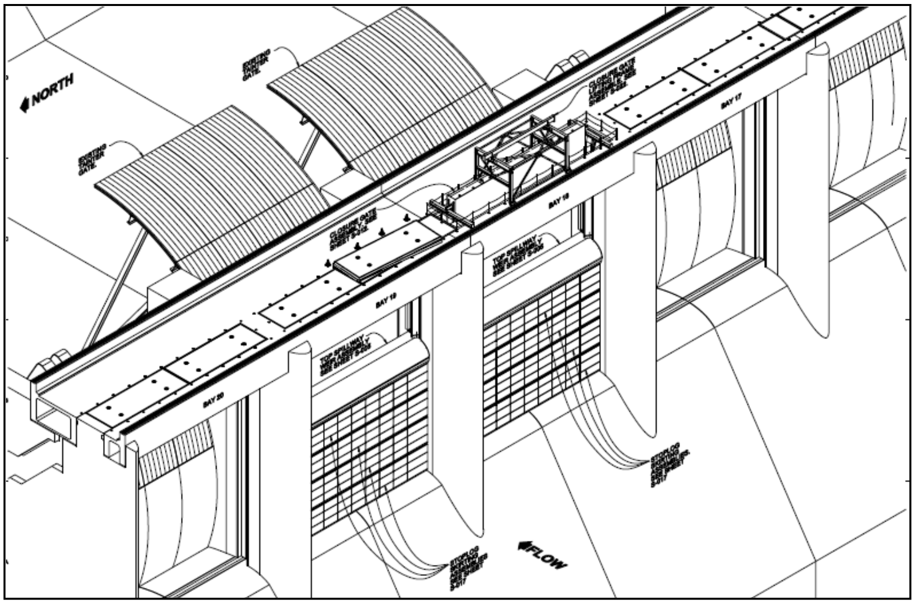

Figure 1.4. Schematic of TSWs at John Day Dam (provided by S. Askelson, USACE)

Table 1.4. Excerpt from an Engineering Design Document for the TSW (provided by S. Askelson, USACE)

ENGINEERING DESIGN SHEET
PROJECT: John Day TSW
SUBJECT: TSW Shape Design Progression

OFFICE SYMBOL: CENWP-EC-HD
COMPUTED BY: SKEA DATE: 10-MAY-07
SHEET: 1 OF: 3
CHECKED BY:

During the Design of the design of the John Day TSW, the overall guiding design criteria were as follow:
* design for approximatly 10 kcfs at typical forebay elevations during the fish passage season
* minimize the impact angle (angle created between the TSW nappe and the ogee upon impact)
* minimize the backroller pool formed by the nappe impact
* minimize areas of potential flow separation along the crest of the TSW
* provide the "smoothest" flow acceleration approaching the TSW device in the forebay

Based on hourly stage readings for juvenile fish migration passage period extending from 1 March through 30 November (period of record: 1995-1999) at John Day the forebay exceedance is as follows:

Percent Exceedance	Stage (ft)
MAX	267.6
1	265.3
5	264.7
10	264.5
20	264.3
30	264.1
40	264.0
50	263.9
60	263.7
70	263.6
80	263.3
90	263.0
95	262.6
99	261.3
99.9	258.5
MIN	257.0

Based on this information, the "design" forbay elevation was selected as 264 ft, but the TSW would be evaluated at forebay elevations from 257 ft through 268 ft (the entire operating range of the John Day forebay).

The TSW is expected to provide acceptable conditions from forebay elevation 262 ft to 268 ft, but has been "optimized" for a forebay elevation of 264 ft. The forebay elevation at John Day is 264 ± 1 ft for more than 85% of the juvenile passage season.

Based on previous TSW work at McNary (NWW), it was determined to achieve a 10 kcfs total flow rate at a forebay elevation of 264 ft, the crest elevation of the TSW would need to have approximatly 14 ft of head, thus setting the crest elevation at an elevation of 250 ft.

1.5 Report Contents

The ensuing sections of this report present the study materials and methods (Section 2.0). The results are in Section 3.0 and the discussion, conclusions, and recommendations are in Section 4.0. References may be found in Section 5.0. The four appendices contain tagging data tables (Appendix A), hydrophone locations (Appendix B), detection probabilities and capture histories (Appendix C), and results of Burnham Tests 2 and 3 (Appendix D).

2.0 Materials and Methods

In this section, we describe the materials and methods used for the 2009 acoustic telemetry evaluation at JDA. 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 rates. 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 rates, 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 BON (Faber et al. 2001) and TDA (Cash et al. 2005). The JSATS has been used below BON in the lower Columbia River and 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 JDA and Camas, Washington (a 150-km reach of the river), to estimate turbine passage and tailwater survival rates at JDA, and dam-passage and tailwater-passage survival rates for TDA and BON (Ploskey et al. 2007). The first deployment of the JSATS cabled system was in 2007 at the BON spillway to estimate route-specific passage and survival rates (Ploskey et al. 2008). In 2008, acoustic telemetry route-specific survival studies were successfully conducted at three sites on the lower Columbia River: JDA (Weiland et al. 2009), BON spillway (Ploskey et al. 2009), and BON second powerhouse (Faber et al. 2009).

2.1 Study Context

The study context includes water discharge and temperature conditions, 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 JDA and provided weekly by JDA operators. The 5-minute discharge data for the entire dam and spillway were averaged by day and plotted with daily averages for the previous 10-year period to provide some historical perspective for 2009 observations. Average water discharge and forebay water temperature data from 1999 through 2008 were downloaded from the DART (Data Access in Real Time) website (http://www.cbr.washington.edu/dart).

2.1.2 Spill Treatments

The effects of 30% and 40% spill treatments on fish-passage and survival rates during spring and summer study periods according to a randomized block experimental design (Figures 2.1 and 2.2, respectively) were evaluated. The design called for 4-day blocks with each 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. Performance metrics included FPE, SPE and SEF, TSWE and TSWEF (spring runs only), and estimates of JDA to TDA forebay-passage survival rate.

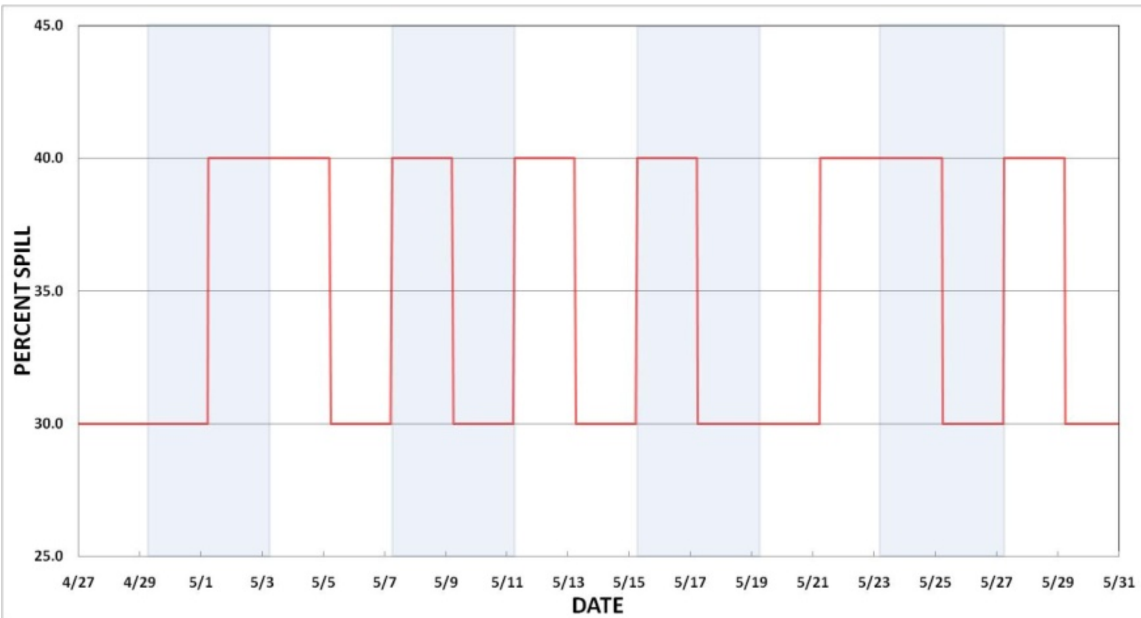

Figure 2.1. Spill Treatment Schedule at JDA from April 29 Through May 31, 2009. The design for spring 2009 called for eight treatment blocks with two treatments per block.

2.1.3 Definitions

Single-release reach survival rates by the upstream and downstream boundaries of the reach of interest are defined. The following additional definitions are needed to clarify the survival metrics:

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 JDA and TDA were 2 km upstream of the dam face. The downstream boundary is the upstream face of the dam, where cabled arrays for tracking fish were installed.

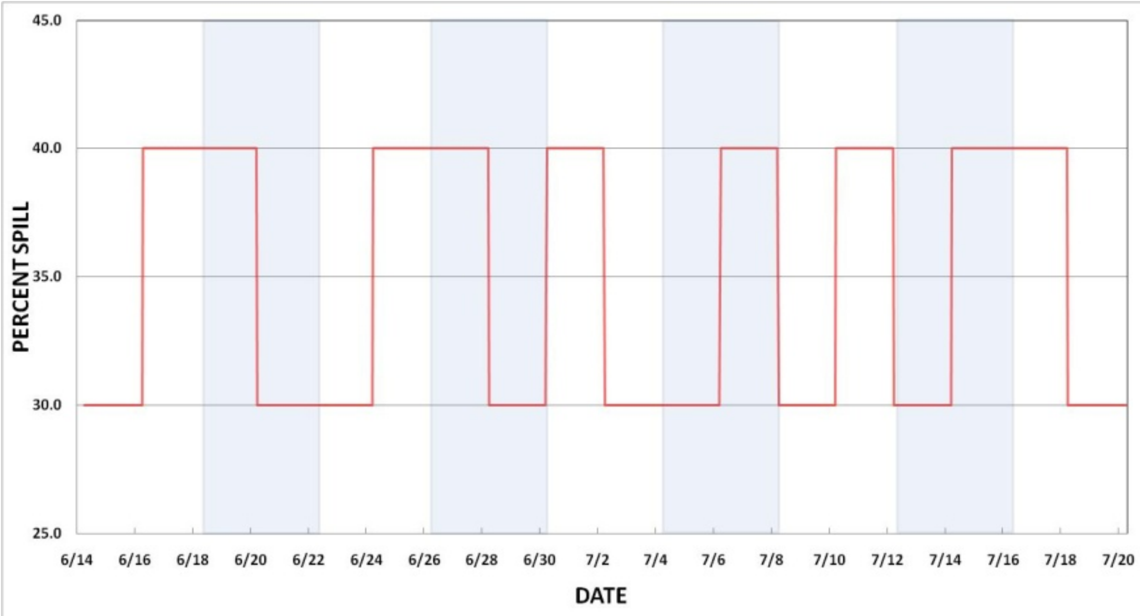

Figure 2.2. Spill Treatment Schedule at JDA from June 14 Through July 20, 2009. The design for summer 2009 called for nine treatment blocks with two treatments per block.

- ***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.
- ***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, TDA pool extends from TDA upstream to near the tailrace of JDA, although it also could be referred to as the tailwater of JDA. In this study, the only release site for fish was 41 km upstream of JDA instead of 121.4 km upstream in the McNary tailrace so the pool was truncated to 34% of the full length to minimize unnecessary losses of fish in the long JDA pool.
- ***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.
- ***Project-passage survival rate*** normally is defined as the probability of fish surviving when passing from the upstream boundary of the pool upstream of a dam to the downstream boundary of the tailrace of the dam. A traditional estimate of project-passage survival rate was not made because the JDA pool was truncated to 34% of its full length and there were no tailrace reference releases in 2009.
- ***Dam-passage survival rate*** normally is the probability of fish surviving when passing from the upstream boundary of the forebay to the downstream boundary of the tailrace and accounts for losses in the forebay, all routes of passage, and in the tailrace. In this study, there were no tailrace reference releases, so dam-passage survival included fish losses in the forebay, dam, tailrace, and tailwater down to the TDA forebay entrance array 2 km upstream of TDA, defined as JDA forebay-to-TDA forebay in this report.

- ***Concrete-passage survival rate*** normally is defined as 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 or tailwater. This is how the 2008 BiOp defines the dam-passage survival rate. The JDA concrete-passage survival rate in this study was based on a single-release model because there were no tailrace reference releases of fish. Therefore, the concrete-passage probability by necessity included losses of fish during route-specific passage, tailrace passage, and JDA tailwater passage down to the TDA forebay entrance array 2 km upstream of TDA, defined as JDA-to-TDA forebay in this report.
- ***Passage-route survival rate*** normally is defined as 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). However, in this study there were no reference releases of fish, so the passage-route survival probability included losses of fish during route-specific, tailrace, and JDA-tailwater passage. Passage routes at JDA included the JBS, turbines, and the spillway (also broken down into TSW spill bays and non-TSW spill bays in spring).

2.2 Fish Collection, Tagging, Transportation, and Release

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 subsequent transportation and release are described in the following sections. A total of 3470 CH1, 3471 STH, and 3461 CH0 were tagged and released.

2.2.1 Collection Site

Juvenile Chinook salmon and STH were collected and tagged at the JDA SMF. The SMF is situated on the south side of JDA 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 non-target 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 13-09PNNL40). The Oregon Department of Fish and Wildlife authorized take for this study under permit number P14273. The federal and Oregon permits were both authorized under the 2008 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 JBS 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 STH).
- 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.

Non-target 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 prior to 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 in Table 2.1.

Table 2.1. Number of Fish Rejected by Criteria During Spring and Summer Tagging at JDA.

Fish Run	Rejection Criteria	Number Rejected
CH1	BKD	2
	Fungus	4
	Lacerations	4
	Operculum Damage	5
	Popeye	1
	Skeletal Deform	1
STH	Already tagged	1
	Damaged Eye	2
	Descaling	5
	Fungus	10
	Lacerations	3
	Operculum. Damage	3
	Pit Tag	1
	Popeye	2
	Size	24
CH0	Descaling	3
	Lacerations	10
	Operculum Damage	4
	Size	5
Total Fish Collected		10,922
Number of Fish Rejected		90
Percent Total Fish Rejected		0.82%

2.2.4 JSATS Acoustic Micro-Transmitter and Tag Implantation

Specifications of the JSATS acoustic tags used in 2009 (Figure 2.3) were as follows: dimensions (mm) = 12 long x 5.21 wide x 3.77 deep; mass (g) = 0.43 in air and 0.29 in water; volume (mL) = 0.14. The nominal pulse-repetition rate was one ping every 3 seconds, and this rate provided an expected tag life of at least 23 days. Tagging tables are presented in Appendix A.

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.

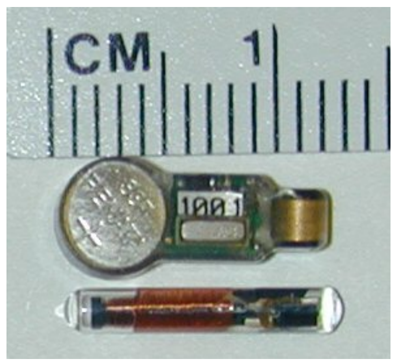

Figure 2.3. JSATS 0.43-g Acoustic Micro-Transmitter and PIT Tag Surgically Implanted in CH1, CH0, and STH Smolts in 2009

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. Surgical Implantation of PIT and Acoustic Tags in the John Day Smolt Monitoring Facility

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 ¾-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 ensure dissolved oxygen and temperature stayed within acceptable limits.

Just before fish were released in the river, fish buckets were opened to check for dead fish. Every dead fish was scanned with a BioMark portable transceiver PIT-tag scanner to identify the implanted PIT-tag code. The associated acoustic tag code was identified later from tagging data which recorded all pairs of PIT and acoustic tags implanted in fish the previous day. In 2009, there were no tailrace reference releases of tagged dead fish to determine whether dead fish were detected on downstream survival-detection arrays. Therefore, PIT and acoustic tags in dead fish were recovered, sterilized, and implanted in a live fish the next day. Post-tagging, pre-release mortalities were low for each run of fish studied in 2009 (CH1 = 0.2%; STH = 0%; CH0 = 0.46%).

The JSATS tagged fish from each of the three stocks were released 41 rkm upstream of JDA near Roosevelt, Washington. The tagging information for every fish is summarized in Appendix A. Fish were released from a boat at three locations along a line transect across the river, unless river conditions were too rough for safe boat operation. The release location on the Oregon side of the channel had the longest fetch (i.e., distance with uninterrupted exposure to wind) followed by the mid-channel location. Sometimes the Oregon location, and less often, the Oregon and mid-channel locations had to be skipped due to strong winds generateing waves capable of swamping or capsizing a boat. On one occasion (July 12 at 2000 hours), river conditions were too rough to release fish from a boat, so the crew released fish from a nearby point of land that extended out into the river from the Washington shore.

For boat releases, fish buckets were moved from the Bonar transport totes into the stern of the boat. 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 field data sheets.

Figure 2.5. Post-Surgery Holding Tank with Recovery Buckets

2.3 Detection of Tagged Fish

Two types of JSATS receiver arrays—cabled and autonomous—were deployed to detect fish tagged with JSATS acoustic transmitters as they passed downstream through the study reach between the fish release site at Roosevelt, Washington, rkm 390; the JDA forebay array, rkm 351; and Kalama, Washington rkm 113 (Table 2.2). The JDA forebay array was used to create a virtual release for fish known to have entered the forebay 2 km upstream of JDA to estimate JDA forebay-to-TDA forebay-passage survival. The JDA dam-face array was used to create a virtual release for fish known to have passed JDA and to estimate JDA-to-TDA forebay and route-specific passage-survival rates based on 3D and last-detection data. Time of last detection on the dam-face array minus the time of first detection on the forebay entrance array at JDA was used to estimate forebay residence time. The time of first detection by the JDA tailwater egress array minus the time of last detection on the dam-face array provided an estimate of relative egress time. TDA forebay array was the primary array for estimating the survival rate for tagged smolts passing through JDA and for defining the virtual release of fish to estimate the survival rate for smolts passing through TDA. The BON forebay array was used as the secondary array for estimating the dam-passage survival rate at JDA and as the primary survival-detection array for virtual and reference releases of fish at TDA. The BON forebay array was also used to create a virtual release for BON survival studies at BON Powerhouse 2 [B2]), although those study results are not discussed in this report. The first BON tailwater array near Lady Island (Camas, Washington) was used as the tertiary array for estimating the product of survival and detection rates (λ) for tagged smolts passing through JDA and as the secondary survival-detection array for estimating TDA-passage survival rate. The second BON tailwater array near Kalama, Washington, was used as a tertiary survival-detection array for estimating the product of survival and detection probabilities for estimating TDA-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 2009. 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	2.0 km downstream JDA	A2CR346	Detect tagged fish to estimate egress rate
TDA Forebay	2 km upstream TDA	A3CR311	JDA primary; regroup fish for virtual releases
BON Forebay	1.5 km upstream BON	A4CR236	JDA secondary; regroup fish for virtual releases; TDA primary;
B2 Dam Face	BON PH2	D2CR235	B2 route specific passage assignments
BON Tailwater 1	Lady Island	A5CR192	JDA tertiary; TDA secondary; BON primary;
BON Tailwater 2	Near Kalama, WA	A6CR113	TDA tertiary; BON secondary;
BON Tailwater 3	Near Oak Point, WA	A7CR086	BON tertiary

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

2.3.1 Cabled Dam-Face Arrays

The cabled dam-face receiver was designed by PNNL for the USACE Portland District using an off-the-shelf user-build system design. 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.

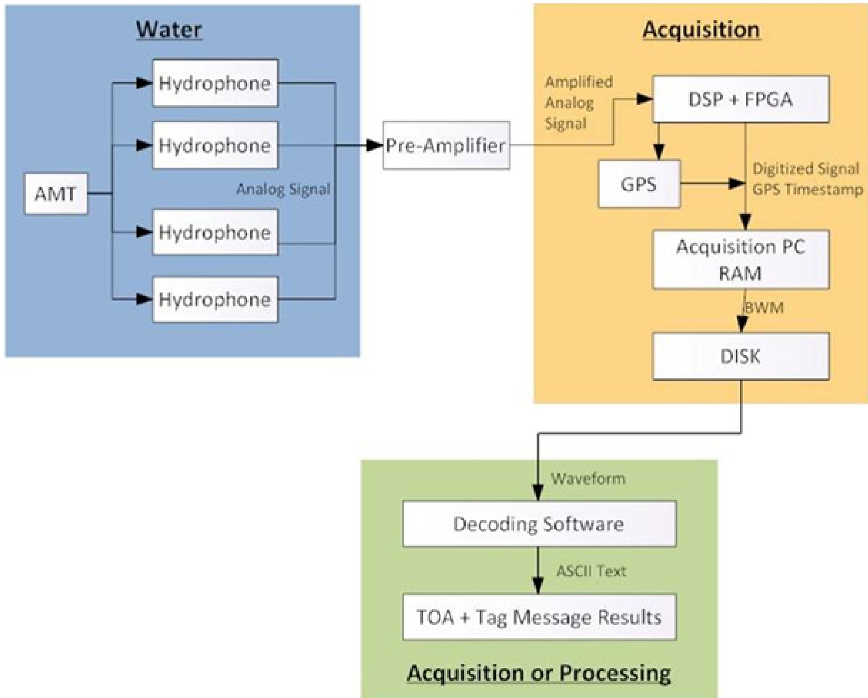

Figure 2.6. Schematic of the JSATS Dam-Face Receiver System Showing the Main Components and the Direction of Signal Acquisition and Processing. Abbreviations are as follows: AMT = acoustic micro-transmitter implanted in fish; DSP = digital signal processing card; FPGA = field programmable logic gate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

A modular JSATS cabled array was deployed along the upstream face of JDA to detect JSATS-tagged smolts approaching the dam. There were two hydrophones deployed at different depths on each main pier and eight hydrophones attached to clump mounts that were lowered to the bottom of the forebay about 33 m upstream of the dam face (Figure 2.7). Clump-mounted hydrophones were deployed to provide additional detections off of the plane of the dam face to increase the resolution of 3D tracking.

The dam-face cabled array consisted of 23 cabled receivers, each supporting four hydrophones. The receivers were housed in trailers on the 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 trolley insertion (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. One hydrophone on each pier was deployed at a shallow elevation (at 255.5 ft above MSL) and another 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.

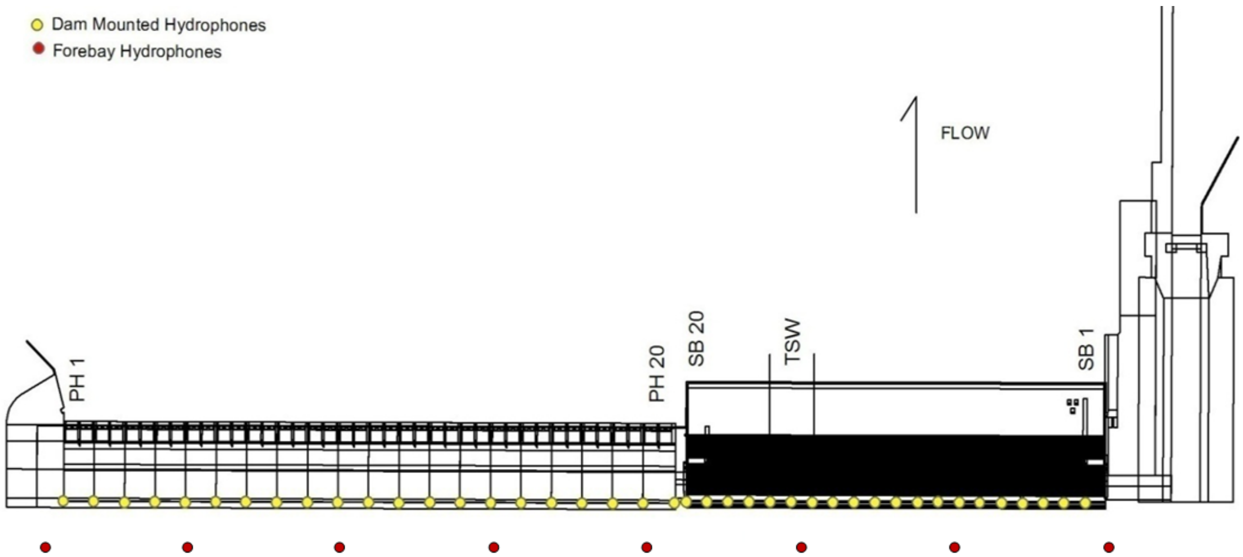

Figure 2.7. Location of Hydrophones on the Dam Face and in the Forebay of JDA, 2009

Figure 2.8. Trolley Pipe Mounted on a Main Pier of the JDA 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).

Figure 2.9. Trolleys Used to Deploy Hydrophones at the John Day Powerhouse and Spillway, 2009. 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 Receiver Arrays

Autonomous acoustic telemetry receivers were deployed in arrays at specific sites in the lower Columbia River study. 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 250 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).

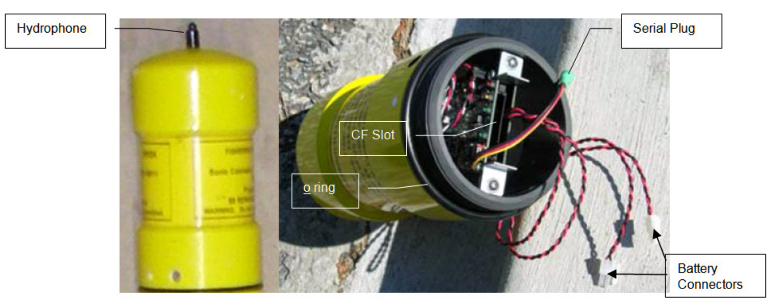

Figure 2.10. Side (left) and Bottom (right) Views of an Autonomous Node Top

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 JDA. A tailwater egress array (A2CR346) was located at rkm 346 about 2 km downstream of the tailrace deck of JDA. TDA forebay entrance array (A3CR311) was located 2 km upstream of TDA spillway. The BON forebay array (A4CR236) was located about 2 km upstream of B2. The tertiary array for estimating the product of detection and survival rates for JDA

(A5CR192) was located near Lady Island in the BON tailwater. The tertiary array for estimating the product of detection and survival for TDA-passage survival estimate was deployed near Kalama, Washington. Appendix B lists the nominal GPS coordinates of autonomous nodes deployed in this study.

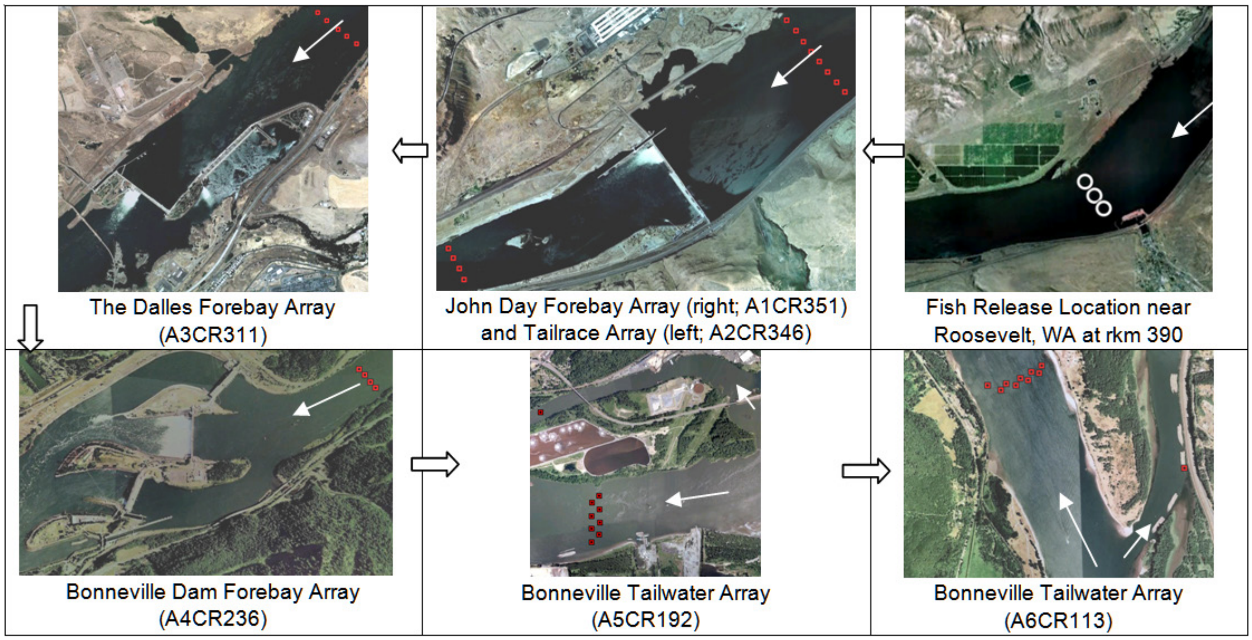

Figure 2.11. Location of the Only Fish-Release Transect (white circles in upper right panel) for the 2009 Study and Locations of Autonomous Nodes (red squares) Deployed in Arrays to Detect Acoustically Tagged Fish Migrating Downstream. Black arrows between Google Earth images indicate the order of images from upstream to downstream, and the direction of water flow within each image is indicated by white arrows. Array names are presented in parentheses, and the three-digit number at the end of each name is the river km upstream from the mouth of the Columbia River.

Nodes were typically retrieved by boat once every 2 weeks to download data, and batteries were replaced once every 28 days. 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 an acoustic modem on the upper end of the acoustic release mechanism. Upon receipt of a coded sound, the release 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. If 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 22 until August 25, 2009.

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 Model 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.

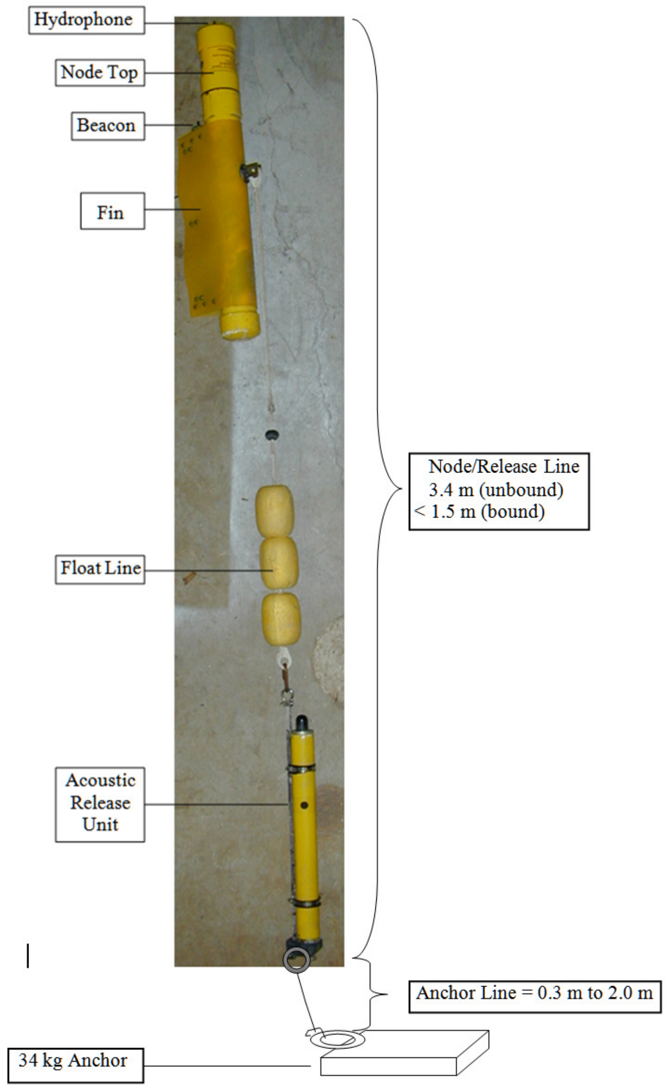

Figure 2.12. Autonomous Node Rigging

2.4 Data Processing and Validation

Data processing and validation efforts included decoding of acoustic signals, filtering the series of decoded signals, and conducting a tag-life study.

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 JDA spillway on June 18, 2008. The waveform files were then processed by a decoding utility (Waveform Utilities developed by the 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.

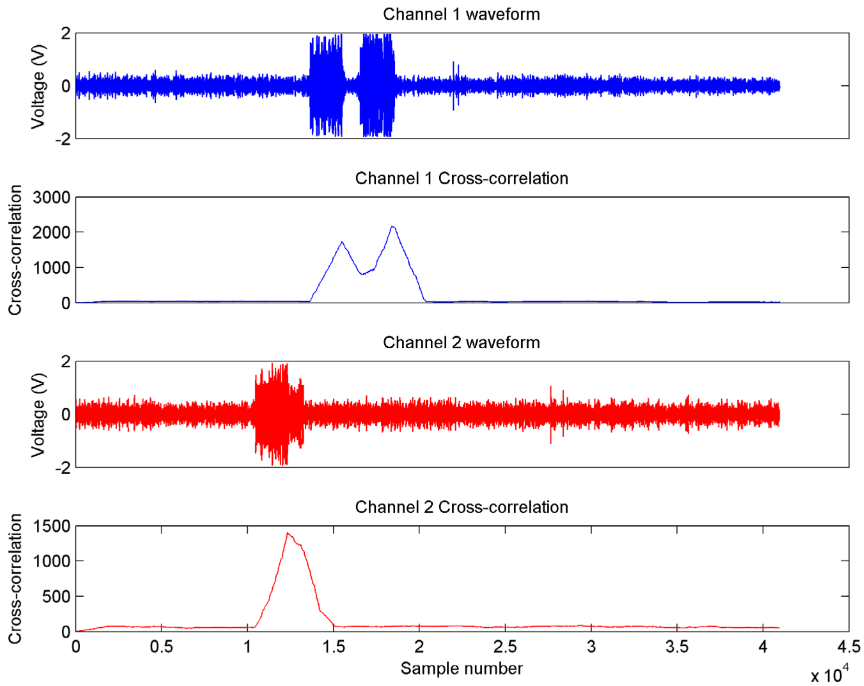

Figure 2.13. Example of Time-Domain Waveforms and Corresponding Cross-Correlations Acquired at the JDA Spillway. The message portion was 1860 samples (744 µs long). Note that multipath components were present in both channels. Decodes from the multipath components were filtered out in post-processing.

Tag-detection data from JSATS autonomous nodes were processed by two independent groups as a quality-control measure like in previous studies (Ploskey et al. 2007, 2008; Weiland et al. 2009) using standardized 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. The 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 were flagged. 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 were 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. The 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 were flagged. 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

For the JDA tag-life study, 98 acoustic tags (3-s ping rate) were randomly chosen from two manufacturing batches of Advanced Telemetry Systems, Inc. tags used in this 2009 study. Nine acoustic tags were already activated when received by PNNL for the tag-life study; thus only 89 tags were used in the tag-life analysis. The acoustic tags were divided into two approximately equal size groups and tag life was monitored separately for each group, but tag-life data from both manufacturing batches were pooled for analysis. All acoustic tags were enclosed in water-filled plastic bags and suspended from a rotating foam ring within a 2-m (diameter) fiberglass tank. Two 90º x 180º hydrophones were positioned 90° apart in the bottom of the tank and angled upward at approximately 60° to maximize coverage for detecting acoustic signals. Hydrophones were cabled to a quad-channel receiver that amplified all acoustic signals. All acoustic signals were then saved, decoded, and post-processed. Post-processing software calculated the number of hourly decodes for each acoustic tag, and therefore tag-failure times could be determined within ± 1 h. Tag life expectancy was 23 days for all acoustic tags in this study.

2.5 Statistical Methods for Estimating Survival Rates

In this section, statistical methods and define test conditions are described.

2.5.1 Defining Virtual Releases for Estimating Survival Rates

Single fish-release location and all virtual release locations and arrays used to calculate survival estimates are described in the following sections.

2.5.1.1 JDA Forebay-to-TDA Forebay, JDA-to-TDA Forebay, and Routes-Specific Survival Rates

The PNNL team released CH1 and STH in spring and CH0 in summer into the river near Roosevelt, Washington, at rkm 390. Most of these tagged fish were detected by the JDA forebay entrance array (A1CR351) and detections were pooled over periods of several days to define virtual releases for estimating the single-release forebay-passage survival rate and the JDA forebay-to-TDA forebay-passage survival rate. Most of the fish also were detected on the dam-face array (D1CR349) and pooled over periods of several days to define virtual releases for estimating single-release JDA-to-TDA forebay and route-specific passage-survival rates. The JDA to TDA forebay- and route-specific passage-survival rates at JDA were estimated using subsequent detection histories for TDA forebay array (A3CR311, primary), BON forebay array (A4CR236, secondary), and the first BON tailwater array (A5CR192, tertiary) as diagramed in Figure 2.14. Paired-release estimates could not be made in 2009 because no tagged fish were released in the JDA tailrace.

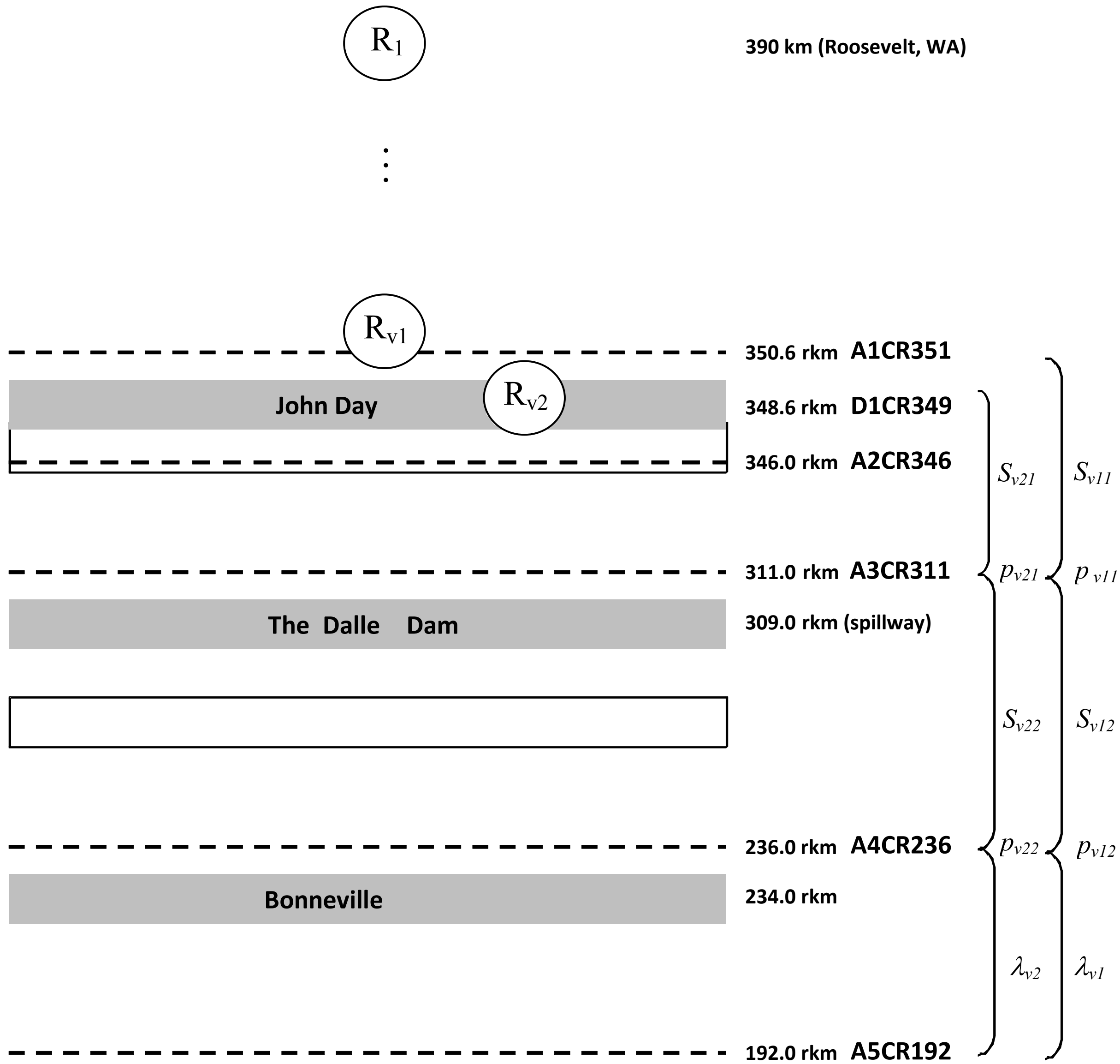

Figure 2.14. Schematic of the Single-Release Design (R_1) and Virtual Releases (R_{v1}, R_{V2}) for Estimating JDA Forebay-to-TDA Forebay and JDA-to-TDA Forebay-Passage Survival Rates (S_{v11} and S_{v21}, respectively) at JDA

2.5.1.2 The Dalles Dam-Passage Survival Rates

Many of the CH1, STH, and CH0 released at site R1 also were detected on TDA forebay entrance array (A3CR311) and pooled over periods of several days to define virtual releases for making single-release estimates of TDA forebay to BON forebay-passage survival rate, as diagramed in Figure 2.15. Those estimates were based on capture-history data from three arrays downstream of TDA. Those arrays were located in the BON forebay (A4CR236) and the BON tailwater (A5CR192 and A6CR113). Paired-release estimates could not be made in 2009 because no tagged fish were released in TDA tailrace in 2009.

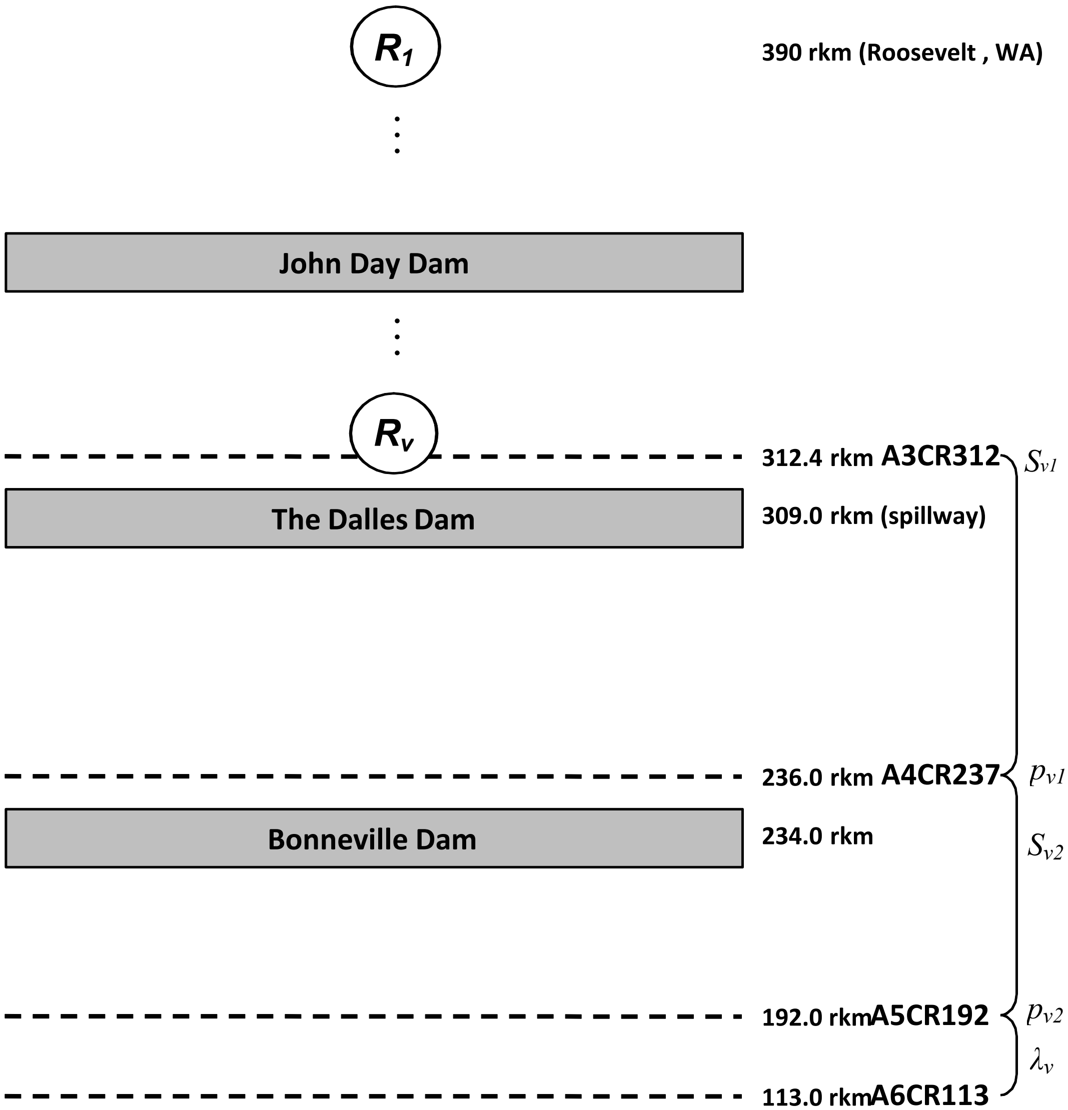

Figure 2.15. Schematic of the Single-Release Design for Estimating Virtual TDA Forebay to BON Forebay-Passage Survival Rates at TDA in Spring and Summer. Many of the tagged fish released upstream of JDA were detected on TDA forebay array and grouped to form virtual releases (R_V) of fish known to have reached TDA. Detection histories of those fish on three downstream arrays provided needed inputs to estimate dam-passage survival.

2.5.2 Estimation of JDA Forebay-to-TDA Forebay and JDA-to-TDA Forebay-Passage Survival Rates

Single release-recapture methods using tagged fish regrouped at the JDA forebay array (R_{V1}), the dam-face array (R_{V2}) (Figure 2.14), the TDA forebay array (Figure 2.15) were used to estimate the survival rates for each fish stock. For JDA, the detection arrays at A3CR311, A4CR236, and A5CR192 provided $2^3 = 8$ possible capture histories for each release group (111, 011, 101, 001, 110, 010, 100, and 000), where a 1 indicates detection, and a zero indicates no detection on each of three successive survival-detection arrays. For example, “111” indicates detection on all three arrays, whereas “010” indicates that detection on the second array but not on the first or third arrays. For TDA, detection arrays A4CR236, A5CR192, and A6CR113 also provided eight possible capture histories. Counts associated with each of the eight capture-history probabilities were input into the Survival with Proportional Hazards (SURPH 2.2b) software developed at the University of Washington (Lady et al. 2001) and generated single-release Cormack (1964), Jolly (1965), Seber (1965) (CJS) estimates of survival and its variance for each run of fish and virtual release grouping (usually pooled over several days). There were no paired-release estimates because reference releases were not made in 2009. 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, the number of fish in each virtual release was used to weight estimates of survival rate for individual ranges of virtual release dates. No tag-life corrections (after Townsend et al. 2006) were applied to the individual release CJS survival estimates because all fish passed the tertiary array before tag-life failure occurred.

2.5.3 Tests of Assumptions

Detections at multiple locations downstream of the single fish release site at Roosevelt, Washington, provided data required to estimate virtual-release reach survival rates 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 for Chinook salmon smolts, then the sample of tagged fish should be drawn from that class of fish. Otherwise, non-statistical inferences are necessary, justifying the similarity between the target population and the representativeness of fish implanted with acoustic transmitters. These assumptions could also be violated if smolts selected for acoustic tagging differ from the target population in a way that biases survival rates (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 out-migrating 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 smolts implanted with acoustic transmitters 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 chance for 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 false-positive detections and upwardly bias estimates of survival rates. For this reason, tailrace hydrophone arrays are not proposed for this set of analyses.

For the single release-recapture model to be valid, certain data patterns should be evident from the capture histories. Virtual releases R_{V1} R_{V2} and R_v 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). For example, the data from virtual release R_{V2} were summarized by an m-array matrix of the form provided below, where the value of m_{ij} are the number of smolts detected at site i that are next detected at site j.

Virtual Release Site	Recovery Site		
	A3CR311(2)	A4CR236 (3)	A5CR192 (4)
JDA Dam Face (1)	m_{12}	m_{13}	m_{14}
TDA Forebay (2)		m_{23}	m_{24}
BON Forebay (3)			m_{34}

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 or detection. For each virtual 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 (2.1)

Tests were performed at α = 0.10. The multiple releases over the season were used to broaden the statistical inference and not to add evidence that the theoretical variances were reasonable. At best, estimates made from individual virtual releases might show some general seasonal trends if the trends are great enough and the detection probabilities were high enough.

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 Third Array (A5CR192)	Capture History to Second Array (A4CR236): 101	111
1		
0		

χ_1^2 (2.2)

This contingency table tests whether detection at the first downstream array (A3CR311) has a subsequent effect on the capture history at the third downstream array (A5CR192).

2.5.4 Probabilities of Detection by Passage Route

Detection probabilities are an integral part of the survival estimation. For any particular passage route, the following variables are defined (Figure 2.16):

- 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

$$\hat{N} = \frac{(n_{10} + n_{11} + 1)(n_{01} + n_{11} + 1)}{(n_{11} + 1)} - 1 \qquad (2.3)$$

or

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(n_{11} + 1)} - 1 \tag{2.4}$$

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

$$\widehat{\text{Var}}(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - n_{11})(n_2 - n_{11})}{(n_{11} + 1)^2 (n_{11} + 2)} \tag{2.5}$$

The estimated probability of detection $\left(p_1\right)$ in the first array is calculated as

$$\hat{p}_1 = \frac{n_{11}}{n_2} \tag{2.6}$$

and the probability of detection $\left(p_2\right)$ in the second array as

$$\hat{p}_2 = \frac{n_{11}}{n_1} \tag{2.7}$$

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

$$\hat{P} = 1 - \left(1 - \hat{p}_1\right)\left(1 - \hat{p}_2\right) = \frac{n_{11}\left(n_1 + n_2 + n_{11}\right)}{n_1 n_2}. \tag{2.8}$$

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:

$$\hat{P}_{\text{PH}} = \frac{\hat{N}_{\text{PH}}}{\hat{N}_{\text{PH}} + \hat{N}_{\text{SP}} + \hat{N}_{\text{TSW}} + N_{\text{JBS}}}. \tag{2.9}$$

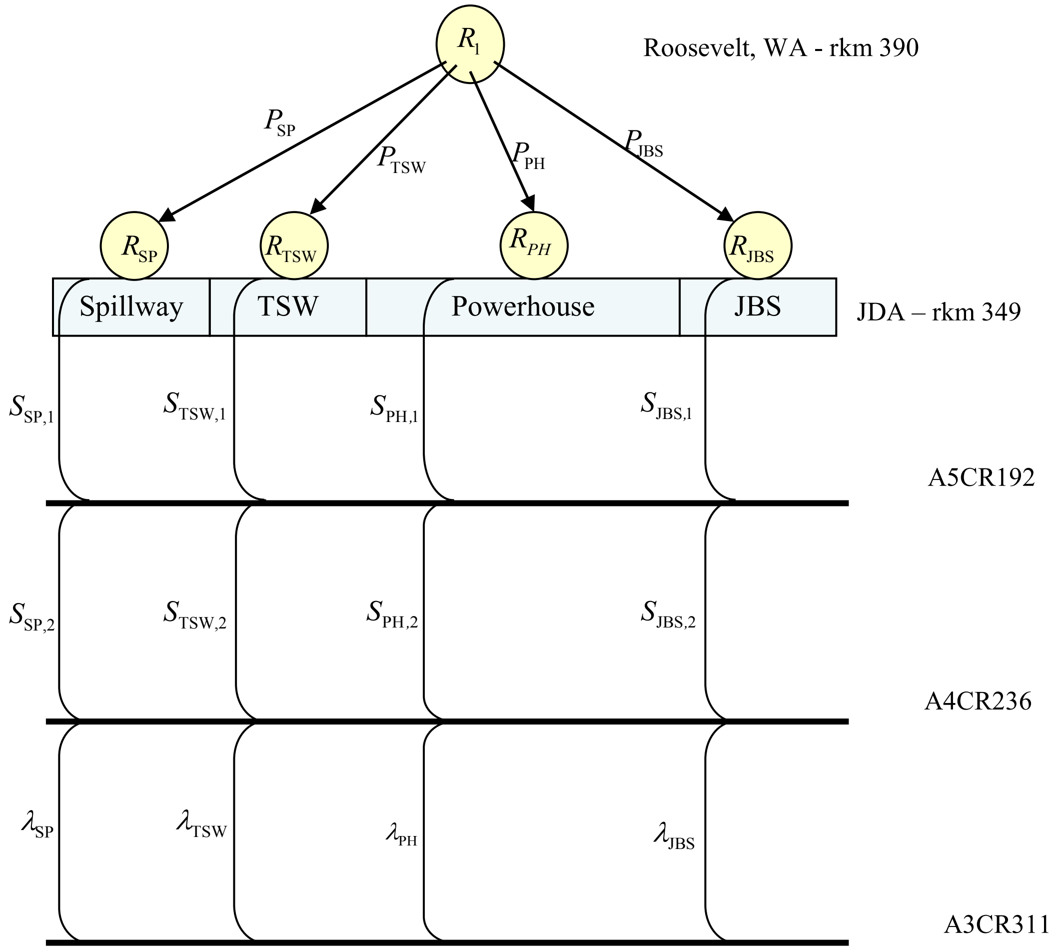

Figure 2.16. Schematic of Route-Specific Passage and Downstream Recoveries for Virtual Releases at the Spillway $\left(R_{\text{SP}}\right)$, TSW $\left(R_{\text{TSW}}\right)$, Powerhouse $\left(R_{\text{PH}}\right)$, and JBS $\left(R_{\text{JBS}}\right)$

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

$$\widehat{\text{Var}}\left(\hat{P}_{\text{PH}}\right)=\frac{\hat{P}_{\text{PH}}\left(1-\hat{P}_{\text{PH}}\right)}{\hat{N}}+\hat{P}_{\text{PH}}^{2}\left(1-\hat{P}_{\text{PH}}\right)^{2}\cdot\left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right)}{\hat{N}_{\text{PH}}^{2}}+\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right)+\widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\left(\hat{N}_{\text{SP}}+\hat{N}_{\text{TSW}}+N_{\text{JBS}}\right)^{2}}\right], \tag{2.10}$$

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 (2.9) and associated variances estimated analogously to Equation (2.10). Note for N_{JBS} that $Var(N_{JBS})=0$.

2.5.5 Route-Specific Relative Survival Rates

The 3D hydrophone array on the JDA upstream dam face 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 JDA (Figure 2.16) were detected by listening devices on downstream arrays to obtain their capture histories. To estimate survival, you first must 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,

$$RS_{\text{SP/PH}} = \frac{\left(\dfrac{n_{\text{SP}}}{R_{\text{SP}}}\right)}{\left(\dfrac{n_{\text{PH}}}{R_{\text{PH}}}\right)}. \tag{2.11}$$

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

$$\widehat{\text{Var}}\left(\widehat{RS}_{\text{SP/PH}}\right) = \widehat{RS}^{2}_{\text{SP/PH}}\left[\frac{1}{n_{\text{PH}}} - \frac{1}{R_{\text{PH}}} + \frac{1}{n_{\text{SP}}} - \frac{1}{R_{\text{SP}}}\right]. \tag{2.12}$$

The estimators of relative survival rates for the other three routes are analogous to Equation (2.11) and their variances are analogous to Equation (2.12).

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 TDA forebay array were estimated using a single release-recapture model

(Figure 2.14). Route-specific survival rates and associated standard errors for the fish passed through the powerhouse, spillway, TSW, JBS, and turbines were estimated using the single-release CJS algorithms programmed in SURPH 2.2b.

2.6 Statistical Methods – Fish Passage

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

2.6.1 Fish-Passage Metrics

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

$$\widehat{\text{FPE}} = \hat{P}_{\text{SP}} + \hat{P}_{\text{TSW}} + \hat{P}_{\text{JBS}} \tag{2.13}$$

with associated variance estimator

$$\widehat{\text{Var}}\left(\widehat{\text{FPE}}\right) = \frac{\widehat{\text{FPE}}\left(1-\widehat{\text{FPE}}\right)}{\hat{N}} + \widehat{\text{FPE}}^{2}\left(1-\widehat{\text{FPE}}\right)^{2} \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right)}{\hat{N}_{\text{PH}}^{2}} + \frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\left(\hat{N}_{\text{SP}} + \hat{N}_{\text{TSW}} + \hat{N}_{\text{JBS}}\right)^{2}}\right]. \tag{2.14}$$

Spill-passage efficiency (SPE) 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

$$\widehat{\text{SE}} = \hat{P}_{\text{SP}} + \hat{P}_{\text{TSW}} \tag{2.15}$$

with associated variance estimator

$$\text{Var}\left(\widehat{\text{SE}}\right) = \frac{\widehat{\text{SE}}\left(1-\widehat{\text{SE}}\right)}{\hat{N}} + \widehat{\text{SE}}^{2}\left(1-\widehat{\text{SE}}\right)^{2} \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right) + \left(\hat{N}_{\text{TSW}}\right)}{\left(\hat{N}_{\text{SP}} + \hat{N}_{\text{TSW}}\right)^{2}} + \frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\left(\hat{N}_{\text{PH}} + \hat{N}_{\text{JBS}}\right)^{2}}\right]. \tag{2.16}$$

Spill-passage effectiveness (SEF) is defined as the ratio of SE 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

$$\widehat{\text{SEF}} = \frac{\hat{P}_{\text{SP}} + \hat{P}_{\text{TSW}}}{\left(\frac{f_{\text{SP}}}{F}\right)} = \widehat{\text{SE}}\left(\frac{F}{f_{\text{SP}}}\right) \tag{2.17}$$

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

$$\widehat{\text{Var}}\left(\widehat{\text{SEF}}\right) = \widehat{\text{Var}}\left(\widehat{\text{SE}}\right)\left(\frac{F}{f}\right)^2 . \tag{2.18}$$

Top-spill 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

$$\widehat{\text{TSWE}} = \hat{P}_{\text{TSW}} \tag{2.19}$$

with associated variance estimator

$$\begin{aligned}\widehat{\text{Var}}\left(\widehat{\text{TSWE}}\right) = {} & \frac{\hat{P}_{\text{TSW}}\left(1-\hat{P}_{\text{TSW}}\right)}{\hat{N}} + \hat{P}_{\text{TSW}}{}^2\left(1-\hat{P}_{\text{TSW}}\right)^2 \\ & \cdot\left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right)}{\hat{N}_{\text{TSW}}^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\left(\hat{N}_{SP} + \hat{N}_{\text{PH}} + \hat{N}_{\text{JBS}}\right)^2}\right].\end{aligned} \tag{2.20}$$

The TSW-passage effectiveness (TSWEF) is defined as TSWE 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

$$\widehat{\text{TSWEF}} = \frac{\hat{P}_{\text{TSW}}}{\left(\frac{f_{\text{TSW}}}{F}\right)} = \widehat{\text{TSWE}}\left(\frac{F}{f_{\text{TSW}}}\right) \tag{2.21}$$

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

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

$$\widehat{\text{Var}}\left(\widehat{\text{TSWEF}}\right) = \widehat{\text{Var}}\left(\widehat{\text{TSWE}}\right)\cdot\left(\frac{F}{f_{\text{TSW}}}\right)^2 . \tag{2.22}$$

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

$$\widehat{\text{FGE}} = \hat{P}_{\text{JBS}} \tag{2.23}$$

with the associated variance estimator

$$\widehat{\text{Var}}\left(\widehat{\text{FGE}}\right) = \frac{\widehat{\text{FGE}}\left(1-\widehat{\text{FGE}}\right)}{\hat{N}} + \widehat{\text{FGE}}^2\left(1-\widehat{\text{FGE}}\right)^2 \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\hat{N}_{\text{JBS}}^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right)}{\left(\hat{N}_{SP} + \hat{N}_{\text{PH}} + \hat{N}_{\text{TSW}}\right)^2}\right]. \tag{2.24}$$

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

$$\text{JBSE} = \hat{P}_{\text{JBS}} \tag{2.25}$$

with the associated variance estimator

$$\widehat{\text{Var}}\left(\widehat{\text{JBSE}}\right) = \frac{\hat{P}_{\text{JBS}}\left(1-\hat{P}_{\text{JBS}}\right)}{\hat{N}} + \hat{P}_{\text{JBS}}^2\left(1-\hat{P}_{\text{JBS}}\right)^2 \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\hat{N}_{\text{JBS}}^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right)}{\left(\hat{N}_{\text{PH}} + \hat{N}_{SP} + \hat{N}_{\text{TSW}}\right)^2}\right]. \tag{2.26}$$

2.6.2 Spatial Trends

Estimates of the horizontal distribution of passage of each stock of fish at JDA according to the individual turbine and spill bay of passage were made based on detections on the dam-face array and 3D tracking. The same 3D tracking data set allowed evaluation of the vertical distribution of smolts within 75 m of the dam.

For a broader picture of fish behavior in the forebay, the distribution of smolts detected on the forebay entrance array 2 km upstream of JDA were compared 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 examination of smolts behavioral responds 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 Travel and Residence Times

As mentioned above, the JDA forebay array was used to create a virtual release for fish as they enter the forebay 2 km upstream of JDA. The JDA dam-face array was used to create a virtual release for fish known to have passed JDA 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 provides an estimate of forebay residence time. The time of first detection by the JDA tailwater egress array minus the time of last detection on the dam-face array provides an estimate of relative egress time.

2.7 Statistical Methods – Fish Behavior

Fish behavior was assessed by 3D tracking of JSATS-tagged fish in the immediate forebay of JDA. 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:

$$\mathbf{S} = (s_x, s_y, s_z)^{\mathrm{T}}$$
$$\mathbf{r}_i = (x_i, y_i, z_i)^{\mathrm{T}} \qquad i = 0,1,2,3 \tag{2.27}$$

The distance between transmitting source and receivers gives

$$(s_x - x_i)^2 + (s_y - y_i)^2 + (s_z - z_i)^2 = c^2(t_i + T_0)^2, \qquad i = 0,1,2,3 \tag{2.28}$$

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 (2.28) for $i = 0$ from Equation (2.28) for $i = 1$, 2 and 3, provides:

$$2\mathbf{R}^T\mathbf{S} + 2c^2\mathbf{t}T_0 = \mathbf{b} \tag{2.29}$$

where,

$$\mathbf{R} = \begin{bmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \\ z_1 & z_2 & z_3 \end{bmatrix}, \quad \mathbf{t} = \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix}, \quad \mathbf{b} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}, \text{ and } b_i = \|\mathbf{r}_i\|^2 - c^2 t_i^2 \tag{2.30}$$

From Equation (2.29),

$$\mathbf{S} = \mathbf{R}^{-T} (\frac{1}{2}\mathbf{b} - c^2 \mathbf{t} T_0) \tag{2.31}$$

substituting Equation (2.31) to the relationship $\mathbf{S}^T\mathbf{S} = c^2 T_0^{\ 2}$ gives

$$T_0 = \frac{-p \pm \sqrt{p^2 - aq}}{a} \tag{2.32}$$

where,

$$a = c^4 \mathbf{t}^T \mathbf{R}^{-1} \mathbf{R}^{-T} \mathbf{t} - c^2, \quad p = -\frac{1}{2} c^2 \mathbf{t}^T \mathbf{R}^{-1} \mathbf{R}^{-T} \mathbf{b}, \text{ and } q = \frac{1}{4} \mathbf{b}^T \mathbf{R}^{-1} \mathbf{R}^{-T} \mathbf{b} \tag{2.33}$$

After T_0 is determined, source position (**S**) is then obtained by Equation (2.31).

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 JDA 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 the location of the sound source is estimated 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 JDA 2008 study because of the high success rates of exact solvers.

After the source location was obtained using 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

$$\Delta T = \sqrt{(t_1' - t_1)^2 + (t_2' - t_2)^2 + (t_3' - t_3)^2 + (T_0' - T_0)^2} \quad (2.34)$$

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 JDA 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.

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 2009 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 JDA SMF, and results of the tag-life study.

3.1.1 Dam Discharge and Temperature

During times when tagged fish were arriving at JDA, mean daily dam discharge usually was above the previous 10-year average in spring and early summer and below average during most of July (Figure 3.1). Spill discharge was frequently above the previous 10-year average in spring and at or above the 10-year average from June 16 through July 29. Discharge was much higher than the 10-year average during the second half of the spring season. Forebay water temperatures were 1–2 degrees below the 10-year average most of spring and within 1 degree of the 10-year average most of summer, except for the last 1.5 weeks in July when they were 1–4 degrees above average (Figure 3.2).

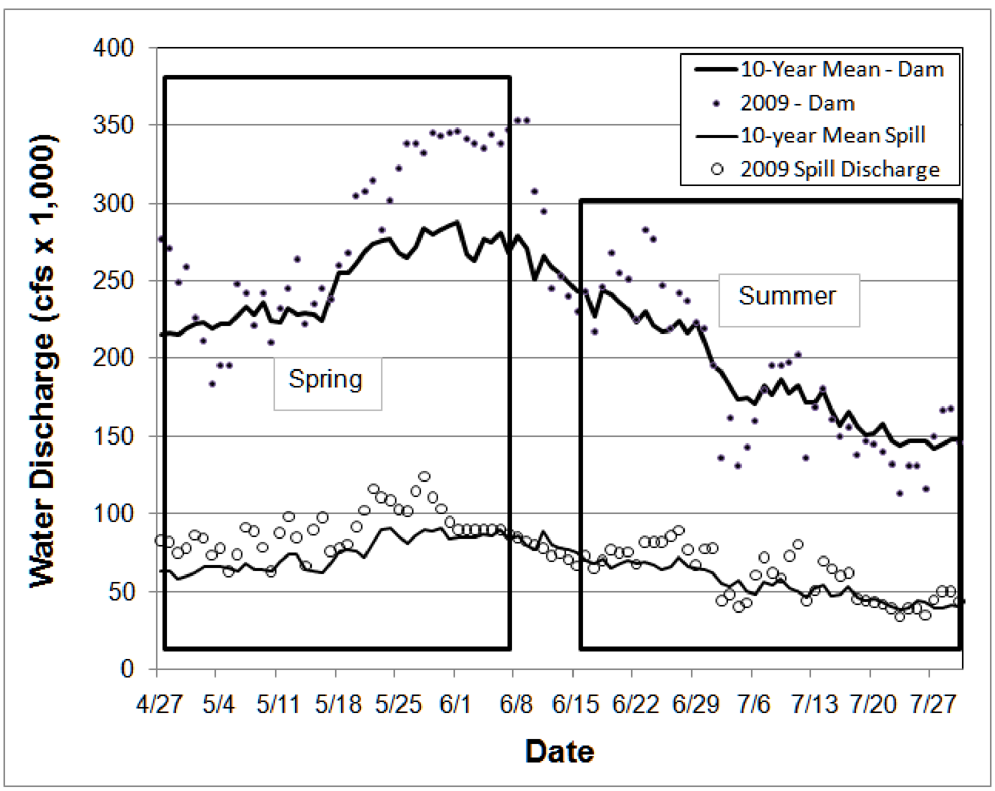

Figure 3.1. Estimated 2009 Daily Dam and Spillway Discharge Relative to the Previous 10-Year Average for JDA. Boxes bracket days when fish implanted with JSATS acoustic tags were arriving at the dam.

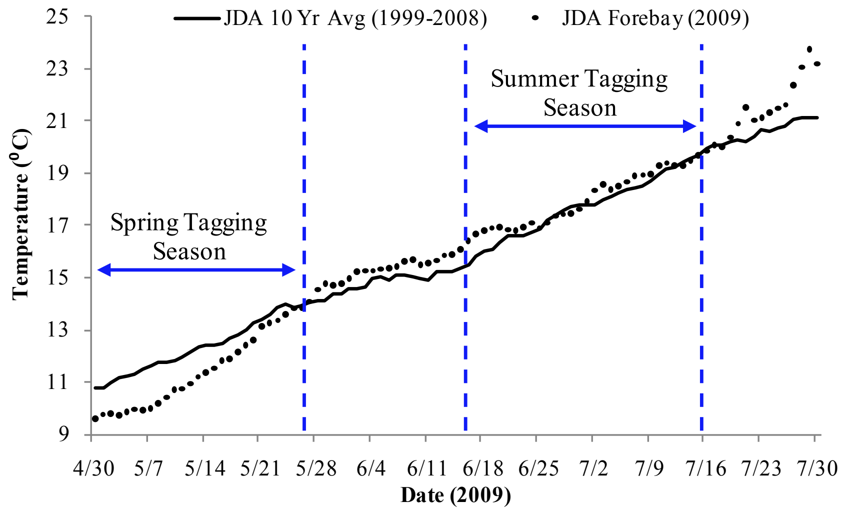

Figure 3.2. Ten-Year Average Forebay Water Temperature (° C) Versus 2009 Daily Estimates from April 30 through July 30 at JDA

3.1.2 Realized Spill Treatment Conditions

During spring 2009, treatment conditions were met for most of blocks 1 through 5, but percent spill varied from prescribed treatment conditions during the 40% spill treatments in blocks 6 through 8 (Figure 3.3). During summer, the TSW and spillbays 17–20 were closed to due hydraulic conditions that resulted in increased bird predation on fish passing through these bays. All spill was passed through spillbays 2–14. Treatment conditions were not met for blocks 1, 2, and 3, but were reasonably well met for in blocks 4 and 5 and very well for blocks 6 through 9 (Figure 3.4). Treatment conditions were not always met due to power-load issues and prevailing flow conditions.

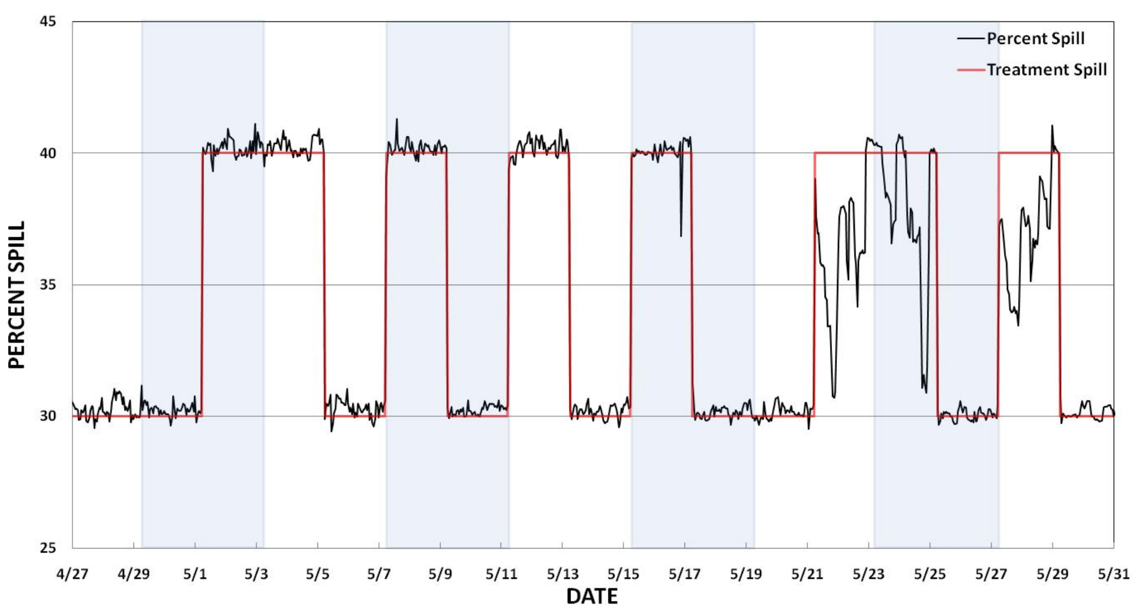

Figure 3.3. Realized Spill Treatments at JDA, April 29 Through May 31, 2009. There were eight 4-day treatment blocks with two 2-day treatments per block.

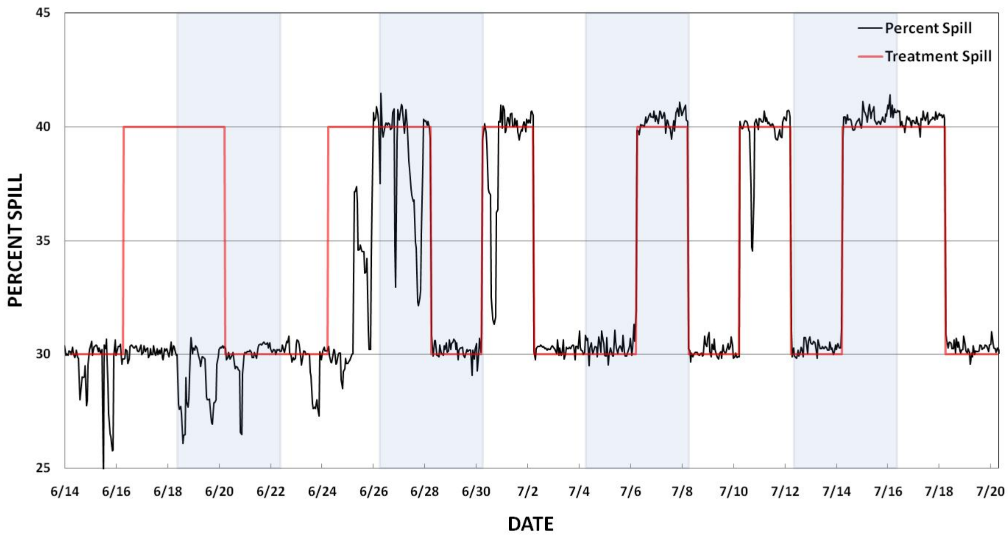

Figure 3.4. Realized Spill Treatments at JDA, June 14 Through July 20, 2009. There were nine 4-day treatment blocks with two 2-day treatments per block.

3.1.3 Run Timing

Run timing for the run-at-large of CH1 and STH both peaked in May 2009 with 50% of the fish passing by May 17 and May 10, respectively (Figures 3.5 and 3.6; Table 3.1). Run timing for CH0 peaked in late June 2009 with 50% of the run-at-large passing by July 1 (Figure 3.7; Table 3.1). As planned, acoustic-tagging occurred for the most part during the central 80% of each run in 2009 (Figures 3.5, 3.6, and 3.7). The 10-year smolt index average was used as an indicator of run timing to determine the start date for tagging fish so that fish arrivals would approximate timing for the run-at-large for each stock (see Tables 3.2 through 3.4).

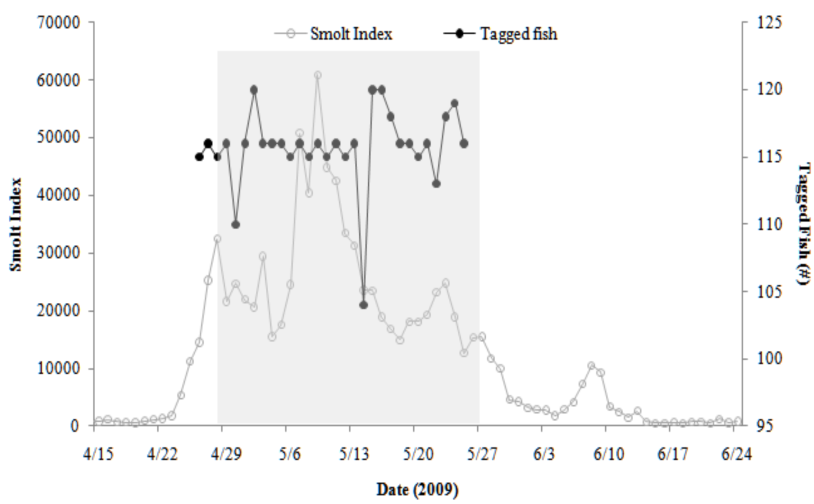

Figure 3.5. Smolt Monitoring Program Passage Index for April 15–June 24, 2009, and the Number of STH Tagged Per Day. Ten to 90 percent of the run passed JDA within the region shaded in gray, and STH arrived from 4/28 through 6/7 in spring. Passage index data were obtained from the DART website (Data Access in Real Time; www.cbr.washington/dart/dart.html).

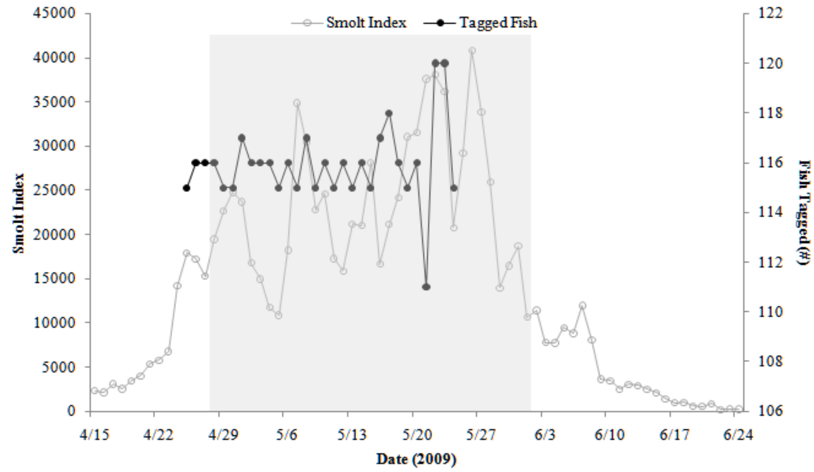

Figure 3.6. Smolt Monitoring Program Passage Index for April 15–June 24, 2009, and the Number of CH1 Tagged Per Day. Ten to 90 percent of the run passed JDA within the region shaded in gray, and yearlings arrived at the dam from 4/28 through 6/7 in spring. Data were obtained from the DART website (Data Access in Real Time; www.cbr.washington/dart/dart.html).

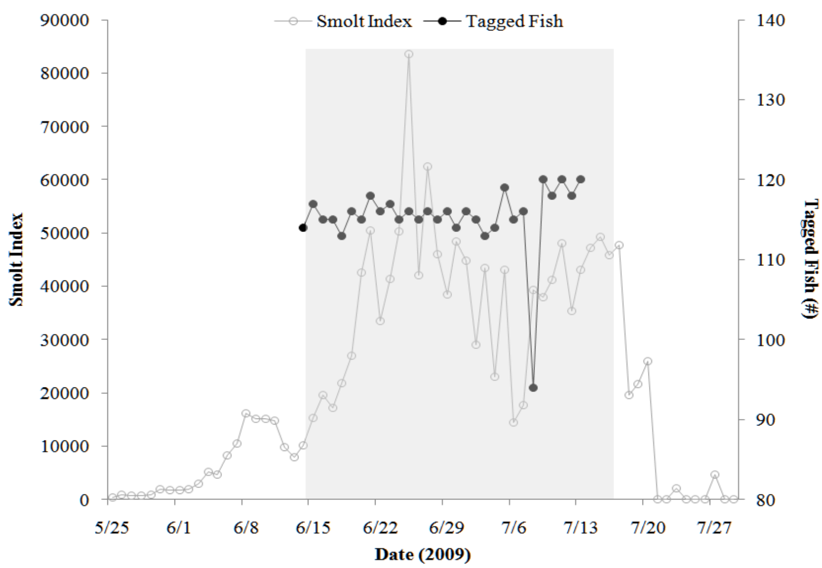

Figure 3.7. Smolt Monitoring Program Passage Index for May 25–July 30, 2009, and the Number of CH0 Tagged Per Day. Ten to 90 percent of the run passed JDA within the region shaded in gray, and subyearlings arrived at the dam from 6/16 through 7/29. Data were obtained from the DART website (Data Access in Real Time; www.cbr.washington/dart/dart.html).

Table 3.1. Yearly and Ten-Year Average of Run Timing for CH1 Sampled at the JDA SMF for Percentiles of the Passage Index

Year	First	1%	5%	10%	50%	90%	95%	Last	Middle 80% Days
1999	4/01	4/10	4/18	4/22	5/13	5/31	6/06	8/30	40
2000	4/04	4/10	4/16	4/21	5/09	5/28	6/05	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

Table 3.1. (contd)

Year	First	1%	5%	10%	50%	90%	95%	Last	Middle 80% Days
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	4/04	4/14	4/22	4/25	5/11	5/24	5/27	9/14	30
2007	4/03	4/16	4/26	5/02	5/13	5/25	5/30	9/13	24
2008	4/02	4/12	4/26	5/04	5/22	6/01	6/06	9/15	29
10-yr avg	3/31	4/12	4/22	4/28	5/15	5/30	6/05	9/12	33
2009	4/01	4/15	4/24	4/27	5/17	6/01	6/06	8/07	36

Table 3.2. Yearly and Ten-Year Average of Run Timing for STH Sampled at the JDA SMF for Percentiles of the Passage Index

Year	First	1%	5%	10%	50%	90%	95%	Last	Middle 80% Days
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	4/30	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
2008	4/2	4/25	5/4	5/7	5/18	5/31	6/4	9/15	25
10-yr avg	3/31	4/14	4/25	4/29	5/16	5/31	6/6	9/14	33
2009	4/1	4/21	4/26	4/28	5/10	5/27	6/6	8/21	30

Table 3.3. Yearly and Ten-Year Average of Run Timing for CH0 Sampled at the JDA SMF for Percentiles of the Passage Index

Year	First	1%	5%	10%	50%	90%	95%	Last	Middle 80% Days
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
2008	5/3	5/28	6/1	6/14	7/7	7/30	8/5	9/15	47
10-yr avg	4/8	5/30	6/8	6/16	7/4	7/27	8/4	9/19	43
2009	4/23	6/4	6/10	6/16	7/1	7/17	7/18	9/15	32

Table 3.4. Percent of the Run Passing a the John Day Dam SMF on the First and Last Days of Tagging and the Dates That 10%, 25%, 50%, 75%, and 90% of Each Run Passed the Dam in 2009 According to SMF Data

	Percent of Run Passage by Date						
Stock	First Arrival	10%	25%	50%	75%	90%	Last Arrival
CH1	4/27 (10%)	4/27	5/5	5/17	5/25	6/1	6/07 (95%)
STH	4/28 (10%)	4/28	5/4	5/10	5/19	6/06	6/07 (95%)
CH0	6/16 (10%)	6/16	6/23	7/1	7/11	7/17	7/29 (>90%)

3.1.4 Length Frequency

Length frequency distributions of tagged and run-of-river juvenile salmon populations were very similar for all three runs in 2009 (Figures 3.8, 3.9, and 3.10). Median lengths of tagged and untagged fish differed by just 2 mm for CH1 and STH and by less than 3 mm for CH0.

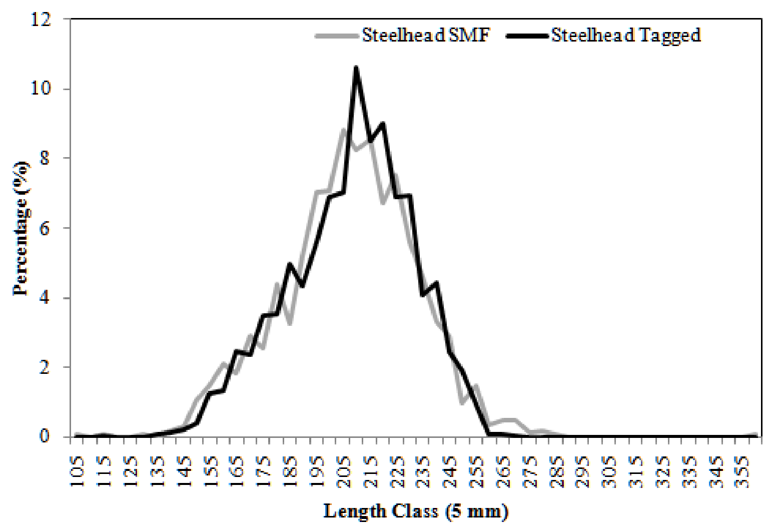

Figure 3.8. Length Frequency Distributions for Tagged and Run-of-River STH in 2009

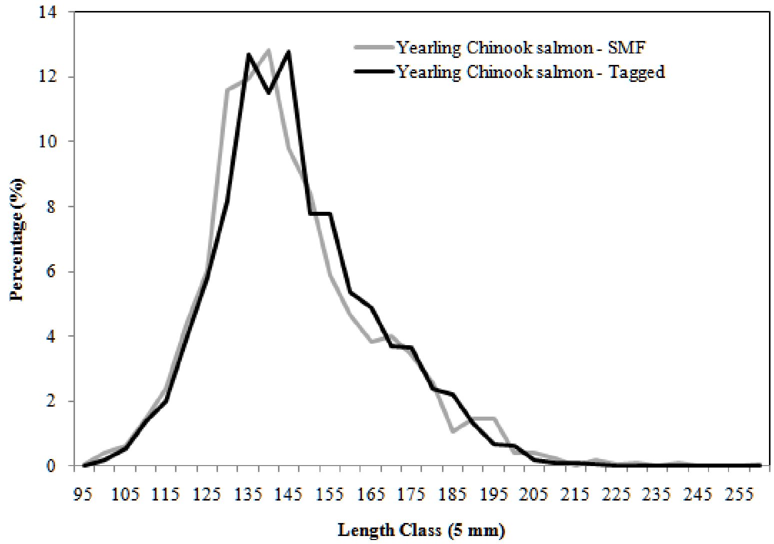

Figure 3.9. Length Frequency Distributions for Tagged and Run-of-River CH1 in 2009

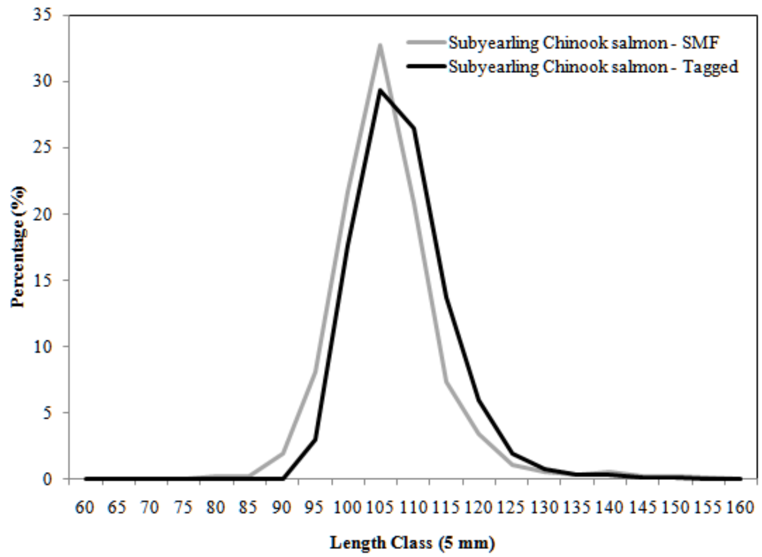

Figure 3.10. Length Frequency Distributions for Tagged and Run-of-River CH0 in 2009

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. Detection probabilities are presented in Appendix C.

3.2.1 Detection Probabilities at Dam-Face Arrays

The combined detection probability of the dam-face array for each of three tagged fish runs exceeded 95%: 95.6% for STH, 96.3% for CH1, and 97.9% for CH0 (Table 3.5).

Table 3.5. Detection Probabilities for the Dam-Face Arrays at JDA During 2009. 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
CH1	3470	2259	467	622	0.784	0.829	0.963
STH	3471	2121	523	603	0.779	0.802	0.956
CH0	3461	2239	340	437	0.837	0.868	0.979

3.2.2 Detection Probabilities and Fish Distributions at Autonomous Nodes

Detection probabilities for survival arrays composed of autonomous nodes were over 99% for arrays deployed upstream of TDA each season and ranged from 92 to 95% for the BON forebay array, from 90 to 98% for the first tailwater reach below BON, and from 92 to 95% for the second tailwater reach (Figure 3.11). For the BON forebay and tailrace arrays, detection probabilities were consistently higher for CH0 passing in summer (95 to 98%) than they were for CH1 (92%) and STH (90 to 92%) passing in spring 2009.

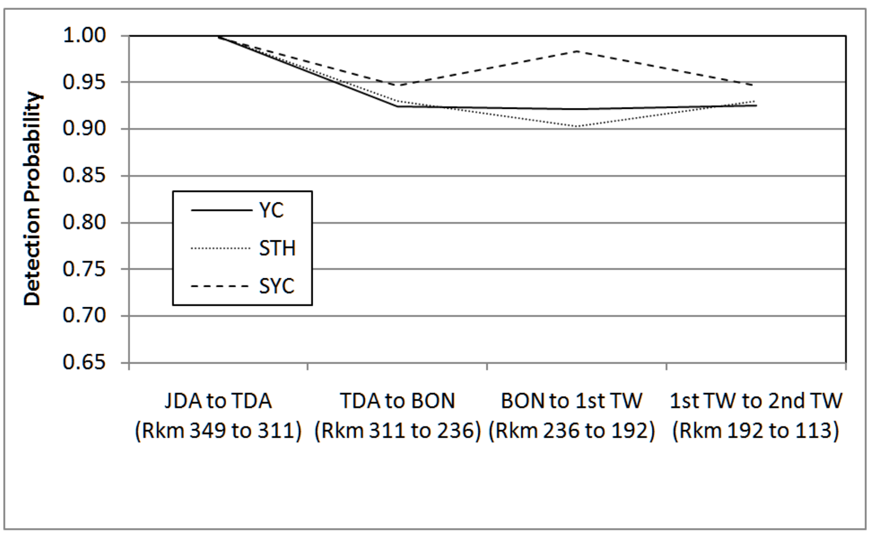

Figure 3.11. Detection Probabilities During 2009 by Reach for the Autonomous Arrays. Tailwater is abbreviated TW.

Most CH1 and CH0 smolts were detected on the spillway side of the JDA forebay entrance array; whereas the offshore distribution of STH smolts was uniform (top row of Figure 3.12). At TDA forebay entrance array (second row of Figure 3.12), more CH1 and STH smolts were detected on the north side than on the south side of the channel, but this northerly trend was not apparent for CH0 smolts. On the BON 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).

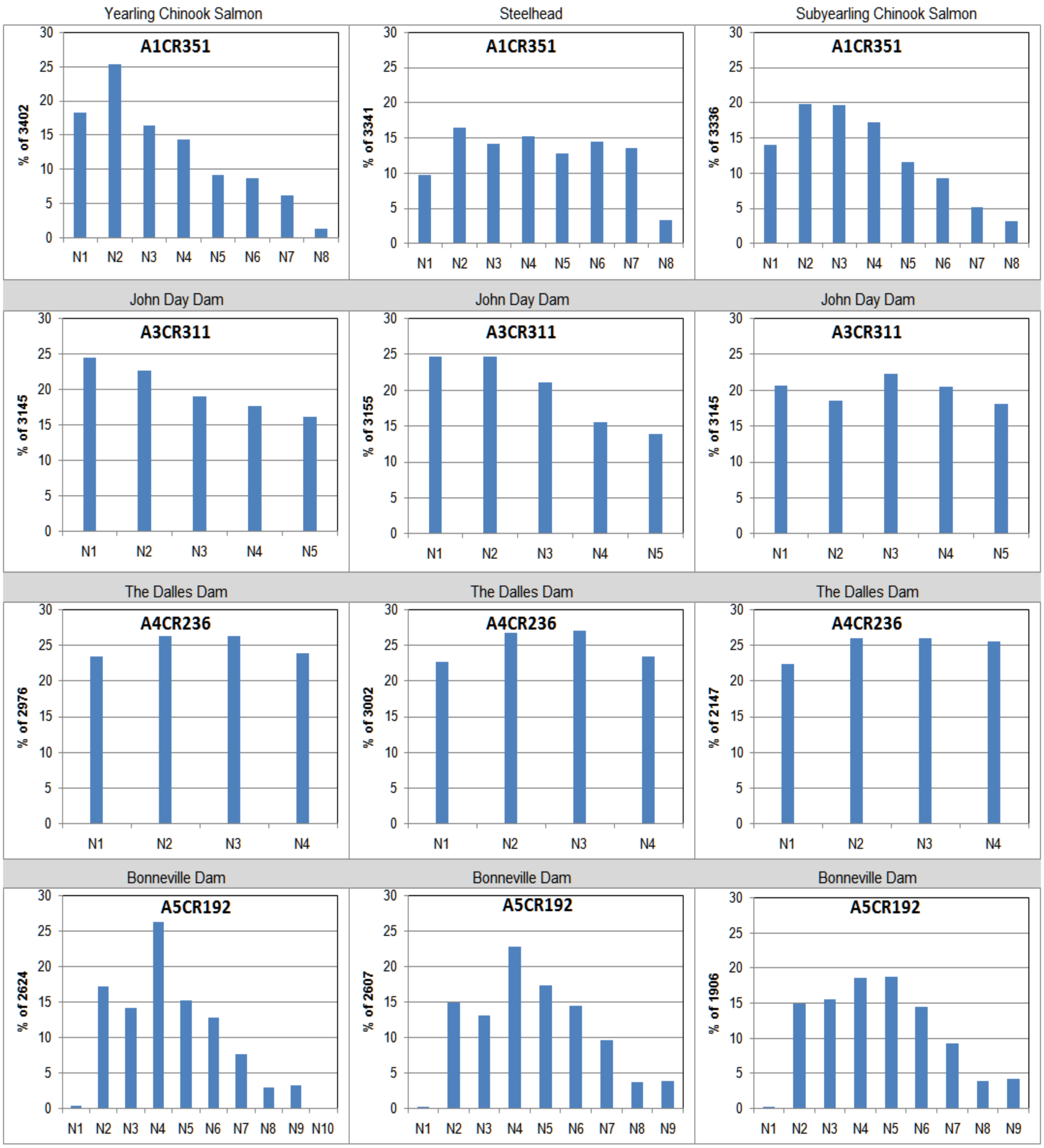

Figure 3.12. Percentage of Acoustic-Tag Detections by Fish Run (Columns) on Autonomous Nodes During 2009. Arrays were deployed in the JDA forebay (1st row), TDA forebay (2nd row), BON forebay (3rd row), and BON tailwater near Lady Island and Camas, Washington (4th row). In general, the Washington shore is on the left side of each panel and the Oregon shore is on the right as if the reader were looking upstream. Node N1 in Array A5CR192 was deployed north of Lady Island outside of the main navigation channel. All other nodes were deployed within the main navigation channel.

Another indicator of autonomous array performance is the frequency of simultaneous detections on multiple nodes within arrays, and the arrays upstream of BON clearly had more multi-node detections than did the first tailwater array downstream of BON (Figure 3.13). For example, the percent of simultaneous CH1 detections on two or more nodes ranged from 96 to 99% on the JDA forebay array, from 93 to 97% on TDA forebay array, and over 99% on the BON forebay array. In contrast, percent detection on two or more nodes of the BON primary array near Camas, Washington, was just 68% for CH1 and STH and 85% for CH0.

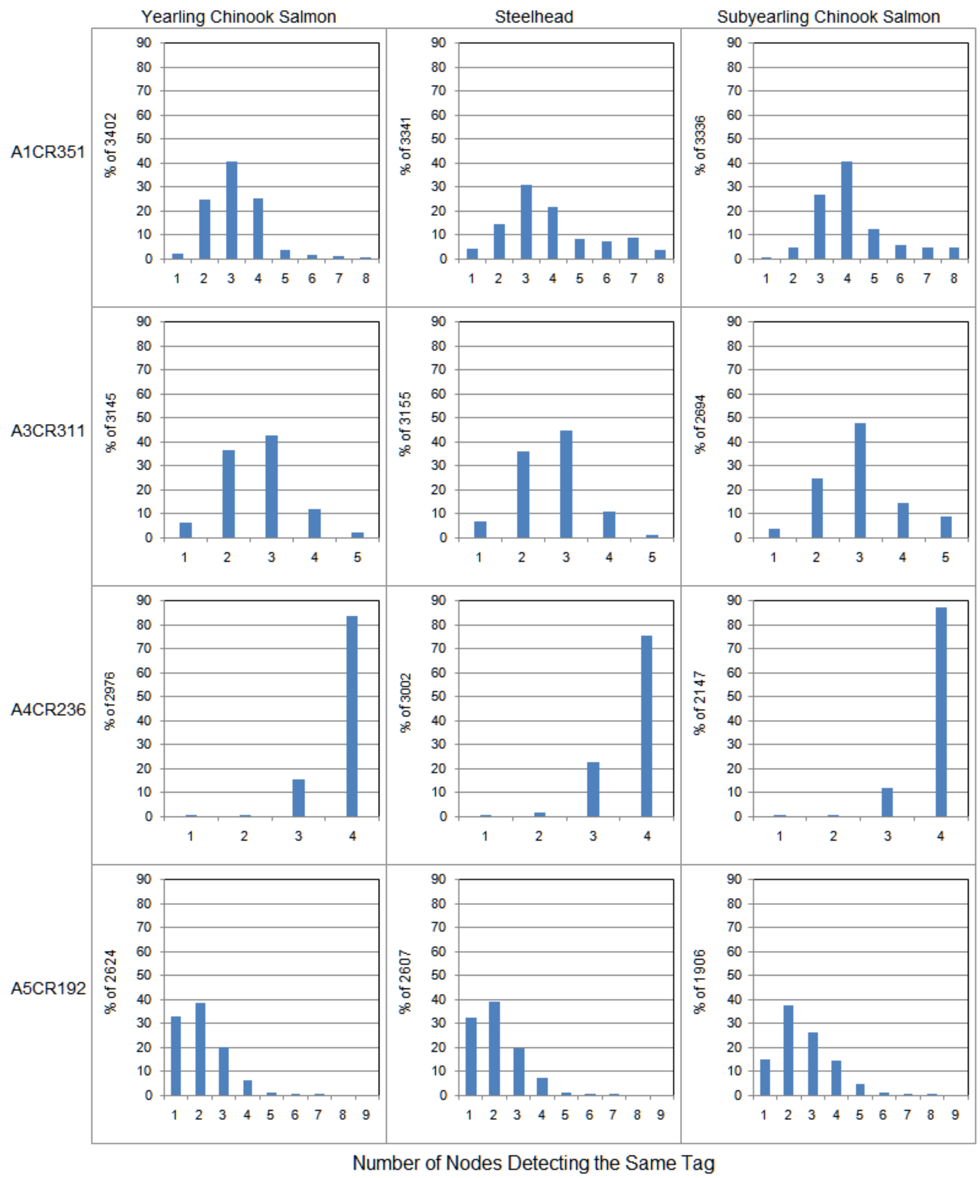

Figure 3.13. Frequency of Detections on Multiple Autonomous Nodes During 2009. Arrays were located in the JDA forebay entrance (A1CR351), TDA forebay entrance (A3CR311), BON forebay entrance (A4CR236), and BON tailwater (A5CR192).

Tagged-fish-detection probabilities for the array near Camas were inversely correlated with river discharge, meaning that detectability decreases and river discharge increases (Figure 3.14). The preferred situation is for detection probabilities to be independent of discharge, as observed for arrays in the TDA and BON forebays. The array near Camas, Washington, served as the tertiary array for the JDA study and as the primary survival array for a study at the BON B2.

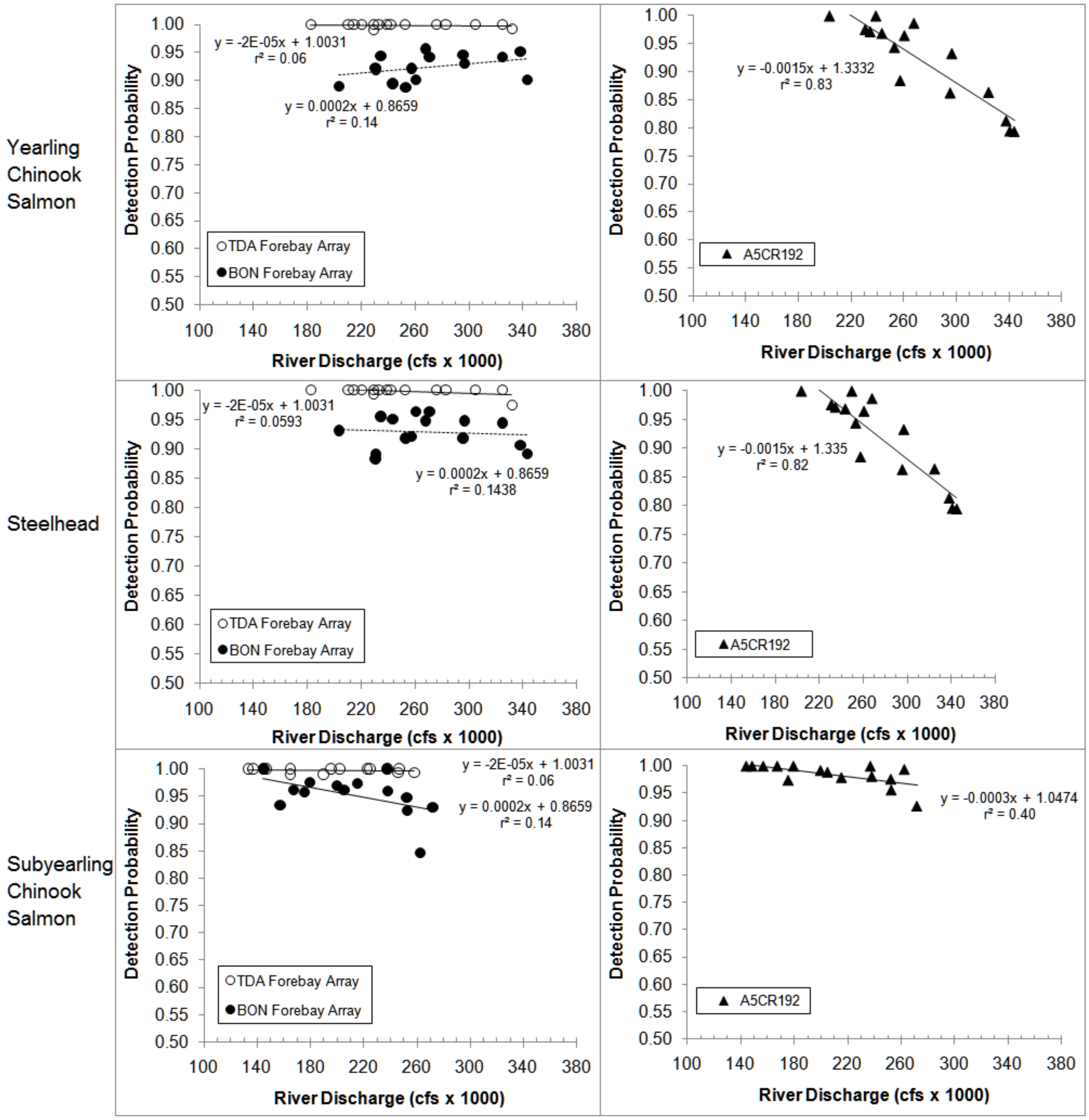

Figure 3.14. Detection Probabilities as a Function of Water Discharge in Three Detection Arrays During 2009. Array A5CR192 was located 42 km downstream of BON adjacent to Lady Island near Camas, Washington.

3.2.3 Tag Life

All acoustic tags in the tag-life study were active for the expected 23 days (Figure 3.15), and mean time to tag failure was 30 ± 1.0 (SE) days. The range in time until tag failure was from 24 to 49 days. All stocks of fish passed the tertiary survival-detection array before there was any significant tag failure (Figure 3.15), so it was not necessary to make tag-life corrections to any single-release survival estimate reported in this study.

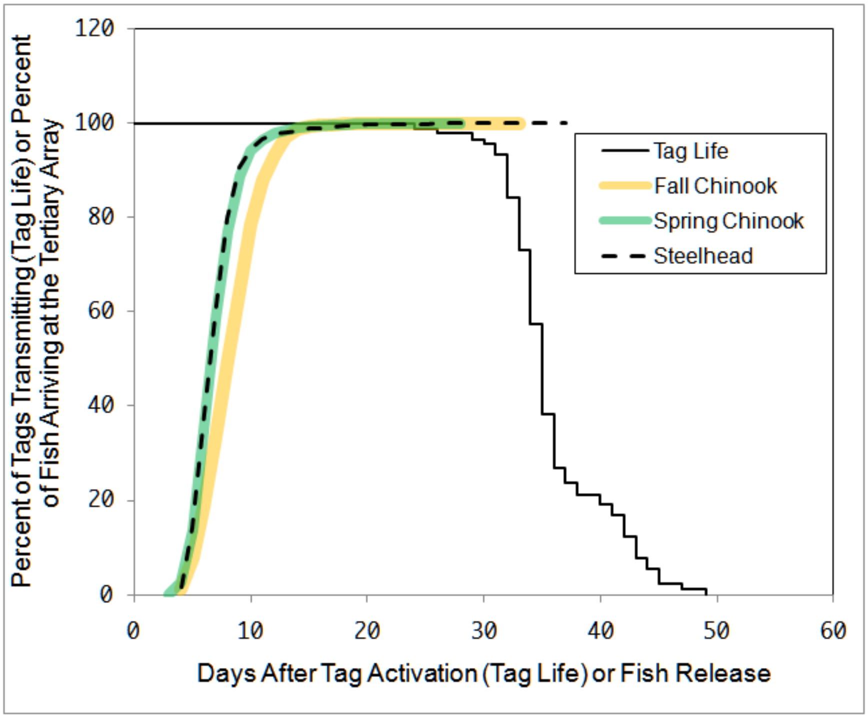

Figure 3.15. Percentage of Acoustic Tags Still Transmitting Versus Time Since Tag Activation During 2009. Expected nominal tag life was 23 days.

3.2.4 Tests of Survival-Model Assumptions

The length frequencies of tagged and untagged fish of each stock were compared in Section 3.1.4 to assess whether tagged fish were reasonably representative of the run at large. Results are examined using the following 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 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.

3.2.4.1 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 D presents the probabilities for Test 2 whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture for every release by fish stock and survival metric reported in this study.

Most of the Goodness-of-Fit analyses for the Burnham Test could not be calculated because of exceptionally high detection probabilities on JDA survival arrays (Appendix D). For CH1, none of the results for Test 2 were significant, and of 74 runs of Test 3, six (8%) were significant at α = 0.1. For STH, 4 of 69 runs (6%) for Test 2 and 4 of 69 runs for Test 3 (6%) were significant. For CH0, 2 of 53 results (4%) for Test 2 were significant and, 2 of 53 (4%) were significant at α = 0.1.

3.2.4.2 Arrival Distribution Tests

There were no tests of arrival distributions in 2009 because there were no reference releases of fish to compare to treatment releases.

3.3 Yearling Chinook Salmon

This section contains estimates of survival rates, travel times, passage metrics, and distributions for CH1 at JDA during spring 2009.

3.3.1 Effect of Spill Conditions on Fish

Two spill levels were compared in a randomized block design during spring and summer 2009 at JDA: 30% and 40% spill discharge out of total project discharge. The purpose of the comparison was to determine which spill level provides the most protection for downstream migrants at the dam.

Dam operators were able to meet spill treatment requirements for the first five of eight blocks in spring and provided treatments that were obviously different, although less consistent than the first five blocks after May 19 for blocks six through eight (Figure 3.16). Fish did not arrive in sufficient numbers during the eighth block so it was dropped as a treatment.

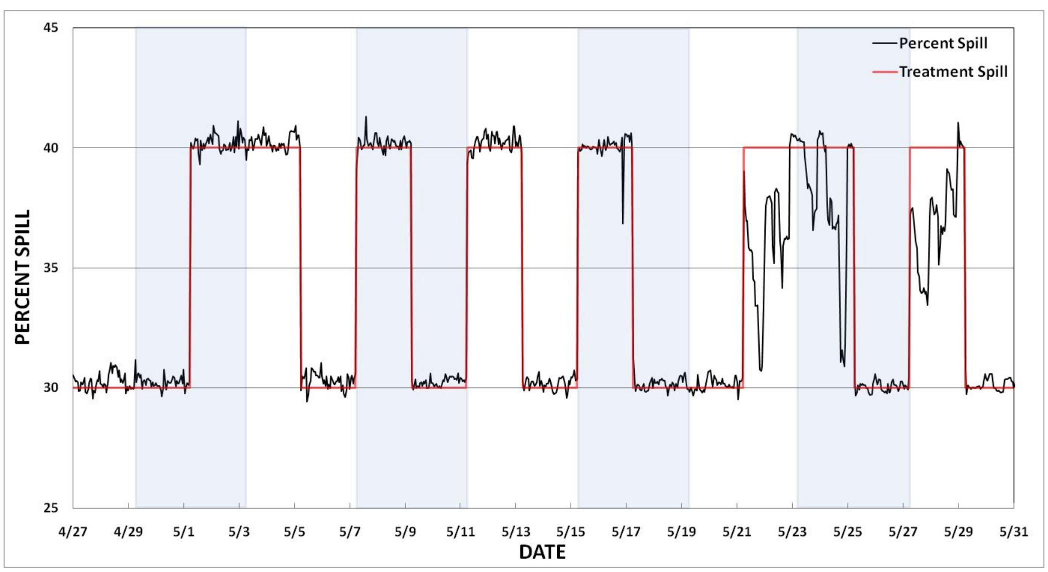

Figure 3.16. Spill Treatments as Prescribed (red line) and Actual Conditions (black line) in Spring 2009. The shaded areas represent odd numbered treatment blocks. (Repeated from Figure 3.3 for ease of reference.)

When comparing spill treatments that occurred during the first five blocks that closely met prescribed treatments, a one-tailed paired t-test showed that survival rates were significantly higher during the 30%

spill treatment than they were during the 40% spill treatment (Table 3.6). Mean survival rates did not differ significantly when data from all seven blocks were analyzed. The mean survival rates for each block used in the analysis and the t-test results are provided for the five block in Tables 3.7 and 3.8 and seven block analysis in Tables 3.9 and 3.10.

Table 3.6. Estimates of JDA Forebay-to-TDA Forebay Passage Survival Rates by Spill Treatment for CH1 During Spring 2009. A one-tailed, paired t-test produced the listed probabilities and those < α = 0.05 were considered to be significant.

Spill Treatment	Blocks Analyzed	Survival Rate (±1/2 95% CI)	One Tailed Probability (P)
30% Spill	5	0.943 ± 0.018	0.0330*
40% Spill	5	0.925 ± 0.010	
30% Spill	7	0.930 ± 0.027	0.2873
40% Spill	7	0.924 ± 0.008	

Table 3.7. Estimates of JDA Forebay-to-TDA Forebay Passage Survival Rates by Two-Day Block and Spill Treatment for CH1, for First Five Blocks, During Spring 2009

Block	30% Spill	½ 95% CI	40% Spill	½ 95% CI
1	0.968	0.022	0.935	0.041
2	0.935	0.029	0.926	0.037
3	0.918	0.035	0.92	0.037
4	0.947	0.029	0.932	0.029
5	0.947	0.029	0.91	0.037

Table 3.8. Results of a One-Tailed, Paired T-Test Comparing Estimates of JDA Forebay–to-TDA Forebay Passage Survival Rates by Two-Day Block and Spill Treatment for CH1, for First Five Blocks, During Spring 2009

	30% Spill	40% Spill
Mean	0.943	0.9246
Variance	0.000336	9.98E-05
Observations	5	5
Pearson Correlation	0.457011	
Hypothesized Mean Difference	0	
df	4	
t Stat	2.509506	
P(T<=t) one-tail	0.033046	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.066092	
t Critical two-tail	2.776445	

Table 3.9. Estimates of JDA Forebay-to-TDA-Forebay-Passage Survival Rates by Two-Day Block and Spill Treatment for CH1, for Seven Blocks, During Spring 2009

Block	30% Spill	½ 95% CI	40% Spill	½ 95% CI
1	0.968	0.022	0.935	0.041
2	0.935	0.029	0.926	0.037
3	0.918	0.035	0.92	0.037
4	0.947	0.029	0.932	0.029
5	0.947	0.029	0.91	0.037
6	0.912	0.033	0.926	0.031
7	0.885	0.041	0.922	0.029

Table 3.10. Results of a One-Tailed, Paired T-Test Comparing Estimates of JDA Forebay-to-TDA Forebay Passage Survival Rates by Two-Day Block and Spill Treatment for CH1, for Seven Blocks, During Spring 2009

	30% Spill	40% Spill
Mean	0.930286	0.924429
Variance	0.000757	6.8E-05
Observations	7	7
Pearson Correlation	0.313975	
Hypothesized Mean Difference	0	
df	6	
t Stat	0.593331	
P(T<=t) one-tail	0.287314	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.574628	
t Critical two-tail	2.446912	

Spill-passage efficiency was significantly higher under the 40% spill treatment than under the 30% spill treatment, but the opposite was true for all other passage metrics except FPE, which did not differ between treatments (Table 3.11). Metrics that were higher during 30% spill than during 40% spill included FGE at turbines (up 8.9%), TSWE (up 8.9%), JBSE (up 8%), SPE (up 0.38), and TSW effectiveness (up 1.42). Combined with the survival results, this means that 9.6% more CH1 smolts are passing through the spillway during 40% spill than during 30% spill, but JDA-to-TDA forebay passage survival rate is 1.8% percentage points lower when spill is at 40% than when it is at 30%.

Table 3.11. Estimates of Major Passage Metrics by Spill Treatment for CH1 During Spring 2009. *A one-tailed, paired t-test produced the listed probabilities and those < α = 0.05 were considered to be significant.

Metric	Spill Treatment	Estimate (±1/2 95% CI)	T-Test Probability
FPE	30%	92.62 ± 0.76%	0.1193
	40%	94.26 ± 0.64%	
SPE	30%	75.86 ± 1.54%	0.0048*
	40%	85.44 ± 1.06%	
FGE	30%	69.44 ± 3.17%	0.0264*
	40%	60.58 ± 3.43%	
TSWE	30%	31.46 ± 1.30%	0.0100*
	40%	22.60 ± 1.43%	
JBSE	30%	16.77 ± 1.48%	0.0027*
	40%	8.82 ± 0.82%	
SEF	30%	2.51 ± 0.05	<0.0001*
	40%	2.21 ± 0.03	
TSWEF	30%	4.35 ± 0.18	0.0060*
	40%	2.98 ± 0.19	

3.3.2 Survival Rates

The survival and capture history of CH1 were evaluated for both JDA and TDA. Capture histories are presented in Appendix C.

3.3.2.1 Seasonal Trends, JDA-to-TDA Forebay, and Route-Specific Survival Rates

Estimates of single-release survival rates [$\hat{S}$ (±1/2 95% CI)] were calculated for CH1 released at Roosevelt, Washington (rkm 390), and regrouped at the JDA dam face to form virtual releases. The single-release, JDA-to-TDA forebay passage survival rate for JDA was 0.927 (±0.010), and there was no significant seasonal trend in estimates by virtual release (Figure 3.17). The highest route-specific survival rate (Table 3.12) was for JBS-passed fish (0.975 ± 0.016) followed closely by the rate for TSW-passed fish (0.951 ± 0.014). The non-TSW spillway-passage survival rate was lower 0.912 ± 0.014 than the rate for TSW-passed fish. The lowest survival rate came from turbine-passed fish (0.851 ± 0.047). Detailed capture histories and survival estimates by release are in Appendix C.

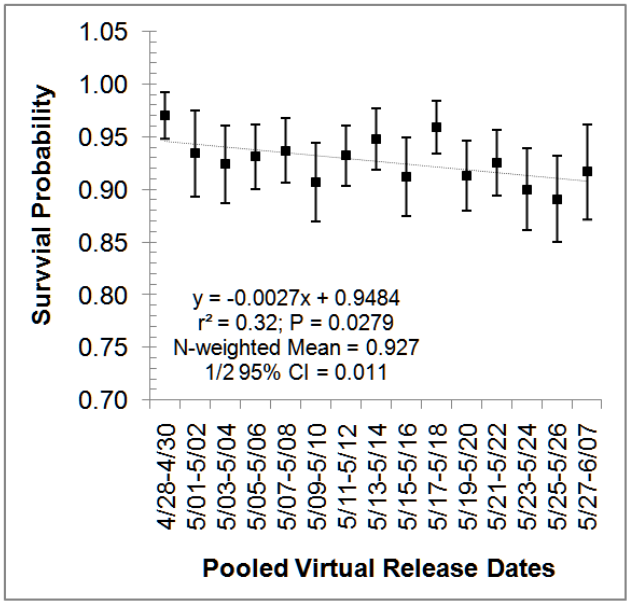

Figure 3.17. Seasonal Trend in Single-Release, JDA to TDA Forebay-Passage Survival Probability for CH1 at JDA in Spring 2009. Vertical bars indicate the extent of individual 95% confidence intervals; the light gray regression line indicates a slight downward trend with a slope that did not differ significantly from zero; regression statistics, the N-weighted mean, and associated ½ 95% confidence intervals are for all data are listed below the points.

Table 3.12. Single-Release Estimates of Survival for CH1 Smolts in Virtual Releases at JDA During 2009 Based on Detections at Three Downstream Arrays (A3CR211, A4CR236, and A5CR192).

Route	Survival	±1/2 95% CI
JDA-to-TDA forebay	0.927	0.010
Non-TSW	0.913	0.014
TSW	0.951	0.014
Turbine	0.851	0.047
JBS	0.975	0.016

3.3.2.2 Day/Night Trends in Survival Rates

For most routes, the survival rate estimate was higher for CH1 smolts that passed at night than it was for smolts that passed during the day (Figure 3.18). Only at spill bays 2–14 was the daytime survival rate higher than that for nighttime, although the result is likely not statistically significant because of overlapping confidence intervals. Recall, during spring, day and night periods were defined as follows: day = 0600 to 2159 h and night = 2200 to 0559 h.

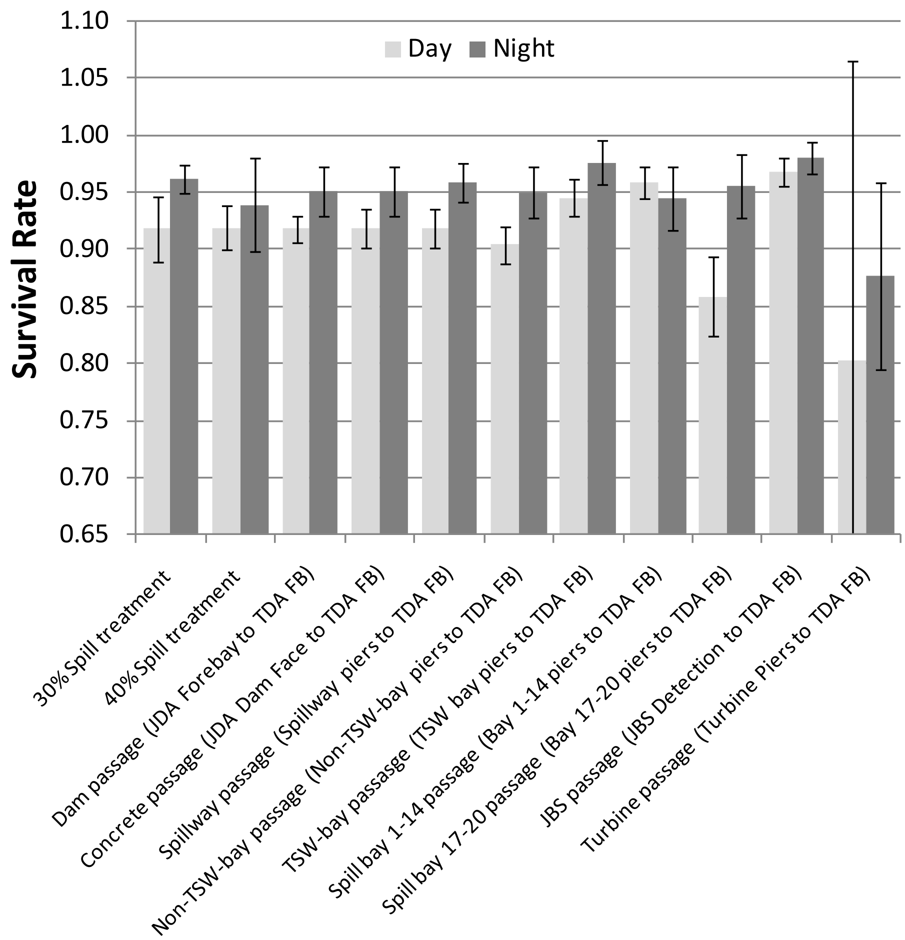

Figure 3.18. Day and Night Single-Release Estimates of CH1 Survival Rates by Route of Passage During Spring 2009

3.3.2.3 Survival Rates at The Dalles Dam

Yearling Chinook salmon released at Roosevelt, Washington (rkm 390), were regrouped on the TDA forebay entrance array and used to estimate TDA forebay to BON forebay-passage survival rate based on subsequent detections on one array in the BON forebay and two arrays in the BON tailwater. The estimate of single-release passage survival rate for CH1 smolts traveling from TDA forebay entrance array to the BON forebay array was 0.890 ± 0.012 (1/2 95% CI), and estimates for individual virtual releases had no significant seasonal trend (Figure 3.19). Detailed capture history and survival results by release are in Appendix C.

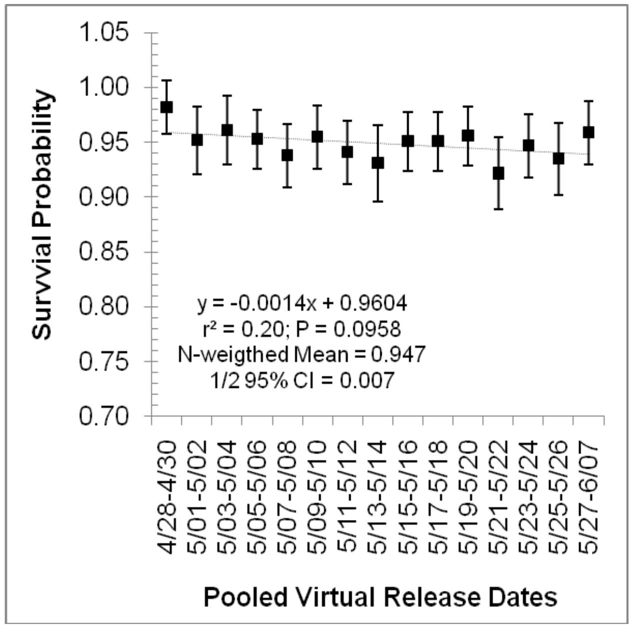

Figure 3.19. Seasonal Trend in Single-Release, Dam-Passage Survival Probability for CH1 at TDA in Spring 2009. Vertical bars indicate the extent of individual 95% confidence intervals; the light gray regression line indicates a slight downward trend with a slope that did not differ significantly from zero; regression statistics, the N-weighted mean, and associated ½ 95% confidence intervals for all data are listed below the points.

No significant difference was observed in TDA passage survival for CH1 passing by four different routes through JDA based on overlap of ½ 95% confidence intervals (Table 3.13).

Table 3.13. Single-Release Estimates of TDA Passage Survival for CH1 That Previously Passed Through Six Routes at JDA During 2009

JDA Passage Route	TDA Survival	½ 95% CI
Spillway (TSW bays 15 & 16)	0.874	0.024
Spillway (All Non-TSW bays)	0.894	0.016
Non-TSW bays 2–14	0.881	0.024
Non-TSW bays 17-20	0.908	0.020
Turbines	0.903	0.043
JBS	0.898	0.029

Passage efficiency and effectiveness, powerhouse and spillway passage, the effect of spill conditions on dam-passage survival rate and passage proportions, and day/night trends in survival rates and passage efficiencies relative to CH1 at JDA during spring 2009 are described below.

3.3.3 Passage Metrics and Distributions

In this section, passage and distribution data are presented for passage efficiency and effectiveness, powerhouse horizontal distribution, the relationship between powerhouse passage and discharge, spillway horizontal distribution, and day/night trends in passage.

3.3.3.1 Passage Efficiency and Effectiveness

For CH1 smolts in spring 2009, JDA FPE was 93.4 SPE was 80.6%; and the two spill bays with TSWs passed 27.1% of all smolts in 7.4% of the water discharged through the dam (Table 3.14). The TSW was 1.54 times more effective than the entire spillway at passing CH1 smolts. Of the 24% of CH1 smolts passing into the powerhouse, 66.2% were diverted by the intake screens into the JBS, and JBSE, relative to total numbers passing through the dam, was 12.8%. About 6.6% of all CH1 smolts passed through turbines.

Table 3.14. Estimates of Major Passage Metrics for CH1 During Spring 2009

Metric	Estimate (±1/2 95% CI)
FPE	93.43 ± 0.94%
SPE	80.59 ± 1.75%
FGE	66.15 ± 4.38%
TSWE	27.08 ± 1.85%
JBSE	12.84 ± 1.56%
SEF	2.37 ± 0.05
TSWEF	3.66 ± 0.25

3.3.3.2 Powerhouse Horizontal Distribution and the Relationship between Passage and Discharge

During spring, 66% of the CH1 smolts that passed through the dam at the powerhouse were guided through the JBS, and the remaining one-third passed through the turbines (Figure 3.20). Turbine discharge varied widely across the powerhouse and was lowest at units 6, 10, and 13 and highest at units 1–3, 5, 11, and 14–16. A regression of number of tagged CH1 smolts passing each turbine in spring on unit-specific discharge was highly significant ($P < 0.0001$) and discharge explained 70% of the variation in CH1 passage (Figure 3.21).

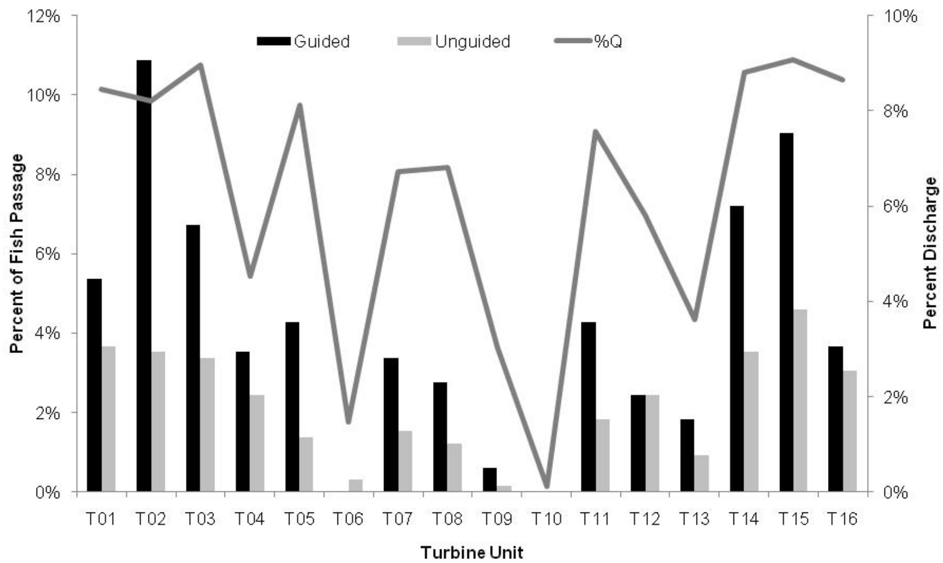

Figure 3.20. Percent Passage for Guided and Unguided CH1 and Percent Discharge by Turbine Unit for the John Day Powerhouse During Spring 2009

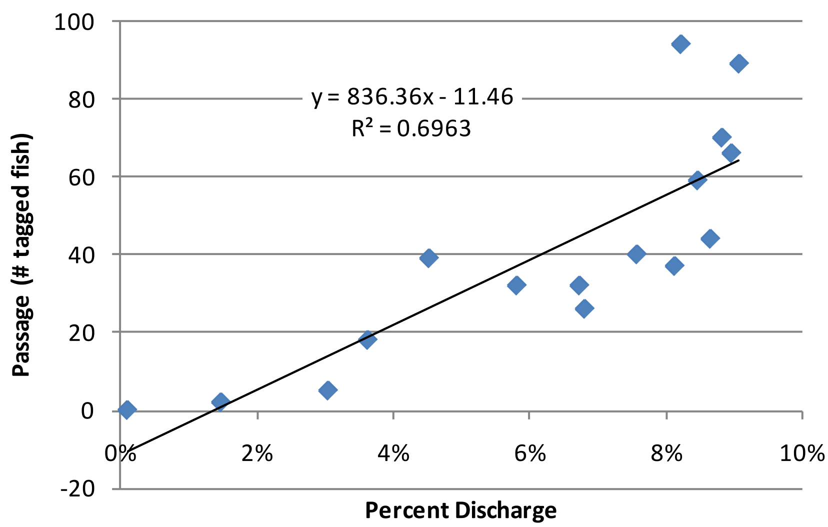

Figure 3.21. Regression of Fish-Passage on Percent Discharge for CH1 at the Powerhouse Turbine Units During Spring 2009

3.3.3.3 Spillway Horizontal Distribution

Of the CH1 smolts passing through the spillway, 73.2% passed through high-discharge bays, including TSW bays 15 and 16 and the nearby bays 14, 17, and 18 (Figure 3.22). Higher discharge at bays near the TSW bays was designed to provide training flow to speed tailrace egress for fish passing through the TSW bays. The average rate of passage at an average TSW spill bay was 7.4 times higher than the average rate for spill bays 1–14 and 1.9 times higher than the rate for bays 17–20 (Figure 3.23).

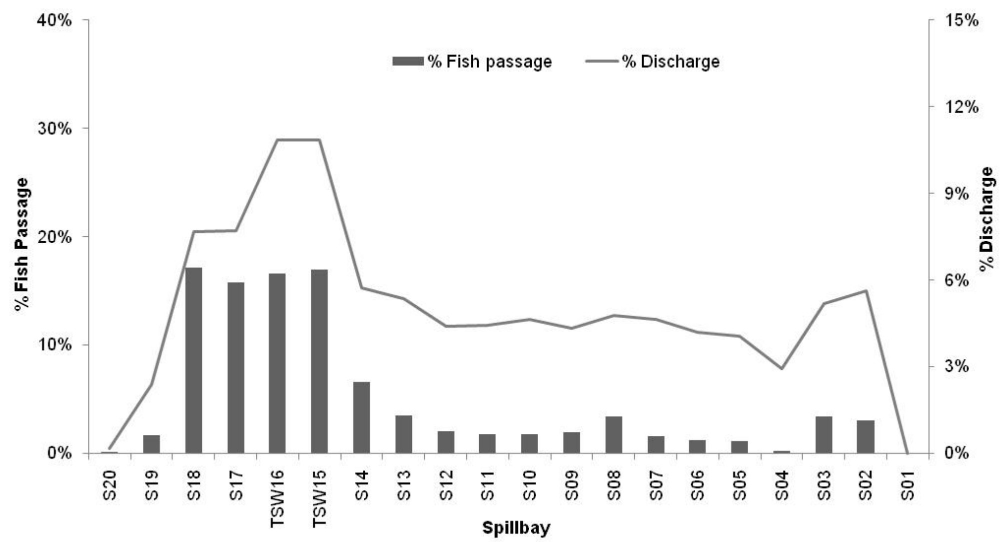

Figure 3.22. Percent CH1 Passage and Percent Discharge by Spill Bay During 2009

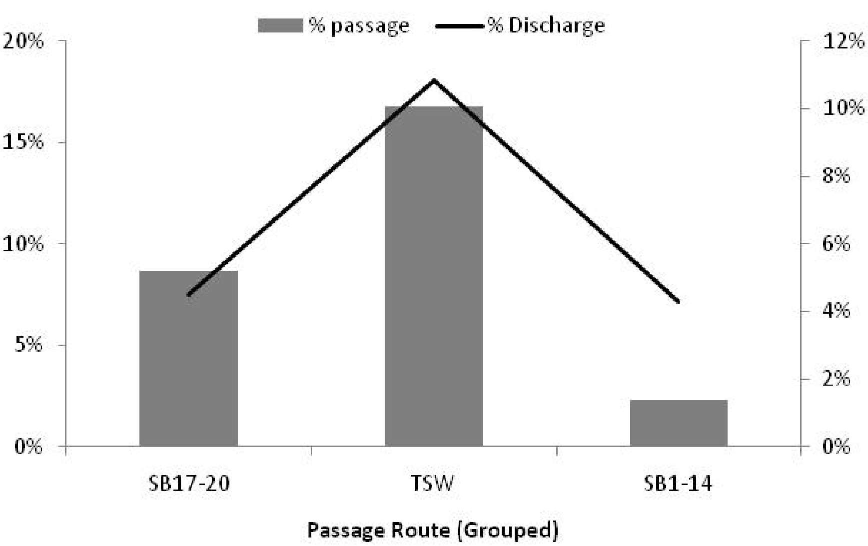

Figure 3.23. Average Percent Passage of CH1 Smolts and Percent Discharge Per Spill Bay Within Groups of Bays During 2009

3.3.3.4 Day/Night Trends in Passage

Total passage and spillway passage rates for CH1 were higher during the day than at night, while fish-passage rates for the powerhouse (JBS and turbines) were higher at night than during the day (Figure 3.24). The numbers of CH1 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. Hourly passage rates through spill bays 2–14, the TSW, and spill bays 17–20 were all higher during the day than they were at night, and both day and night passage rates per bay and hour were higher at TSW bays than they were at other spill bays (Figure 3.25).

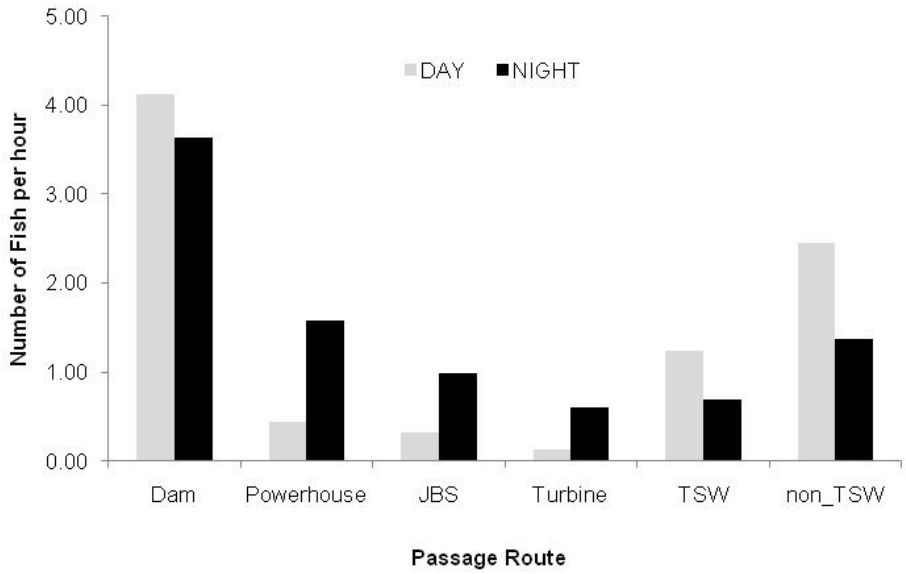

Figure 3.24. Day and Night Differences in Passage Rates for CH1 During 2009

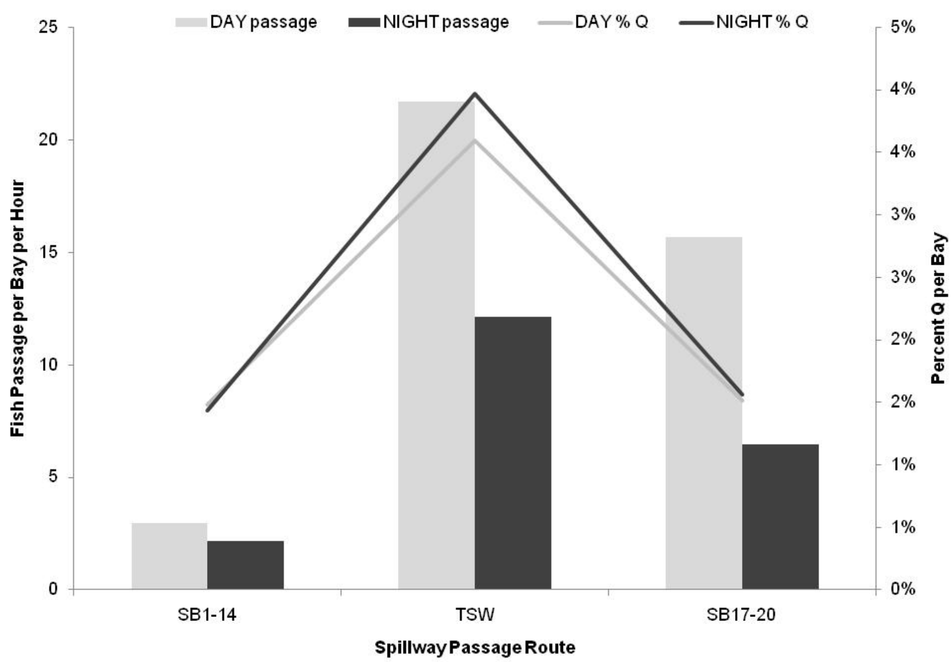

Figure 3.25. Day and Night Differences in Passage Rates (number/hour/bay) for CH1 and Percentage of Discharge (Q) for Groups of Spill Bays During 2009

3.3.4 Fish Behavior

This section contains a description of the arrival and passage patterns, day and night differences in behavior, vertical distributions, and travel and forebay residence times of fish, implanted with JSATS acoustic transmitters, in the forebay of JDA. The autonomous node array located 2 km upstream of JDA 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. For analysis purposes, fish arriving at JDA were grouped into arrival blocks and passage-route blocks. The arrival blocks were assigned from autonomous nodes located in the JDA 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, bays 1–14, 15–16 (TSW), and 17–20.

3.3.4.1 Approach and Route of Passage

The approach of CH1 at JDA during 2009 was as follows: 40% at the powerhouse, 13% at the skeleton bays, and 47% at the spillway (Figure 3.26). Of the tagged CH1 first detected approaching the powerhouse or skeleton bays, 66% eventually moved north and passed at the spillway. Fish approaching at the spillway were more likely to pass through the dam at the spillway (46% of total approach) than at the powerhouse (1.6% of total approach).

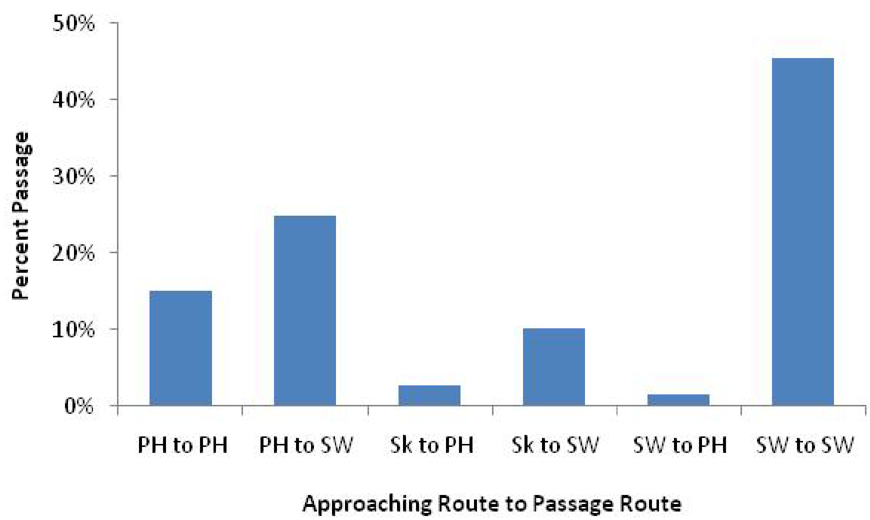

Figure 3.26. Yearling Chinook Salmon Approach and Passage Distributions at JDA During Spring 2009. The first abbreviation is for the approach location and the second is for the passage location. Abbreviations are: PH = powerhouse; Sk = skeleton bay; SW = spillway.

Of all fish passing the dam, ~7% approached at the powerhouse but passed at the TSWs (spillway block 15–16) (Figure 3.27). In contrast, ~13% of total passage occurring at the TSWs came from fish arriving at the powerhouse. More than half of the CH1 arriving at the powerhouse moved north to pass at the spillway. On the other hand, few fish approached the spillway and moved south to pass at the powerhouse. Only 5% of the tagged CH1 approached the dam in the forebay of the TSWs (Figure 3.27), while 27% passed there (Table 3.14).

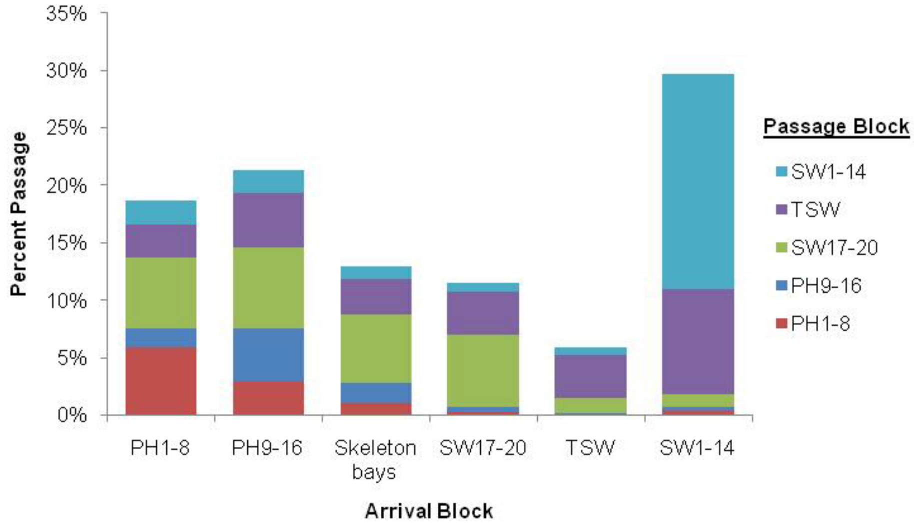

Figure 3.27. Yearling Chinook Salmon Approach and Passage Behavior Patterns at JDA During 2009

3.3.4.2 Day/Night Behavior Patterns

Yearling Chinook salmon passing the powerhouse at night tended to approach at the powerhouse (Figure 3.28). However, during daytime, CH1 approaching the powerhouse were more likely to migrate and pass through the spillway rather than pass at the powerhouse. A similar pattern was observed for fish approaching the skeleton bay area. Upon approaching the spillway, CH1 displayed a tendency to pass there during the day; this pattern was also evident at night, although less so.

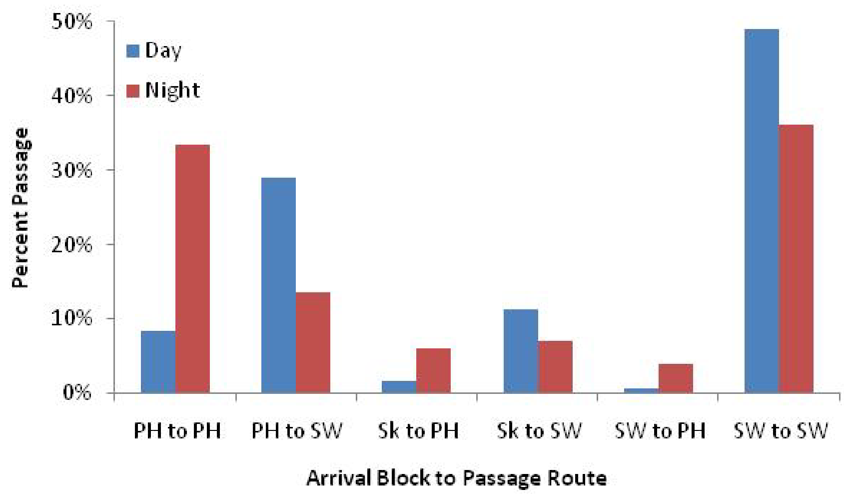

Figure 3.28. Yearling Chinook Salmon Approach and Passage Behavior Patterns During Day and Night, Spring 2009. Day/night allocation was defined by when the fish passed the dam.

Most CH1 arriving at the powerhouse eventually passed through spill bays 17–20 during the day (Figure 3.29). This was not the case at night; most CH1 arriving at the powerhouse passed there at night (Figure 3.30). Approach and passage behavioral patterns for the spillway were similar for day and night (Figures 3.29 and 3.30).

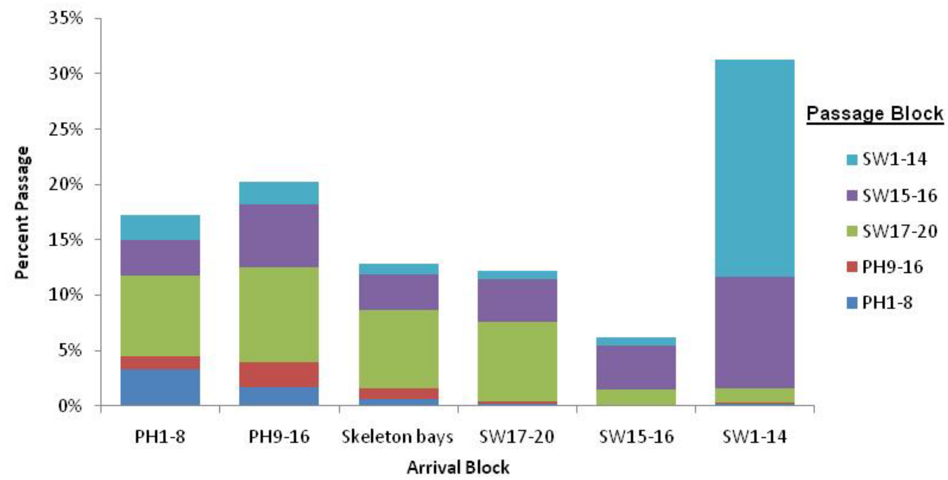

Figure 3.29. Approach and Passage Patterns for CH1 During Daytime at JDA, Spring 2009

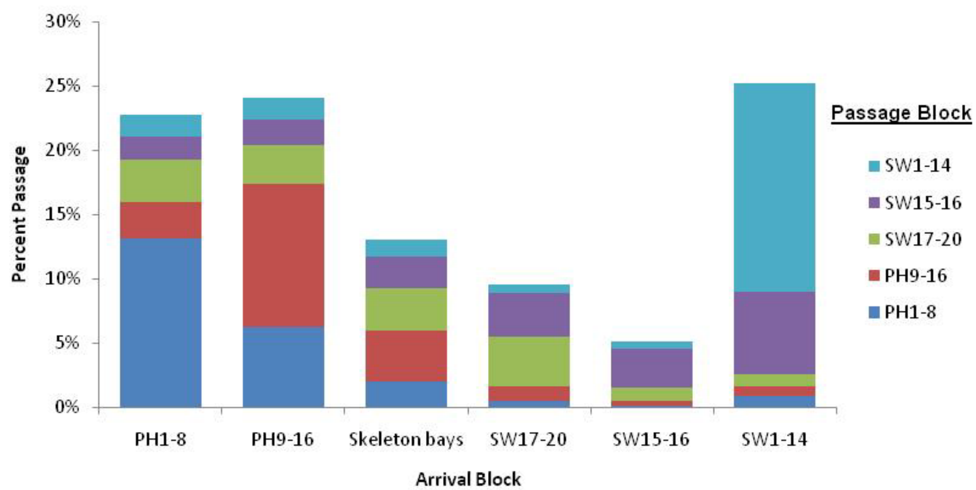

Figure 3.30. Approach and Passage Patterns for CH1 Passing JDA at Night During Spring 2009

3.3.4.3 Vertical Distribution Behavior Patterns

As CH1 approached the powerhouse, median depth of passage gradually decreased as distance from the dam decreased from 75 m to 10 m from the face of the powerhouse (Figure 3.31). However, < 5 m from the face of the powerhouse, median depth increased to over 20 m where the turbine intakes are located (Figure 3.31). At the spillway, CH1 approached at shallow depths (~2–3 m). Any sudden increases in depth associated with passage under the tainter gates (~15 m deep) were not detected because the dam-face hydrophones at the spillway were mounted on piers well upstream of the spill ogee. There were no day and night differences in vertical distributions for powerhouse- or spillway-passed fish.

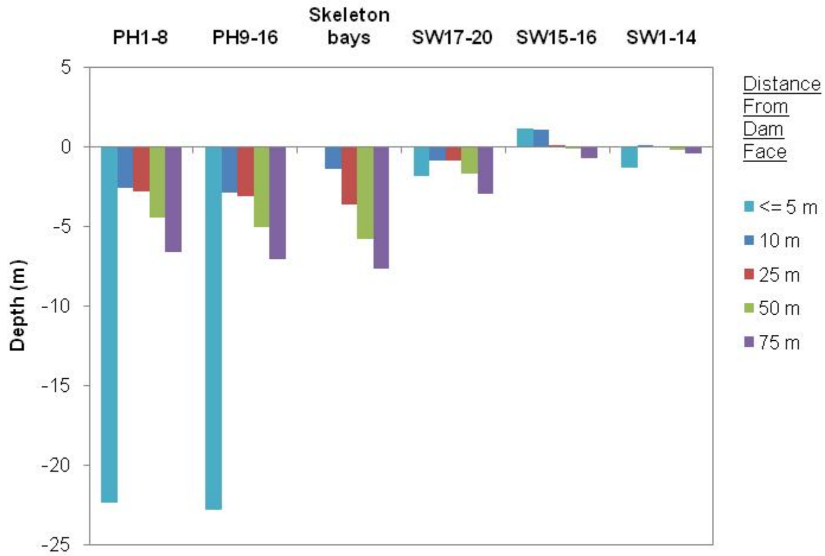

Figure 3.31. Median Depths of Last Detection of Tagged CH1 at JDA During 2009. Zero depth was referenced to the elevation of the shallow hydrophone deployed on the south side of Turbine Unit 1 at elevation 255.23 ft above MSL. Mean forebay water surface elevation was 263.5 ft above MSL.

Turbine- and JBS-passed CH1 smolts had median last-detection depths of 25 m and 20 m, respectively (Figure 3.32). Fish that pass into the JBS at JDA 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.

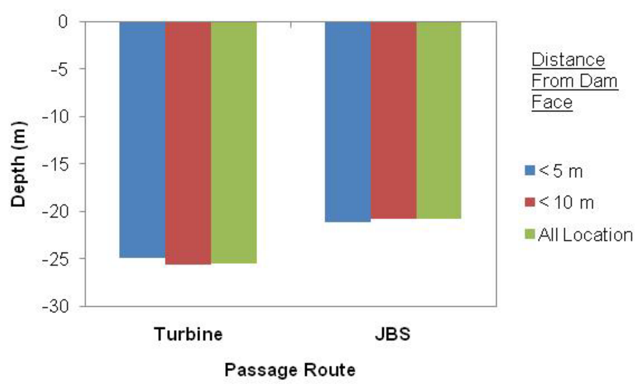

Figure 3.32. Median Depths of CH1 Passing into the JBS and Turbines, JDA 2009

3.3.4.4 Travel Times and Forebay Residence Times

During spring 2009, the median travel time for CH1 between the release station near Roosevelt, Washington, and the JDA forebay array was 33.0 hours (Table 3.15). For tagged CH1 detected on the forebay array, the median travel time until passage through JDA was 2.9 hours. Median travel time from the JDA face to the tailrace egress array 10 km downstream of the dam was 0.5 hours. From the JDA egress array to TDA forebay array, the median travel time was 14.6 hours. There was a median travel time of 29.0 hours to migrate from the TDA forebay to the BON forebay array. CH1 travel times were longest for the JBS route and shortest for the TSW at JDA during spring 2009.

Table 3.15. Distance of Travel and Median and Mean Travel Times (±1/2 95% CI) for Acoustic-Tagged CH1 Passing Through Specific River Reaches Between Roosevelt, Washington, and the BON Forebay

Reach	Distance (km)	Median Travel Time (h)	Mean Travel Time (h)	1/2 95% CI
Roosevelt to JDA Forebay	39.4	33.0	40.4	0.6
JDA Forebay to JDA Passage	2			
Project		2.9	4.8	0.1
JBS		4.0	5.8	0.3
Turbine		2.7	4.6	0.2
TSW		2.6	4.5	0.2
NON-TSW		3.7	6.3	1.0
JDA Passage to JDA Tailwater	2.6			
Project		0.5	2.3	0.2
JBS		6.9	14.6	1.5
Turbine		0.5	0.9	0.2
TSW		0.4	0.6	0.1
NON-TSW		0.7	1.5	0.3
JDA Passage to JDA Tailwater 30% Spill	2.6			
Project		0.5	3.0	0.3
JBS		5.6	14.9	1.9
Turbine		0.5	0.9	0.2
TSW		0.4	0.7	0.1
NON-TSW		0.7	1.7	0.5
JDA Passage to JDA Tailwater 40% Spill	2.6			
Project		0.5	1.8	0.3
JBS		8.4	14.1	2.0
Turbine		0.5	0.9	0.3
TSW		0.5	0.5	0.0
NON-TSW		0.8	0.8	0.1
JDA Tailwater to TDA Forebay	34.6	14.6	15.6	0.1
TDA Forebay to BON Forebay	75.4	29.0	31.0	0.2

The CH1 approaching 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 10-fold higher (Figure 3.33). 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 almost 3 hours.

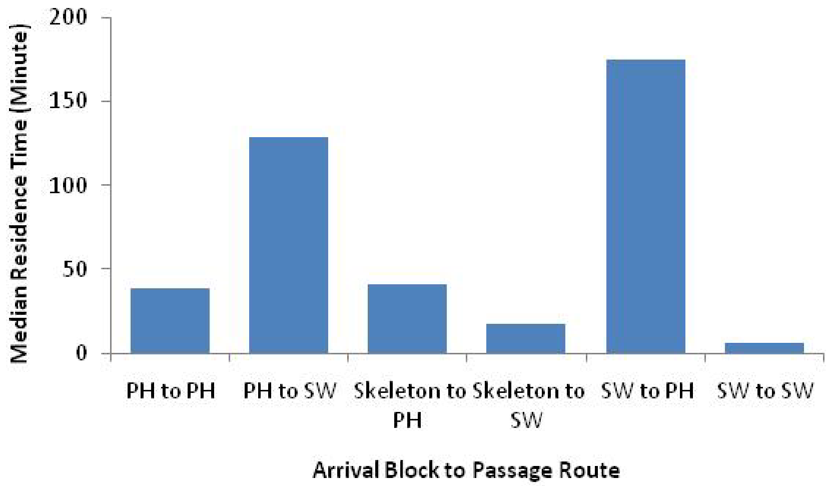

Figure 3.33. Yearling Chinook Salmon Median Passage Times During 2009

For CH1 approaching the powerhouse and passing the spillway, residence times were 2.5 times greater at night than during the day (Figure 3.34). In contrast, CH1 approaching the spillway and passing there had a median residence time of just 4 minutes whether during day or night. The longest residence time (over 4 hours) was for CH1 moving from approach at the powerhouse to passing at the spillway at night.

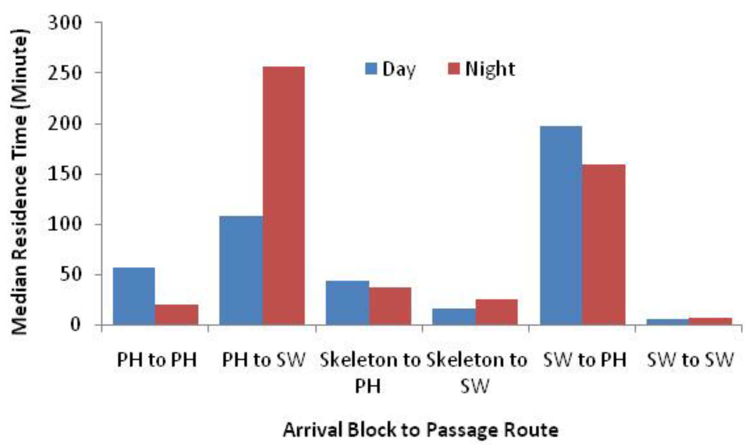

Figure 3.34. Yearling Chinook Salmon Day/Night Median Passage Times by Approach and Passage Blocks at JDA During 2009

3.4 Steelhead

This section contains estimates of survival rates, travel times, passage metrics, and distributions for STH at JDA during spring 2009.

3.4.1 Effect of Spill Conditions on Fish

As mentioned previously, dam operators were able to meet the prescribed 30%/40% spill schedule for the first five blocks but were less consistent for blocks six through eight during spring 2009 (Figure 3.35). Fish did not arrive in sufficient numbers during the eighth block so it was dropped as a treatment.

Passage survival rates for STH were high for both the 30% and 40% spill treatments, although the rate was 0.8 and 1.2 percentage points higher for 30% than 40% spill for analysis of five and seven blocks, respectively (Table 3.16). The survival difference for STH was significant for the seven-block test (P=0.0295), but not the five-block test (P=0.1430). The mean survival rates for each block used in the analysis and the t-test results are provided for the five-block analysis in Tables 3.17 and 3.18 and seven-block analysis in Tables 3.19 and 3.20.

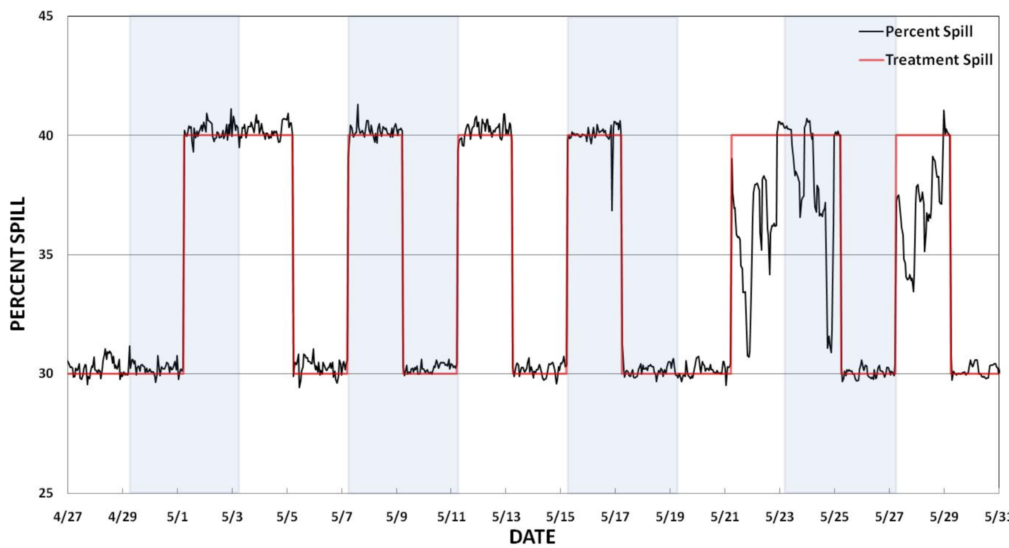

Figure 3.35. Spill Treatments as Prescribed (red line) and Actual Conditions (black line) in Spring During 2009. The shaded areas represent odd numbered treatment blocks. Repeated from Figure 3.3 for ease of reference.

Table 3.16. Estimates of JDA Forebay-to-TDA Forebay Passage Survival by Spill Condition for STH Smolts During Spring 2009. A one-tailed, paired t-test produced the listed probabilities and those < $\alpha = 0.05$ were considered to be significant.

Spill Treatment	Blocks Analyzed	Survival Rate (±1/2 95% CI)	One Tailed Probability (P)
30% Spill	5	0.955 ± 0.019	0.1430
40% Spill	5	0.947 ± 0.016	
30% Spill	7	0.959 ± 0.018	0.0295*
40% Spill	7	0.947 ± 0.014	

Table 3.17. Estimates of JDA Forebay-to-TDA Forebay-Passage Survival Rates by Two-Day Block and Spill Treatment for STH, for First Five Blocks, During Spring 2009

Block	30% Spill	½ 95% CI	40% Spill	½ 95% CI
1	0.966	0.022	0.962	0.027
2	0.975	0.018	0.943	0.035
3	0.953	0.029	0.951	0.027
4	0.958	0.027	0.96	0.025
5	0.923	0.037	0.921	0.033

Table 3.18. Results of a One-Tailed, Paired T-Test Comparing Estimates of JDA Forebay-to-TDA Forebay-Passage Survival Rates by Two-Day Block and Spill Treatment for STH, for First Five Blocks, During Spring 2009

	30% Spill	40% Spill
Mean	0.955	0.9474
Variance	0.000389	0.000275
Observations	5	5
Pearson Correlation	0.723755	
Hypothesized Mean Difference	0	
df	4	
t Stat	1.230295	
P(T<=t) one-tail	0.142996	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.285992	
t Critical two-tail	2.776445	

Table 3.19. Estimates of JDA Forebay-to-TDA Forebay Passage Survival Rates by Two-Day Block and Spill Treatment for STH, for Seven Blocks, During Spring 2009

Block	30% Spill	½ 95% CI	40% Spill	½ 95% CI
1	0.966	0.022	0.962	0.027
2	0.975	0.018	0.943	0.035
3	0.953	0.029	0.951	0.027
4	0.958	0.027	0.96	0.025
5	0.923	0.037	0.921	0.033
6	0.975	0.02	0.955	0.025
7	0.962	0.024	0.937	0.027

Table 3.20. Results of a One-Tailed, Paired T-Test Comparing Estimates of JDA Forebay-to-TDA Forebay Passage Survival Rates by Two-Day Block and Spill Treatment for CH1, for Seven Blocks, During Spring 2009

	30% Spill	40% Spill
Mean	0.958857	0.947
Variance	0.000317	0.000211
Observations	7	7
Pearson Correlation	0.668771	
Hypothesized Mean Difference	0	
df	6	
t Stat	2.324465	
P(T<=t) one-tail	0.029543	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.059087	
t Critical two-tail	2.446912	

For STH during 2009, spill efficiency was significantly higher during the 40% spill than 30% spill treatment (Table 3.21). However, JBS efficiency and spill effectiveness were significantly higher during 30% spill than 40% spill. Point estimates for FPE were 1.23 percentage points higher during 40% than 30% spill.

Table 3.21. Estimates of Major Passage Metrics by Spill Treatment for STH During Spring 2009. *A one-tailed, paired t-test produced the listed probabilities and those < $\alpha = 0.05$ were considered to be significant.

Metric	Spill Treatment	Estimate (±1/2 95% CI)	T-Test Probability
FPE	30%	96.78 ± 0.49%	0.0612
	40%	98.01 ± 0.38%	
SPE	30%	71.51 ± 1.26%	0.0012*
	40%	81.18 ± 1.20%	
FGE	30%	88.70 ± 1.65%	0.4644
	40%	89.40 ± 1.92%	
TSWE	30%	48.48 ± 1.38%	0.2043
	40%	51.84 ± 1.71%	
JBSE	30%	25.27 ± 2.44%	0.0027*
	40%	16.82 ± 2.31%	
SFE	30%	2.37 ± 0.04	0.0020*
	40%	2.10 ± 0.03	
TSWEF	30%	6.70± 0.19	0.4035
	40%	6.84 ± 0.23	

3.4.2 Survival Rates

The survival and detection histories of STH in spring were evaluated for both JDA and TDA. Capture histories are presented in Appendix C.

3.4.2.1 Seasonal Trends, JDA-to-TDA Forebay-Passage, and Route-Specific Survival Rates

Survival estimates were calculated from JDA dam-face virtual releases of STH originally released at Roosevelt, Washington (rkm 390). The single-release estimate of survival rate for JDA, from the JDA dam-face to the TDA forebay, was 0.953 ± 0.008 (1/2 95% CI), and there was no significant temporal trend in spring (Figure 3.36). The single-release survival rate was highest for JBS-passed fish (0.966 ± 0.014) followed closely by rates of (0.963 ± 0.010) for TSW-passed fish. The rate for non-TSW fish passed through the spillway (0.936 ± 0.016) was lower than that for TSW-passed fish, but the lowest rate was for turbine-passed fish (0.824 ± 0.080; Table 3.22). Detailed capture history and survival results by release date are in Appendix C.

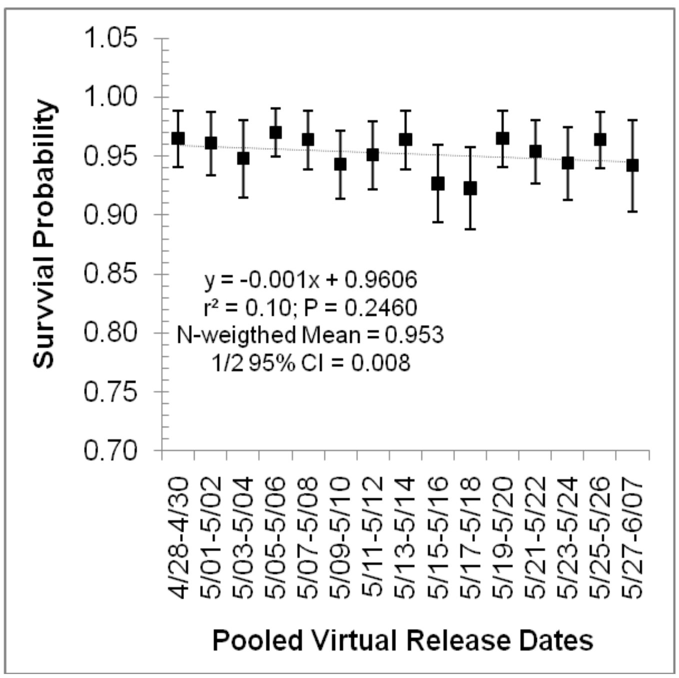

Figure 3.36. Seasonal Trend in Single-Release, JDA-to-TDA Forebay-Passage Survival Probability for STH at JDA in Spring 2009. Vertical bars indicate the extent of individual 95% confidence intervals; the light gray regression line indicates a slight downward trend with a slope that did not differ significantly from zero; regression statistics, the N-weighted mean, and associated ½ 95% confidence intervals are for all data are listed below the points.

Table 3.22. Single Release Estimates of Survival for STH Smolts Regrouped at the Corresponding Routes at the Dam to Form Virtual Releases During 2009. Survival estimates were based on pooled data.

Route	Survival	±1/2 95% CI
JDA-to-TDA forebay	0.953	0.008
Non-TSW	0.936	0.016
TSW	0.963	0.010
Turbine	0.824	0.080
JBS	0.966	0.014

3.4.2.2 Day/Night Trends in Survival Rates

Survival estimates for STH were generally higher during night than during day regardless of route or condition (Figure 3.37). The day and night difference in turbine passage survival was higher at night (84.1%) than it was during day (75.0%) (Figure 3.37).

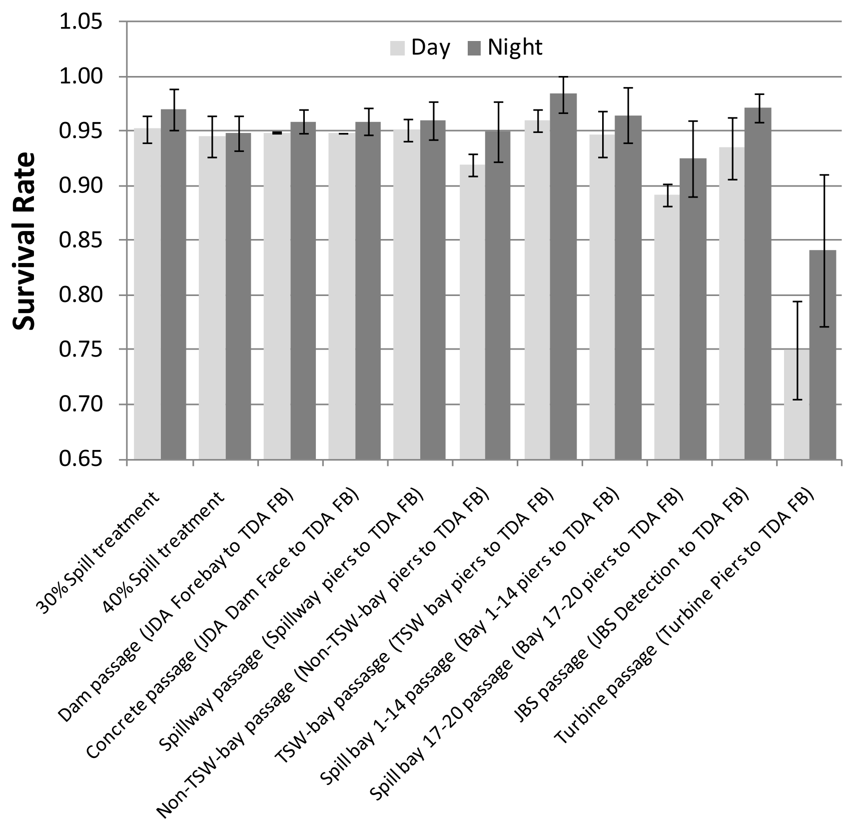

Figure 3.37. Day and Night Single-Release Estimates of STH Survival Rates by Route of Passage During Spring 2009

3.4.2.3 Survival Rates at The Dalles Dam

Steelhead smolts were released near Roosevelt, Washington (rkm 390), and regrouped on TDA forebay entrance array to create virtual releases for estimating single-release TDA forebay to BON forebay-passage survival rates for TDA. The weighted mean passage survival rate from 2 km upstream of TDA to the BON forebay was 0.896 ± 0.012 (1/2 95% CI), and there was no significant temporal trend in rates among virtual releases (Figure 3.38). Detailed capture history and survival results by release are in Appendix C.

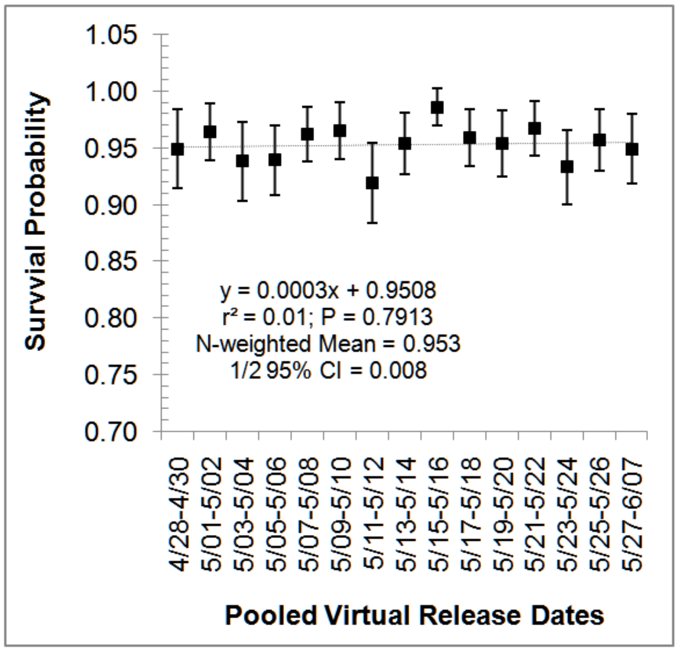

Figure 3.38. Seasonal Trend in Single-Release, TDA Forebay to BON Forebay-Passage Survival Probability for STH at TDA in Spring 2009. Vertical bars indicate the extent of individual 95% confidence intervals; the light gray regression line indicates a slight upward trend with a slope that did not differ significantly from zero; regression statistics, the N-weighted mean, and associated ½ 95% confidence intervals are for all data are listed below the points.

No significant difference was observed in TDA-passage survival for STH smolts passing by six different routes through JDA based on overlap of ½ 95% confidence intervals. However, the point estimate of the weighted mean TDA-passage survival estimate for STH smolts was 5% lower for fish that passed through JDA turbines than it was for fish passing through any other route. The ½ 95% confidence interval for turbine passed fish was 2.7 to 5.6 time higher for turbine passed STH than it was for STH passing through other routes (Table 3.23).

Table 3.23. Single-Release Estimates of TDA-Passage Survival for STH Smolts That Previously Passed Through Six Routes at JDA During 2009

JDA Passage Route	TDA Survival	½ 95% CI
Spillway (TSW bays 15 & 16)	0.898	0.016
Spillway (All Non-TSW bays)	0.904	0.022
Non-TSW bays 2-14	0.905	0.029
Non-TSW bays 17-20	0.902	0.033
Turbines	0.838	0.090
JBS	0.888	0.025

3.4.3 Passage Metrics and Distribution

Steelhead smolt, passage efficiency and effectiveness, powerhouse and spillway-passage, the effect of spill conditions on passage survival rates and passage proportions among routes, and day/night trends in survival rates and passage efficiencies at JDA during spring 2009 are described in the following sections.

3.4.3.1 Passage Efficiency and Effectiveness

During 2009, estimates of major passage metrics at JDA show that the TSWs passed 50% of all STH smolts that passed the dam (Table 3.24). The spillway routes passed 76.3% of all STH smolts that passed JDA. Of the STH smolts passing into the powerhouse, about 89% were diverted by the intake screens into the JBS. Of total dam passage, only about 3% of STH smolts passed through turbines. Non-TSW spill bays were only 52% as efficient as TSW spill bays for passing STH smolts. TSW passage effectiveness (6.8) was three times higher than spillway passage effectiveness (2.24; Table 3.24).

Table 3.24. Estimates of Major Passage Metrics for Yearling STH During Spring 2009

Metric	Estimate (±1/2 95% CI)
FPE	97.39 ± 0.59%
SPE	76.28 ± 1.69%
FGE	88.98 ± 2.40%
TSWE	50.14 ± 1.99%
JBSE	21.10 ± 1.63%
SPEF	2.24 ±0.05
TSWEF	6.78 ± 0.27

3.4.3.2 Powerhouse Horizontal Distribution and the Relationship between Passage and Discharge

During spring, 89% of all STH smolts passing into the powerhouse were guided by screens into the JBS (Figure 3.39). A regression of number of tagged STH smolts passing each turbine on unit-specific discharge was highly significant ($P < 0.0001$) with discharge explaining 64% of the variation in STH passage (Figure 3.40).

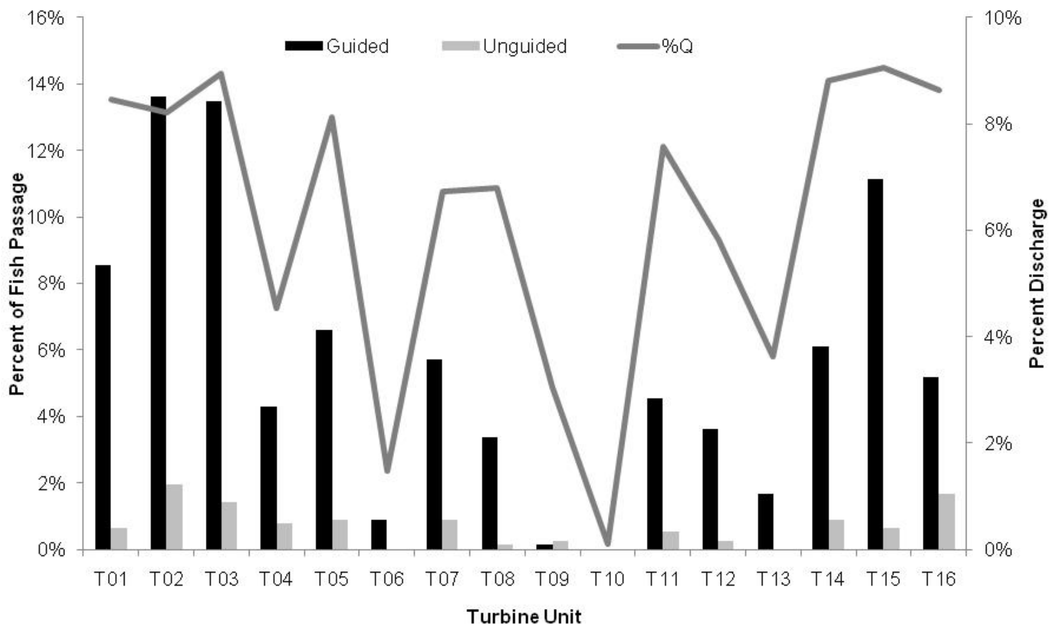

Figure 3.39. Percent Passage for Guided and Unguided STH Smolts and Percent Discharge by Turbine Unit for the John Day Powerhouse During Spring 2009

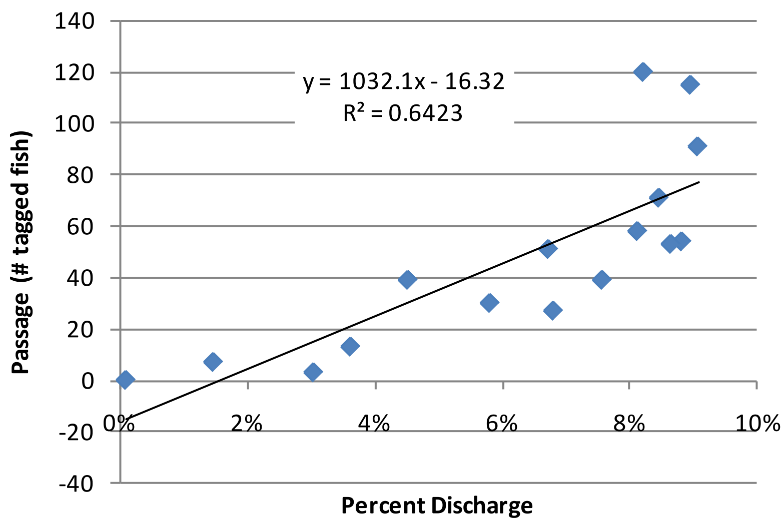

Figure 3.40. Percent Passage for Guided and Unguided STH and Percent Discharge by Turbine Unit for the John Day Powerhouse During Spring 2009

3.4.3.3 Spillway Horizontal Distribution

Among routes through the spillway, TSW spill bays 15 and 16 passed 66.6% of STH smolts (Figure 3.41). On a per-bay basis, percent passage through an average TSW bay was 33 times higher than that through an average spill bay from spill bays 1 through 14 and 8.3 times higher than that through an average bay from spill bays 17 through 20 (Figure 3.42).

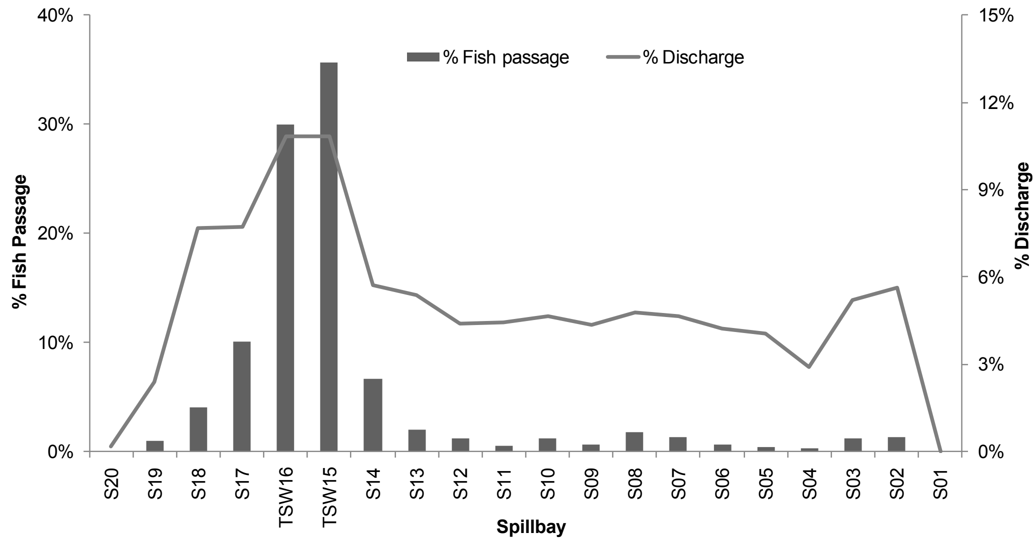

Figure 3.41. Steelhead Passage and Percent Discharge by Spill Bay During 2009

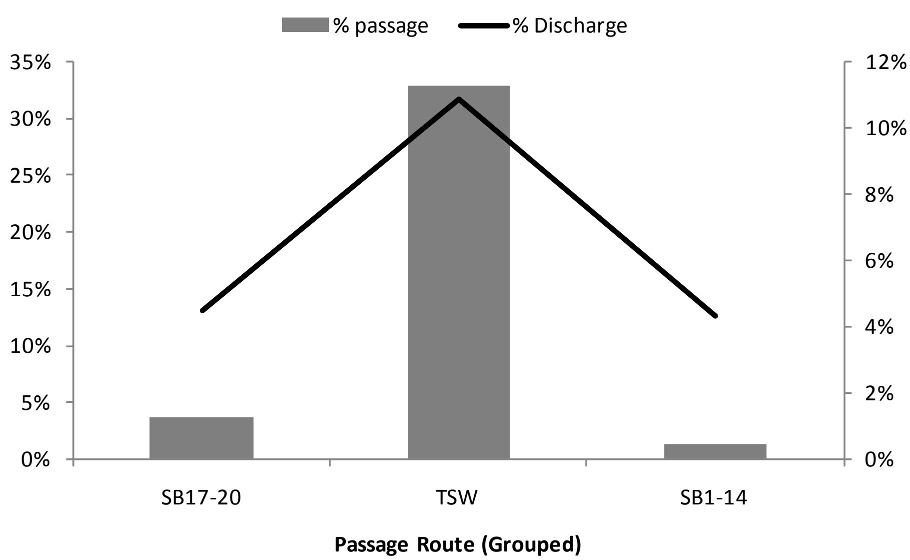

Figure 3.42. Percent Passage of STH Smolts and Discharge for an Average Spill Bay Within Groups of Bays During 2009

3.4.3.4 Day/Night Trends in Passage

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 3.43). On a per-bay basis, the TSW had a higher passage rate than other locations within the spillway, and the rate was much higher during the day than it was at night (Figure 3.44). 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 3.43) was mostly due to high daytime passage at TSW bays (Figure 3.44).

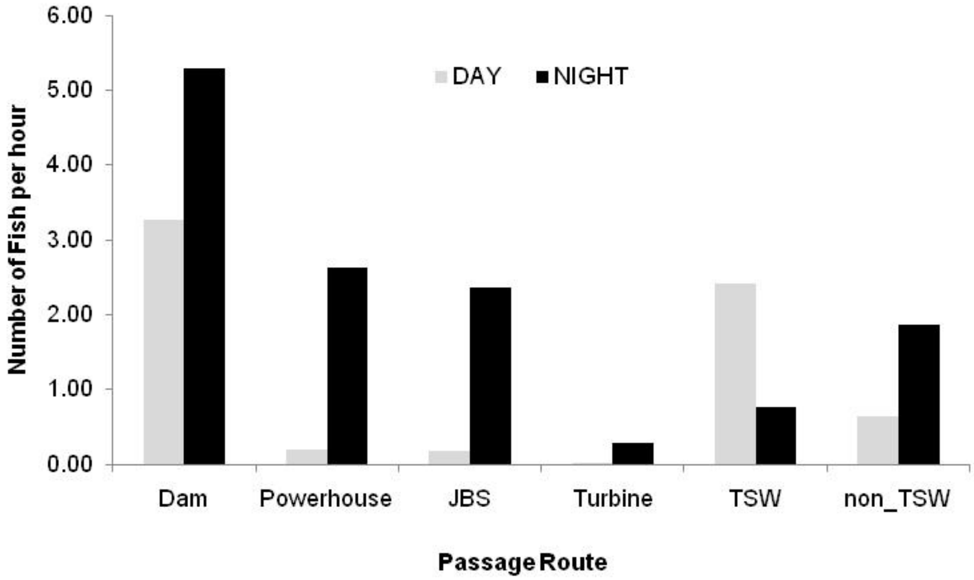

Figure 3.43. Day and Night Passage Rates (number/hour) of STH by Route During Spring 2009

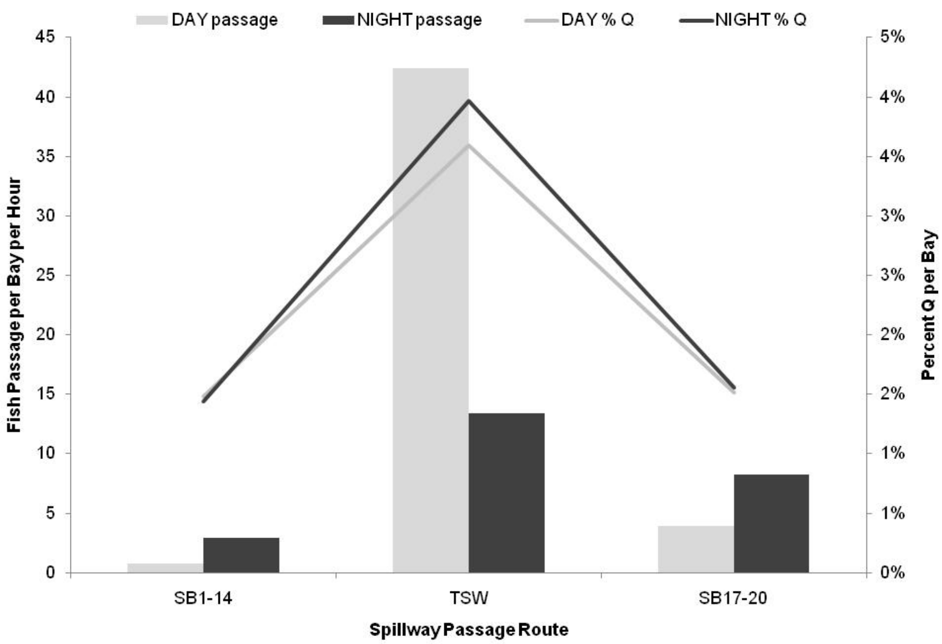

Figure 3.44. Day and Night Passage Rates (number/hour/bay) for STH and Percent Discharge for Groups of Spill Bays

3.4.4 Fish Behavior

3.4.4.1 Approach and Route of Passage

The forebay approach pattern for STH was 46% at the powerhouse, 11% at the skeleton bays, and 43% at the spillway (Figure 3.45). Of the tagged STH first detected approaching the powerhouse or skeleton bays, 65% moved north and passed at the spillway. As with CH1, STH approaching at the spillway were more likely to pass through the dam at the spillway (39% of total approach) than at the powerhouse (3.8% of total approach).

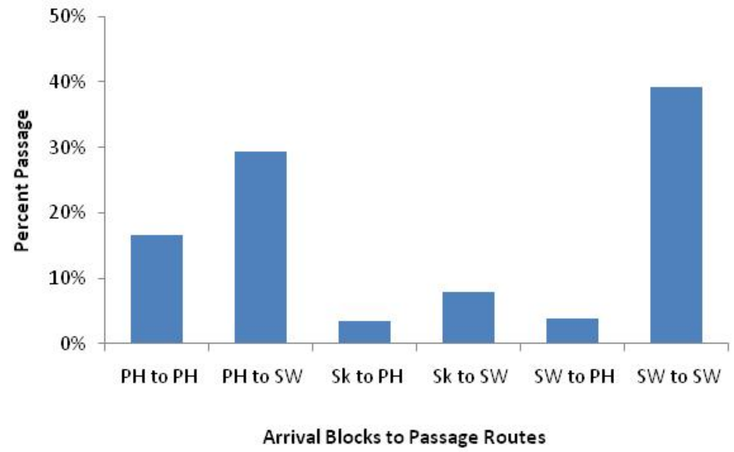

Figure 3.45. Steelhead Percent Passage by Approach and Passage Blocks at JDA During 2009. Abbreviations are as follows: PH = powerhouse; Sk = skeleton bay; SW = spillway.

Of the STH approaching at the powerhouse and skeleton bays in spring, 46% eventually pass the TSW in spill bays 15 and 16 (Figure 3.46). In contrast, only 12% 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. Only 6% of the tagged STH approached the dam in the forebay of the TSWs (Figure 3.46), while 50% passed there (Table 3.25).

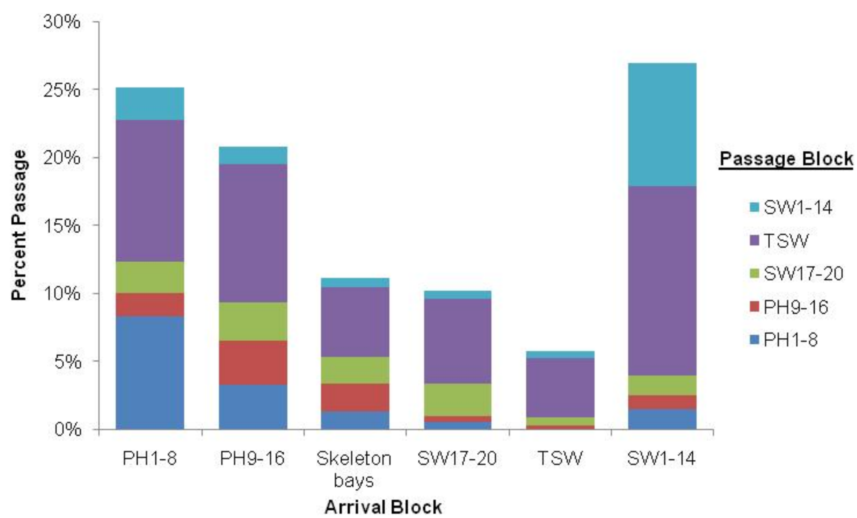

Figure 3.46. Steelhead Approach and Passage Behavior Patterns at JDA During 2009

3.4.4.2 Day/Night Behavior Patterns

Steelhead approaching the powerhouse had a much greater tendency to pass the spillway during the day than they did at night; 55% during day and 18% at night (Figure 3.47). The powerhouse was much more effective at passing STH that arrived at night, as seen previously with CH1. The spillway was more effective at retaining approaching STH with 38% passage during the day and 25% passage at night.

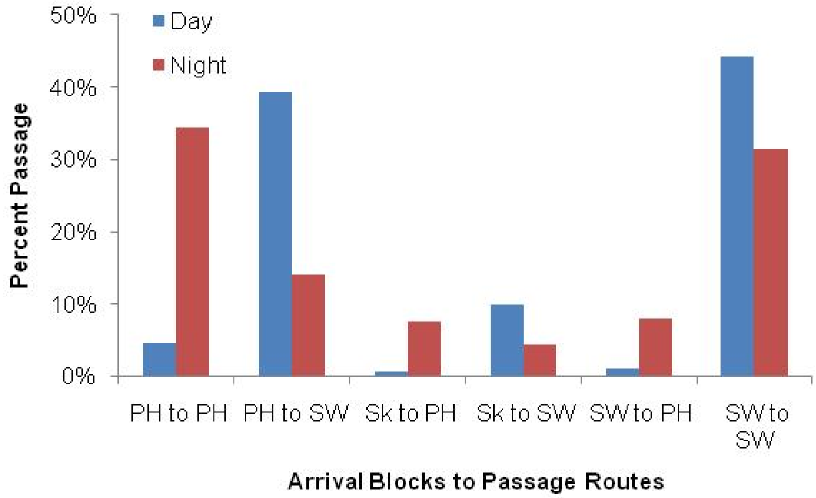

Figure 3.47. Steelhead Approach and Passage Patterns During Day and Night at JDA, 2009. Day/night allocation was defined by when the fish passed the dam.

Most STH arriving at the powerhouse eventually passed through the TSWs during the day (Figure 3.48). This was not the case at night; most CH1 arriving at the powerhouse also passed there at night (Figure 3.49). Approach and passage behavioral patterns for the spillway were different for day and night; during day, TSW passage predominated while passage at SW1–14 upon approach at the spillway was the common behavior at night (Figures 3.48 and 3.49).

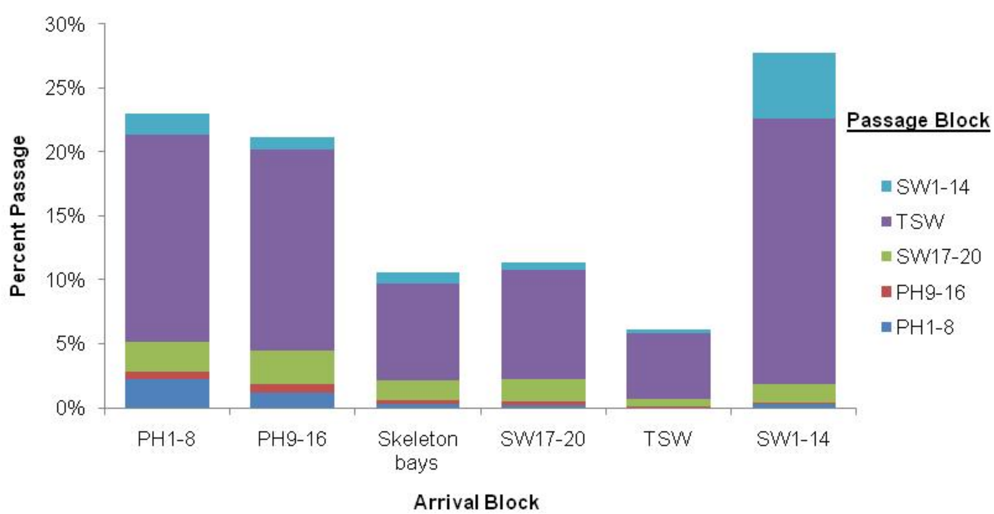

Figure 3.48. Approach and Passage Patterns for STH During Daytime, Spring 2009

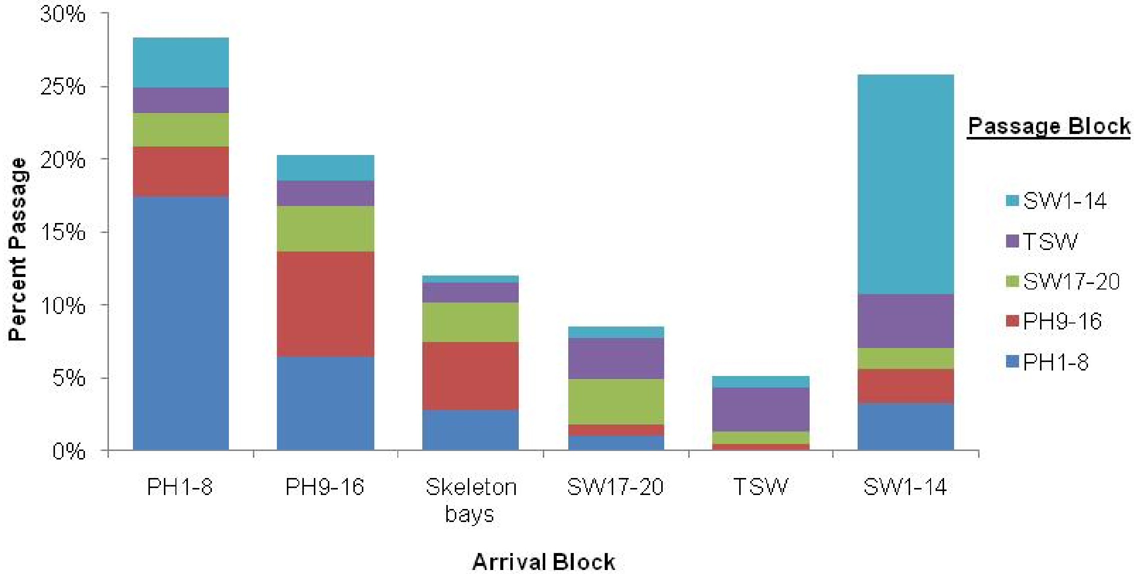

Figure 3.49. Approach and Passage Patterns for STH During Nighttime, Spring 2009

3.4.4.3 Vertical Distribution Behavior Patterns

The median depths of STH approaching within 75 m of the powerhouse or skeleton bays were less than 7 m (Figure 3.50). As with CH1, median depth decreased as distance to the powerhouse decreased, until the fish were within 5 m of the dam where depth abruptly increased in front of the powerhouse turbine intakes. For tagged STH approaching the spillway, median depths of detection were within the surface 2 m of the water column (Figure 3.50).

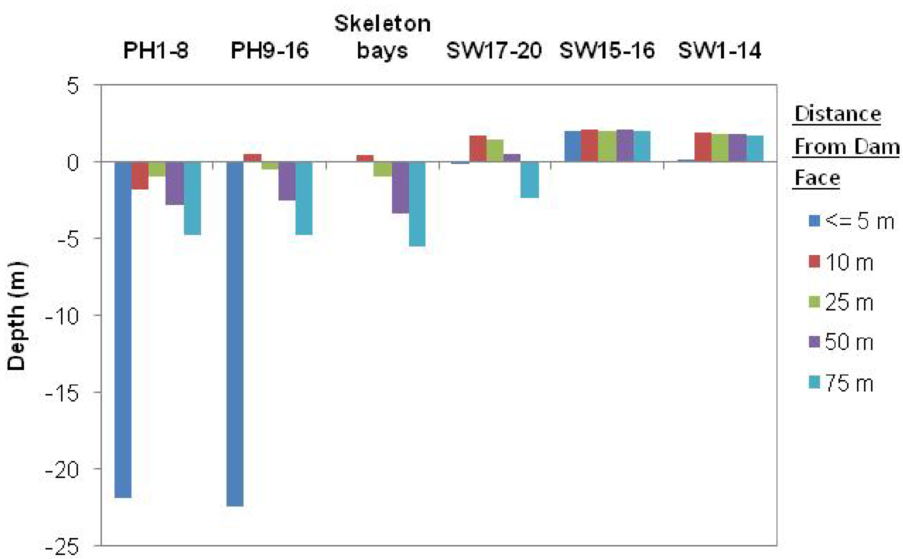

Figure 3.50. Median Depths of Last Detection of Tagged STH at JDA During 2009. Zero depth was referenced to the elevation of the shallow hydrophone deployed on the south side of Turbine Unit 1 at elevation 255.23 ft above MSL. Mean forebay water surface elevation was 263.5 ft above MSL.

The vertical distribution of STH was 3–5 m deeper during night than day (Figures 3.51 and 3.52). The depths of STH ultimately passing through turbines was about 5 m greater than the depth of STH routed into the JBS (Figure 3.53).

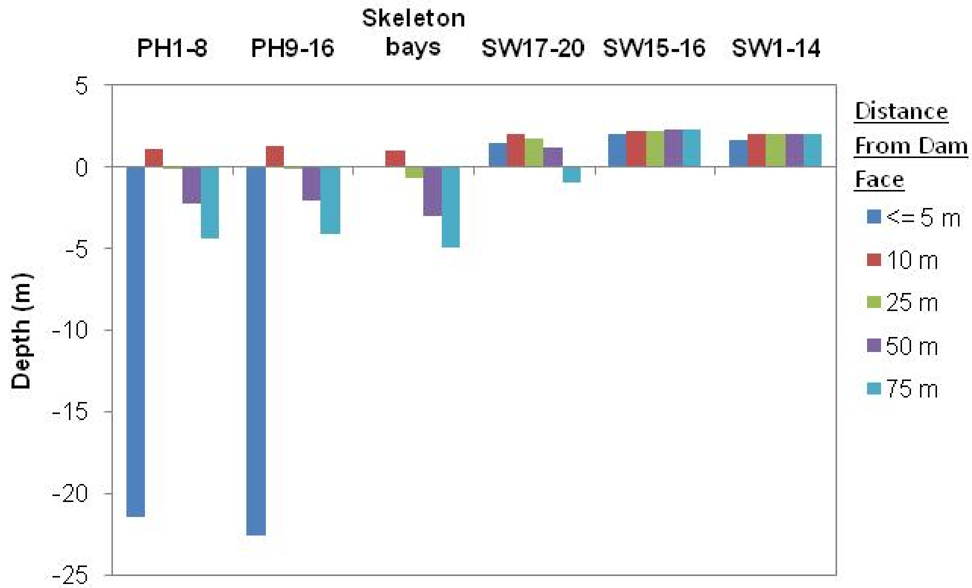

Figure 3.51. Median Depths of Last Detection of Tagged STH Smolts at JDA During the Day. Zero depth was referenced to the elevation of the shallow hydrophone deployed on the south side of Turbine Unit 1 at elevation 255.23 ft above MSL, and mean forebay water surface elevation was 263.5 ft above MSL.

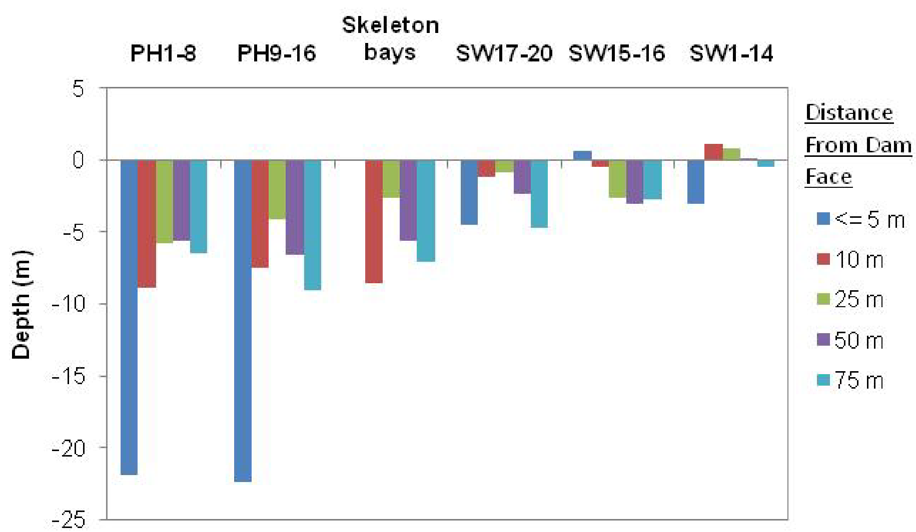

Figure 3.52. Median Depths of Last Detection of Tagged STH Smolts at JDA at Night. Zero depth was referenced to the elevation of the shallow hydrophone deployed on the south side of Turbine Unit 1 at elevation 255.23 ft above MSL, and mean forebay water surface elevation was 263.5 ft above MSL.

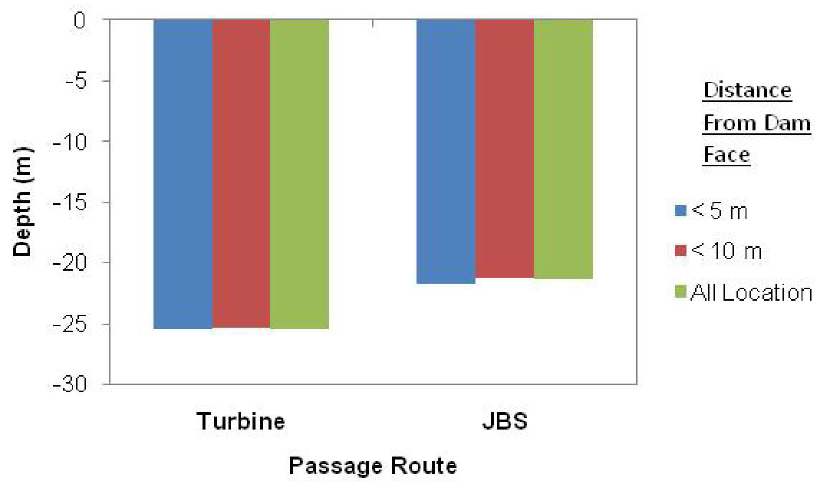

Figure 3.53. Steelhead Median Last-Detection Depths for Turbine- and JBS-Passed Fish

3.4.4.4 Travel Times and Forebay Residence Times

The median travel time between the release station and the JDA forebay array was 29.2 hours for STH implanted with JSATS acoustic transmitters during spring 2009 (Table 3.25). The median travel time until passage through JDA was 5.5 hours for tagged STH detected on the forebay array. Median travel time from the JDA face to the tailrace egress array 10 km downstream of the dam was 0.5 hours. The median travel time was 10.2 hours from the JDA egress array to TDA forebay array. The median travel time from the TDA forebay to the BON forebay array was 24.6 hours. As with CH1, STH travel times were longest for the JBS route and shortest for the TSW at JDA during spring 2009.

Table 3.25. Distance of Travel and Median and Mean Travel Times (±1/2 95% CI) for Acoustic-Tagged STH Passing Through Specific River Reaches Between Roosevelt, Washington, and the BON Forebay

Reach	Distance (km)	Median Travel Time (h)	Mean Travel Time (h)	1/2 95% CI
Roosevelt to JDA Forebay	39.4	29.2	32.2	0.3
JDA Forebay to JDA Passage	2			
Project		5.5	8.9	0.2
JBS		7.5	10.2	0.4
Turbine		6.1	13.3	2.7
TSW		4.8	8.2	0.2
NON-TSW		5.5	8.8	0.4
JDA Passage to JDA Tailwater	2.6			
Project		0.5	4.6	0.4
JBS		4.2	19.8	1.7
Turbine		0.9	12.2	5.1
TSW		0.4	0.6	0.1
NON-TSW		0.4	0.6	0.0

Table 3.25. (contd)

Reach	Distance (km)	Median Travel Time (h)	Mean Travel Time (h)	1/2 95% CI
JDA Passage to JDA Tailwater 30% Spill	2.6			
Project		0.5	5.2	0.6
JBS		4.1	19.2	2.1
Turbine		0.9	15.0	7.0
TSW		0.4	0.5	0.0
NON-TSW		0.5	0.6	0.0
JDA Passage to JDA Tailwater 40% Spill	2.6			
Project		0.4	3.9	0.5
JBS		4.8	20.8	3.1
Turbine		0.8	5.6	4.5
TSW		0.4	0.7	0.3
NON-TSW		0.4	0.6	0.0
JDA Tailwater to TDA Forebay	34.6	10.2	11.1	0.2
TDA Forebay to BON Forebay	75.4	24.6	26.4	0.3

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 (Figure 3.54). In contrast, STH approaching the powerhouse but passing at the spillway had a median residence time of about 3 hours (Figure 3.54). This was especially true for STH approaching the spillway but eventually passing the powerhouse during the night (median ~7 hours) (Figure 3.55). The STH approaching the spillway and passing there had the lowest residence time (8 minutes).

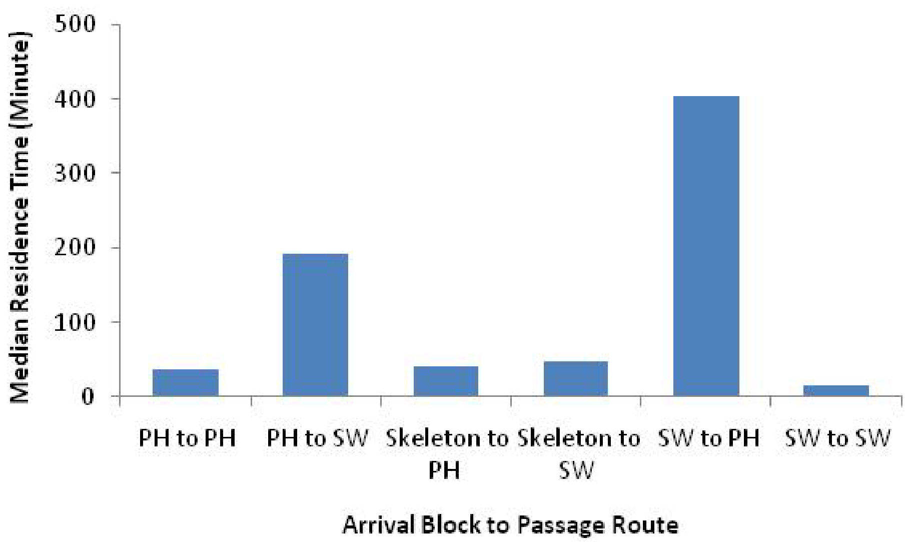

Figure 3.54. Steelhead Median Passage Times by Approach and Passage Routes During 2009

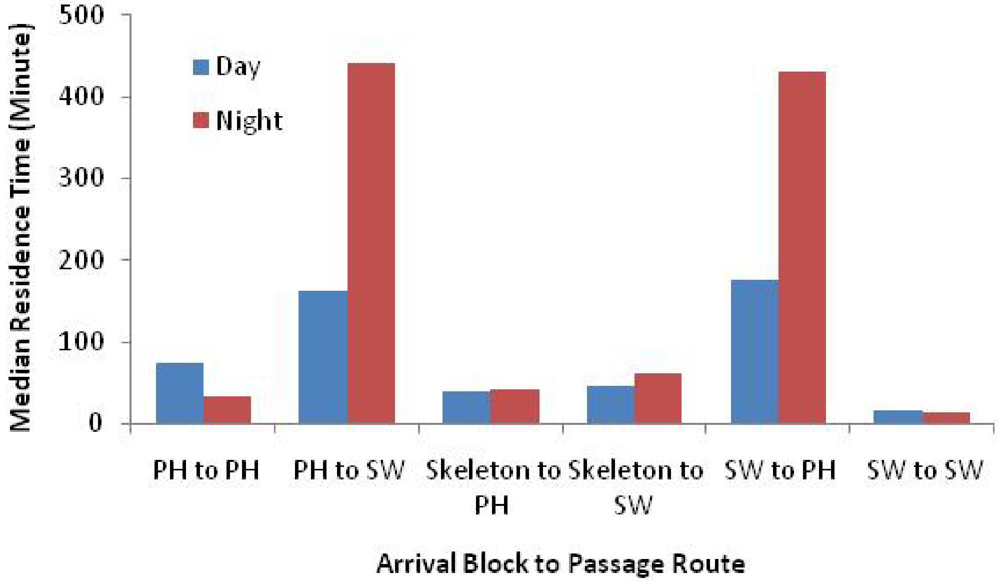

Figure 3.55. Steelhead Diel Median Passage Times at JDA

3.5 Subyearling Chinook Salmon

This section contains estimates of survival rates, travel times, passage metrics, and distributions for CH0 at JDA during spring 2009.

3.5.1 Effect of Spill Conditions on Fish

Dam operations met the prescribed spill treatments reasonably well during the last seven blocks and very well during the last five blocks of the summer test (Figure 3.56). Passage survival rates for CH0 were about 84–85% for both the 30% and 40% spill treatments and were not statistically different (Table 3.26). The survival rates were comparable whether five or seven blocks were analyzed. The mean survival rates for each block used in the analysis and the t-test results are provided for the five-block analysis in Tables 3.27 and 3.28 and seven-block analysis in Tables 3.29 and 3.30.

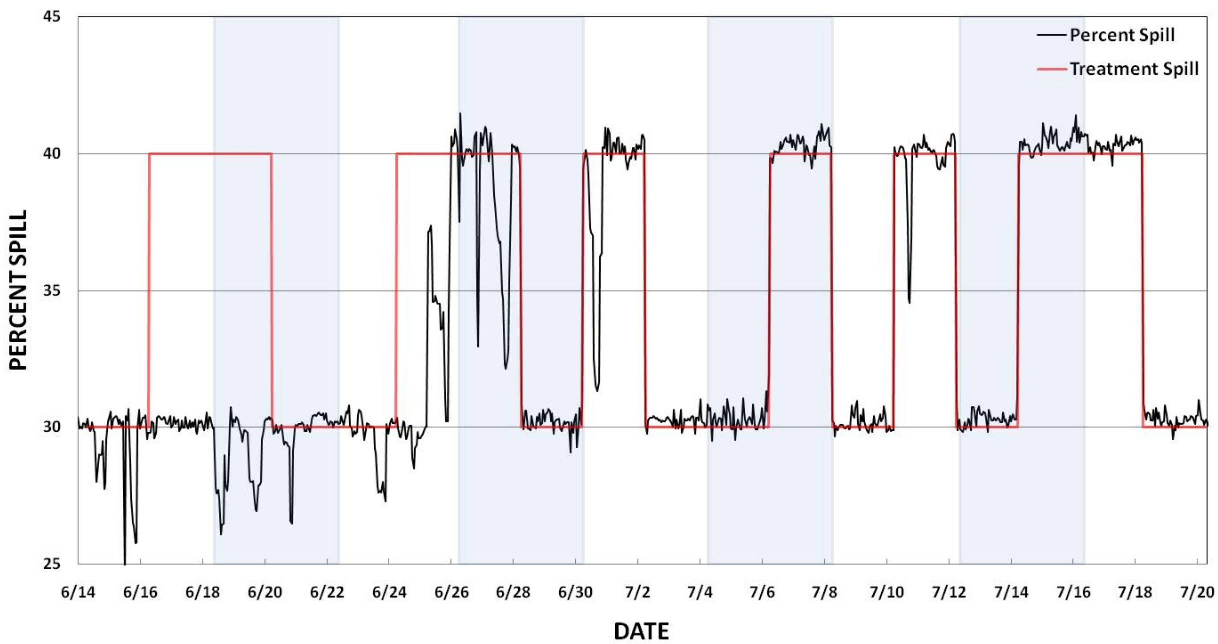

Figure 3.56. Spill Treatments as Prescribed (red line) and Actual Conditions (black line) in Summer

Table 3.26. Single Release Estimates of JDA Forebay-to-TDA Forebay Survival by Spill Condition for CH0 During Summer 2009. A one-tailed, paired t-test produced the listed probabilities and those < $\alpha = 0.05$ were considered to be significant.

Spill Treatment	Blocks Analyzed	Survival Rate (±1/2 95% CI)	One Tailed Probability (P)
30% Spill	5	0.851 ± 0.042	0.4269
40% Spill	5	0.855 ± 0.048	
30% Spill	7	0.842 ± 0.040	0.4535
40% Spill	7	0.840 ± 0.051	

Table 3.27. Estimates of JDA Forebay-to-TDA Forebay-Passage Survival Rates by Two-Day Block and Spill Treatment for CH0, for First Five Blocks, During Spring 2009

Block	30% Spill	½ 95% CI	40% Spill	½ 95% CI
1	0.840	0.055	0.905	0.045
2	0.832	0.061	0.888	0.039
3	0.801	0.067	0.779	0.049
4	0.847	0.053	0.838	0.047
5	0.793	0.061	0.763	0.049

Table 3.28. Results of a One-Tailed, Paired T-Test Comparing Estimates of JDA Forebay-to-TDA Forebay-Passage Survival Rates by Two-Day Block and Spill Treatment for CH0, for First Five Blocks, During Spring 2009

	30% Spill	40% Spill
Mean	0.8226	0.8346
Variance	0.000582	0.004009
Observations	5	5
Pearson Correlation	0.839395	
Hypothesized Mean Difference	0	
df	4	
t Stat	-0.59606	
P(T<=t) one-tail	0.291612	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.583224	
t Critical two-tail	2.776445	

Table 3.29. Estimates of JDA Forebay to TDA Forebay-Passage Survival Rates by Two-Day Block and Spill Treatment for CH0, for Seven Blocks, During Spring 2009

Block	30% Spill	½ 95% CI	40% Spill	½ 95% CI
1	0.914	0.037	0.850	0.039
2	0.866	0.045	0.855	0.047
3	0.840	0.055	0.905	0.045
4	0.832	0.061	0.888	0.039
5	0.801	0.067	0.779	0.049
6	0.847	0.053	0.838	0.047
7	0.793	0.061	0.763	0.049

Table 3.30. Results of a One-Tailed, Paired T-Test Comparing Estimates of JDA Forebay to TDA Forebay-Passage Survival Rates by Two-Day Block and Spill Treatment for CH0, for Seven Blocks, During Spring 2009

	30% Spill	40% Spill
Mean	0.841857	0.839714
Variance	0.001662	0.002751
Observations	7	7
Pearson Correlation	0.524866	
Hypothesized Mean Difference	0	
df	6	

Table 3.30. (contd)

	30% Spill	40% Spill
t Stat	0.121749	
P(T<=t) one-tail	0.453537	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.907073	
t Critical two-tail	2.446912	

Estimates of the major fish-passage metrics for CH0 during 2009 were not statistically different between 30% and 40% spill treatments, except for JBSE, which was significantly higher during 30% spill than 40% spill (Table 3.31). Fish-passage efficiency and SPE were 2.54 and 6.36 percentage points higher for 40% than 30% spill, respectively.

Table 3.31. Estimates of Major Passage Metrics by Spill Treatment for CH0 During Summer 2009. *A one-tailed, paired t-test produced the listed probabilities and those < $\alpha = 0.05$ were considered to be significant.

Metric	Spill Treatment	Estimate (±1/2 95% CI)	T-Test Probability
FPE	30%	83.07 ± 2.22%	0.2485
	40%	85.61 ± 2.15%	
SPE	30%	69.68 ± 2.92%	0.1212
	40%	76.04 ± 2.44%	
FGE	30%	45.09 ± 6.95%	0.2185
	40%	39.68 ± 6.46%	
TSWE	30%	NA	NA
	40%	NA	
JBSE	30%	13.77 ± 1.72%	0.0225*
	40%	9.61 ± 1.06%	
SEF	30%	2.32 ± 0.10	0.1308
	40%	2.11 ± 0.07	
TSWEF	30%	NA	NA
	40%	NA	

3.5.2 Survival Rates

The JDA and TDA estimated survival rates and detection histories for CH0 are described in the following sections. Capture histories are presented in Appendix C.

3.5.2.1 Seasonal Trends, JDA to TDA Forebay-Passage, and Route-Specific Survival Rates

The single-release estimate of the JDA to TDA forebay-passage survival / residualization rate for CH0 smolts was 0.839 ± 0.014 (1/2 95% CI), and there was a significant decrease in the combined rate during the summer migration (Figure 3.57). The highest route-specific point estimate was for JBS-passed smolts at 0.908 ± 0.031 (1/2 95% CI) followed by smolts passing through the spillway through non-TSW bays 0.847± 0.016 (1/2 95% CI) and smolts passing through turbines (0.749± 0.039; Table 3.32). Detailed capture history and survival results by release date are in Appendix C.

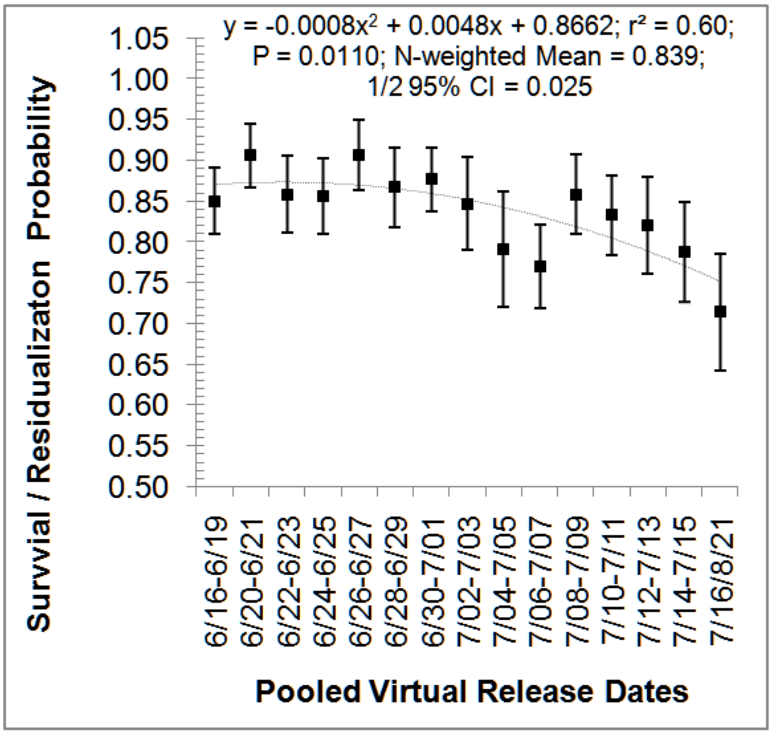

Figure 3.57. Seasonal Trend in Single-Release, Combined JDA to TDA Forebay-Passage Survival and Residualization Probability for CH0 at JDA in Summer 2009. Vertical bars indicate the extent of individual 95% confidence intervals; the light gray regression line indicates a significant downward trend; regression statistics, the N-weighted mean, and associated ½ 95% confidence intervals are for all data are listed above the points.

Table 3.32. Single-Release Estimates of Survival for Subyearling Chinook Smolts in Virtual Release at JDA Based on Three Downstream Arrays During 2009. Survival estimates were based on pooled data.

Route	Survival	±1/2 95% CI
JDA to TDA forebay	0.839	0.014
Non-TSW	0.847	0.016
TSW	NA	NA
Turbine	0.749	0.039
JBS	0.908	0.031

3.5.2.2 Day/Night Trends in Survival Rates

The survival rate of CH0 was higher at night than during the day for smolts passing JDA, turbines, JBS, spillway to the TDA forebay (Figure 3.58). In fact, the high day/night survival rate was for CH0 passing the JBS during night, while the lowest was for daytime turbine passage.

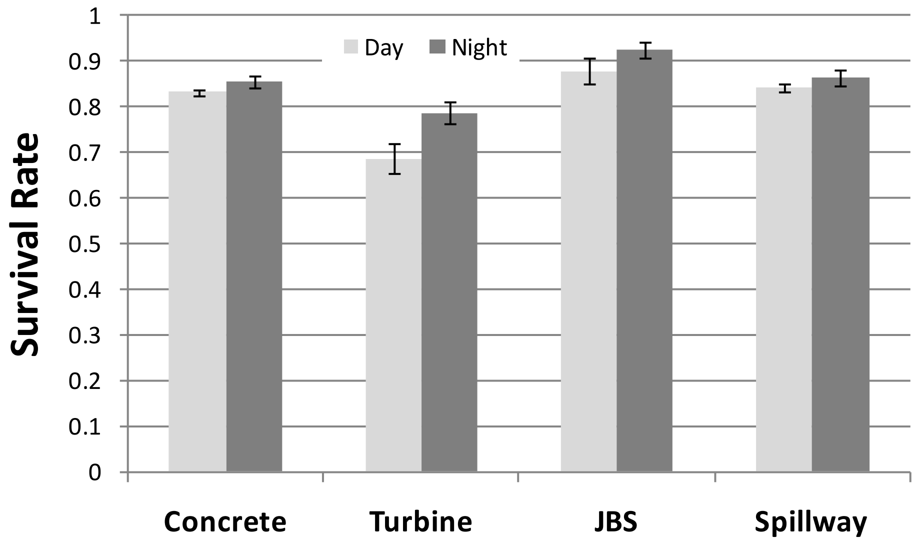

Figure 3.58. Day and Night Single-Release Estimates of CH0 Survival Rates by Route of Passage During Summer 2009

3.5.2.3 Survival Rates at The Dalles Dam

Subyearling Chinook salmon smolts were released near Roosevelt, Washington (rkm 390), in summer, and regrouped on TDA forebay entrance array to create virtual releases for estimating passage survival rates from TDA forebay to BON forebay. The weighted mean dam-passage survival and residualization rate from 2 km upstream of TDA to the BON forebay was 0.639 ± 0.020 (1/2 95% CI), and there was a highly significant decline in survival rates among virtual releases as summer progressed (Figure 3.59). Detailed capture history and survival results by release are in Appendix C.

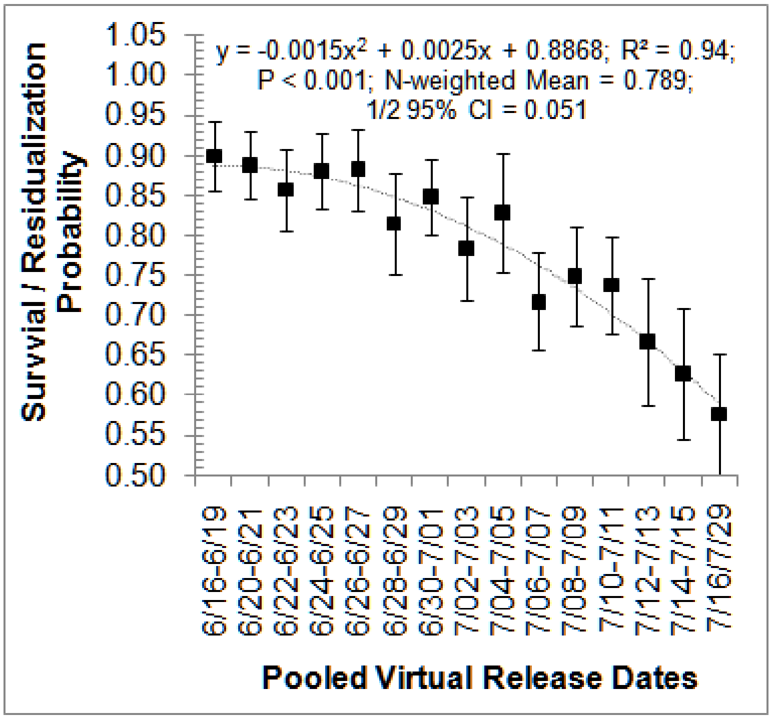

Figure 3.59. Seasonal Trend in Single-Release, Passage Survival/Residualization Probability for CH0 at TDA in Summer 2009. Vertical bars indicate the extent of individual 95% confidence intervals; the light gray regression line indicates a significant downward trend; the N-weighted mean and associated ½ 95% confidence intervals are for all data collected during this migration.

The TDA-passage survival / residualization for CH0 smolts that previously passed through turbines at JDA was significantly lower than the TDA-passage survival for CH0 smolts that previously passed through the JDA spillway or JBS (Table 3.33).

Table 3.33. Single-Release Estimates of TDA-Passage Survival/Residualization for CH0 That Passed Through Three Available Routes at JDA in Summer 2009

JDA Passage Route	TDA Survival/Residualization	½ 95% CI
Spillway (All Non-TSW bays)	0.650	0.022
Turbines	0.555	0.053
JBS	0.670	0.053

3.5.3 Passage Metrics and Distribution

Passage efficiency and effectiveness, powerhouse and spillway passage, the effect of spill conditions on passage survival rate and fish-passage proportions among routes, and diel trends in survival rates and passage efficiencies for acoustic tagged CH0 at JDA during 2009 are described below.

3.5.3.1 Passage Efficiency and Effectiveness

During 2009, FPE for CH0 was 84.5%, with 11.3% of total dam passage guided by in-turbine screens to the JBS and 73.2% passing through the spillway (Table 3.34). Fish guidance efficiency of the in-turbine screen system was 42.2% for CH0 during 2009. The proportion of total dam passage through the spillway was 2.2 times higher than the proportion of total discharge through the spillway.

Table 3.34. Estimates of Major Passage Metrics for CH0. *The TSWs were not operated during summer 2009.

Metric	Estimate (±1/2 95% CI)
FPE	84.51 ± 1.33%
SPE	73.20 ± 1.63%
FGE	42.20 ± 4.12%
TSWE	NA
JBSE	11.31 ± 0.82%
SEF	2.21 ± 0.05
TSWEF	NA

3.5.3.2 Powerhouse Horizontal Distribution and the Relationship Between Passage and Discharge

During summer, only 42% of the CH0 that passed through the dam at the powerhouse were guided through the JBS, and the remaining 58% passed through turbines. Guided passage exceeded unguided passage at turbine units 11 and 12, but was less than unguided passage at the other 14 units (Figure 3.60). A regression of number of tagged CH0 smolts passing each turbine on unit-specific discharge was highly significant ($P < 0.0001$) with discharge explaining 81% of the variation in STH passage (Figure 3.61).

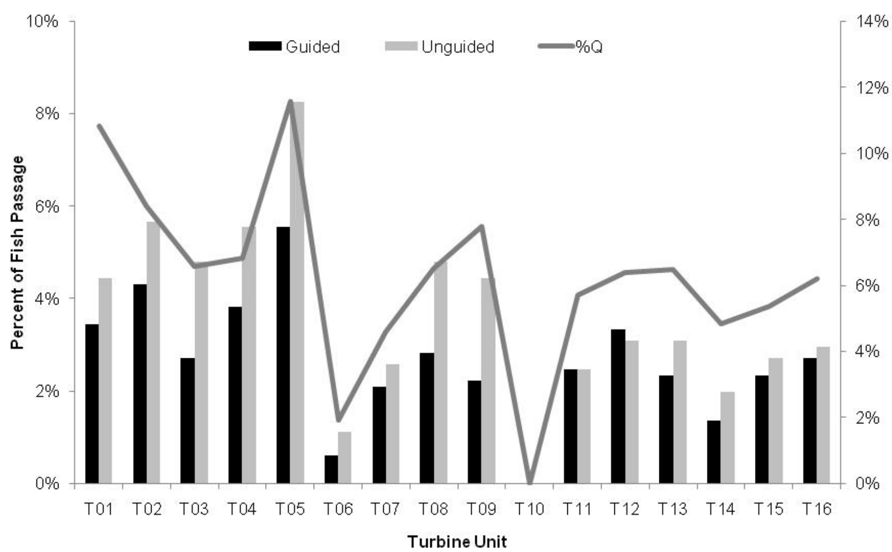

Figure 3.60. Percent Passage for Guided and Unguided CH0 and Percent Discharge by Turbine Unit for the John Day Powerhouse During Summer 2009

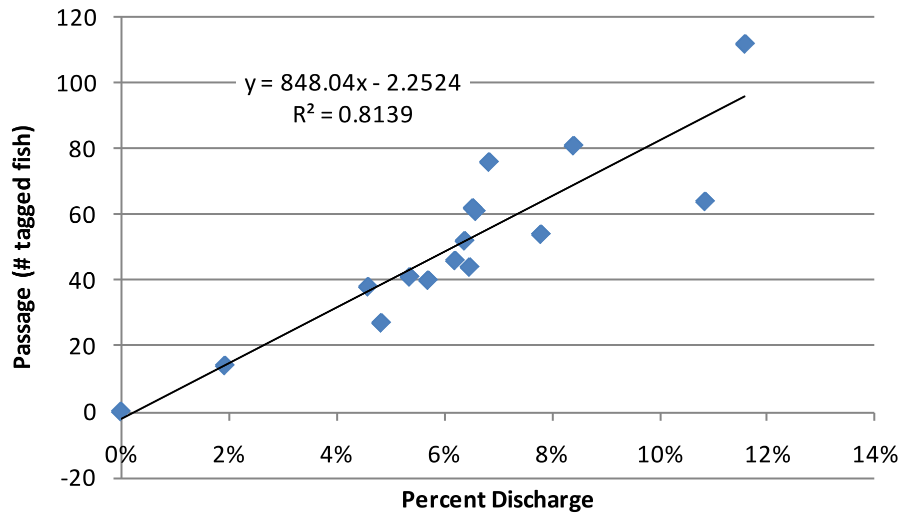

Figure 3.61. Percent Passage for Guided and Unguided CH0 and Percent Discharge by Turbine Unit for the John Day Powerhouse During Summer 2009

3.5.3.3 Spillway Horizontal Distribution

Of the CH0 smolts passing through the spillway, 73.2% passed through the operating bays 2–14 (Figure 3.62). Spillway passage peaked at bay 14, although was otherwise fairly uniform.

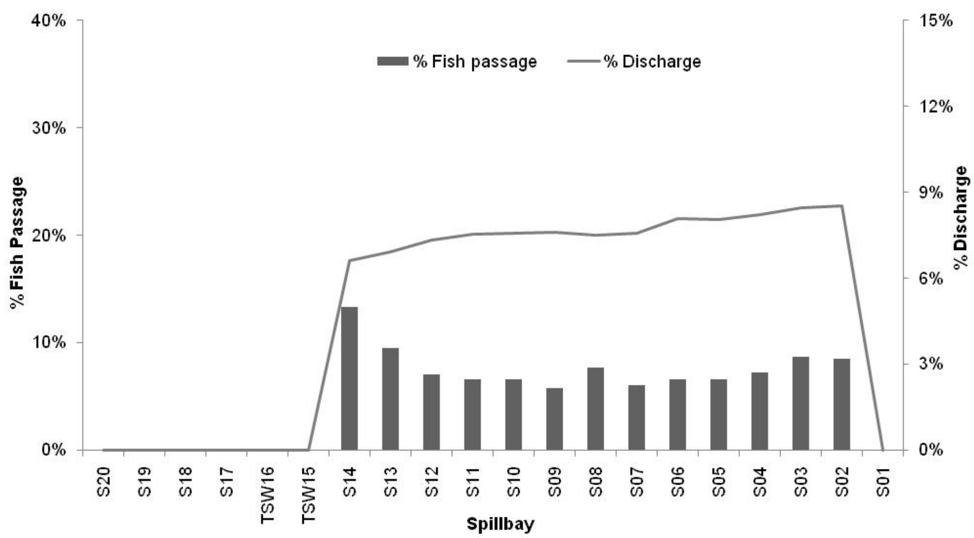

Figure 3.62. Percent Discharge and Passage of CH0 Smolts by Spill Bay During Summer 2009

3.5.3.4 Day/Night Trends in Passage

The hourly rate of passage of CH0 through the dam, powerhouse, turbines, and JBS was higher at night than during the day (Figure 3.63). Only the spillway passed more CH0 during the day (2.2 fish/h) than it did at night (1.9 fish/h). The TSWs were not operational in summer 2009.

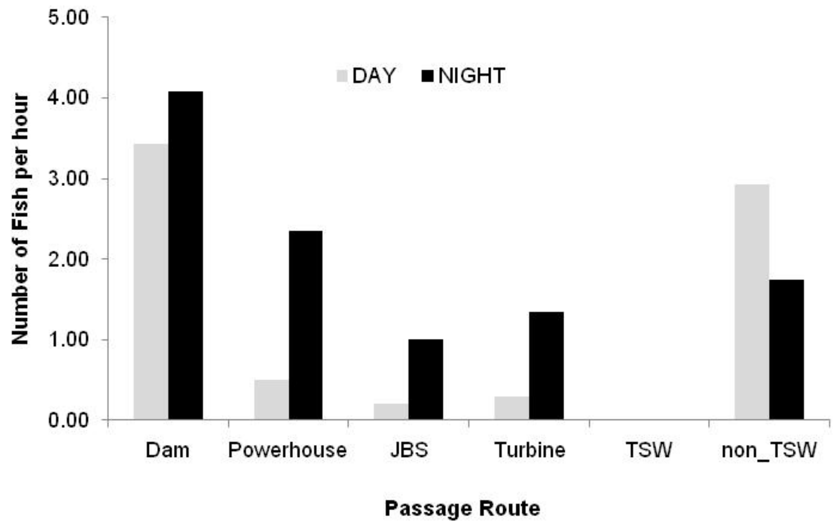

Figure 3.63. Day and Night Passage Rates by Route for CH0 During Summer 2009

3.5.4 Fish Behavior

Fish behavior relative to approach and rate of passage, day and night, vertical distribution, and travel and forebay residence times are described in the following sections.

3.5.4.1 Approach and Route of Passage

The CH0 approach to JDA was similar to spring with over 50% of first detections at the powerhouse and skeleton bays (Figure 3.64). Of the CH0 approaching the dam in the powerhouse forebay, over 20% eventually move north to pass at the spillway. The CH0 approaching the spillway were more than 8 times as likely to pass at the spillway than at the powerhouse.

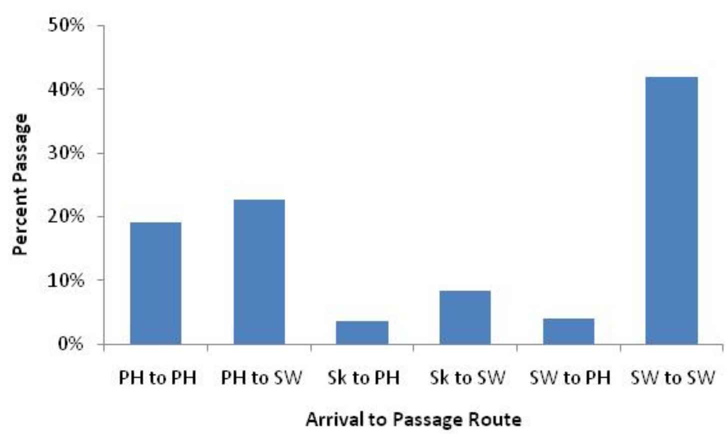

Figure 3.64. Subyearling Chinook Salmon Percent Passage by Approach and Passage Blocks at JDA During 2009. Abbreviations are as follows: PH = powerhouse; Sk = skeleton bay; SW = spillway.

For CH0, 42% approached in the forebay of the powerhouse, 12% at the skeleton bays, and 46% at the spillway forebay (Figure 3.65). Of the CH0 approaching at the powerhouse and skeleton bays, 58% ended up passing at the spillway even with the TSWs closed. Few CH0 approaching the spillway moved south to pass at the powerhouse (4.1% of total approach).

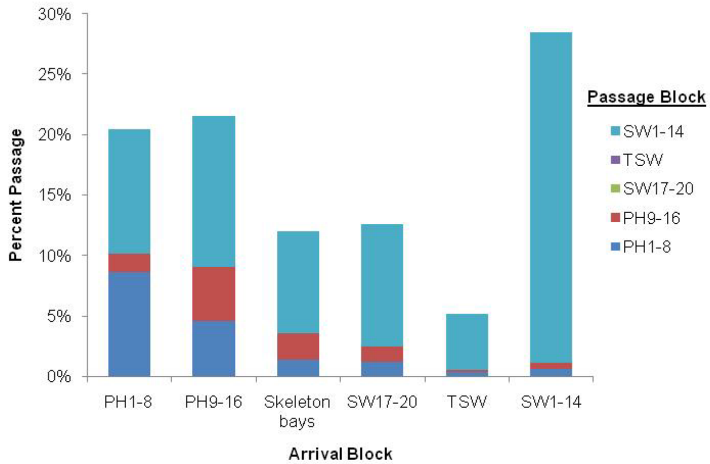

Figure 3.65. Subyearling Chinook Salmon Approach and Passage Behavior Patterns at JDA During 2009. Note, the TSWs were closed during summer 2009.

3.5.4.2 Day/Night Behavior Patterns

SubyearlingChinook salmon approaching the powerhouse had a much greater tendency to move south to pass the spillway during the day than they did at night; 28% during day and 8% at night (Figure 3.66). The powerhouse was more effective at passing CH0 that arrived at night, as seen previously with CH1 and STH. Upon approach to the spillway, CH0 behavior was to pass there, especially during day (42%) as compared to night (30%).

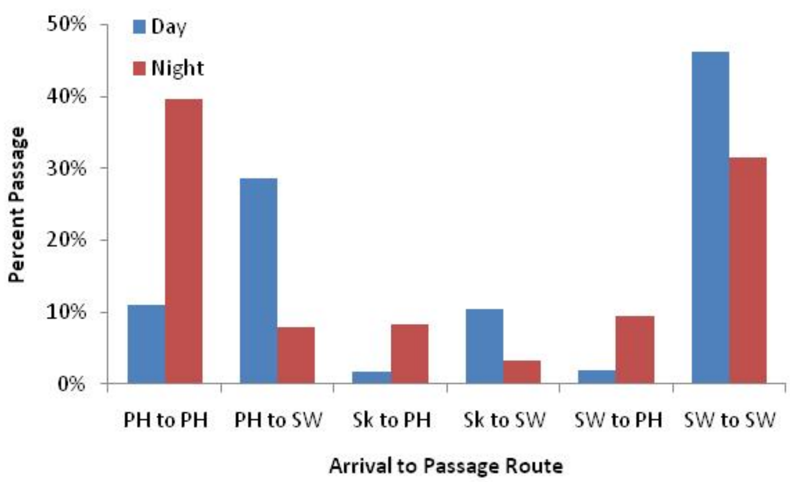

Figure 3.66. Subyearling Chinook Salmon Approach and Passage Patterns at JDA During Day and Night, 2009. Day/night allocation was defined by when the fish *passed* the dam.

Passage distributions for CH0 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 3.67). This trend was not as evident at night (Figure 3.68). At night, CH0 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.

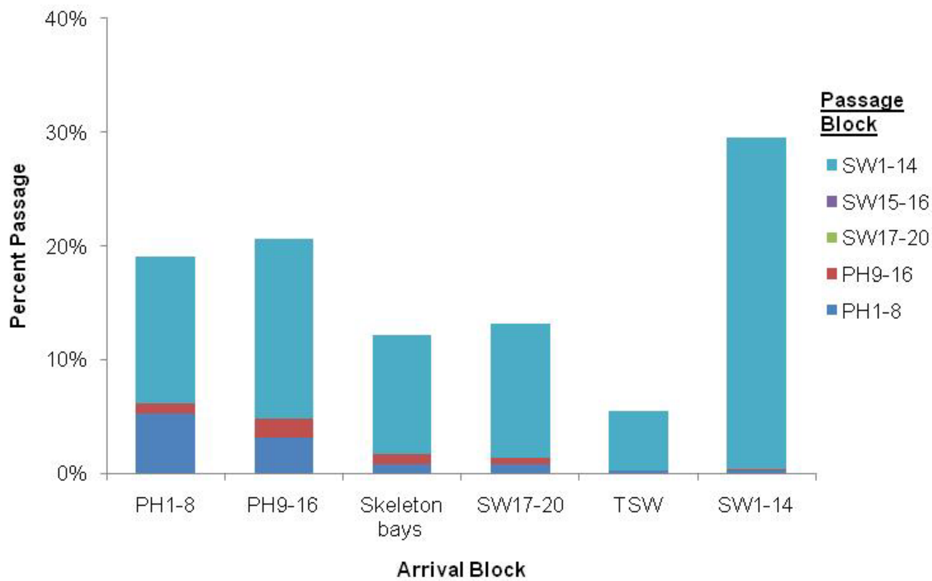

Figure 3.67. Approach and Passage Patterns for CH0 During Daytime at JDA, Summer 2009

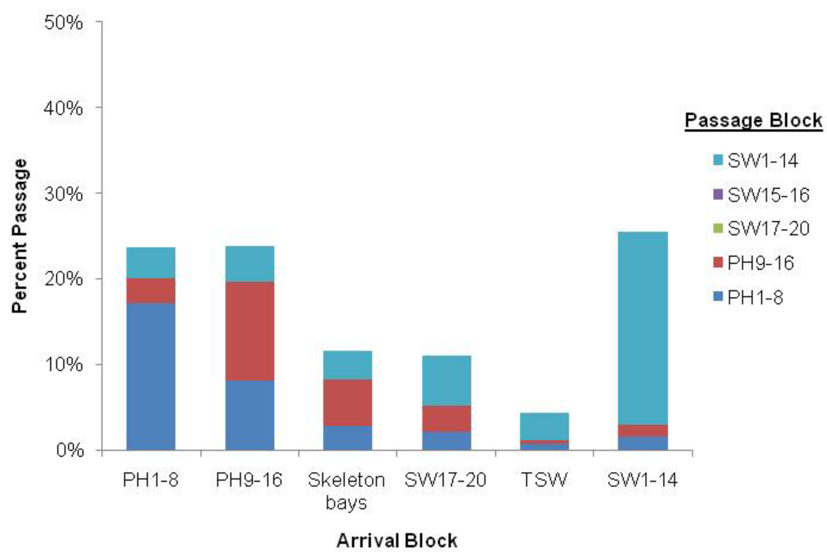

Figure 3.68. Approach and Passage Patterns for CH0 During Nighttime at JDA, Summer 2009

3.5.4.3 Vertical Distribution Behavior Patterns

The median depths of CH0 approaching within 75 m of the powerhouse or skeleton bays were less than 12m (Figure 3.69). As with CH1 and STH, median depth decreased as distance to the powerhouse decreased, until the fish were within 5 m of the dam where depth abruptly increased in front of the powerhouse turbine intakes. For tagged CH0 approaching the spillway, median depths of detection were within the surface 7 m of the water column, the deepest of the three tagged stocks (Figure 3.69). The CH0 that passed turbines were approximately 5 m deeper than those that were screened into the JBS (Figure 3.70).

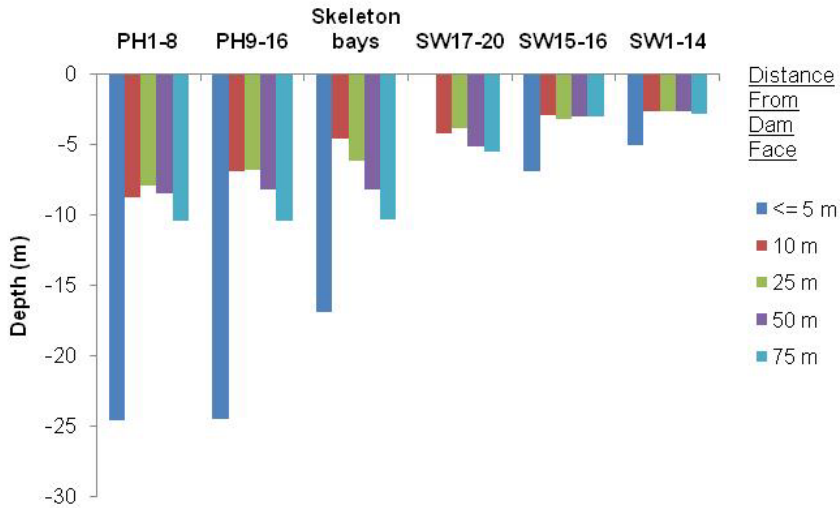

Figure 3.69. Median Depths of the Last Detection of Tagged CH0 Smolts at JDA. Zero depth was referenced to the elevation of the shallow hydrophone deployed on the south side of Turbine Unit 1 at elevation 255.23 ft above MSL, and mean forebay water surface elevation was 263.5 ft above MSL.

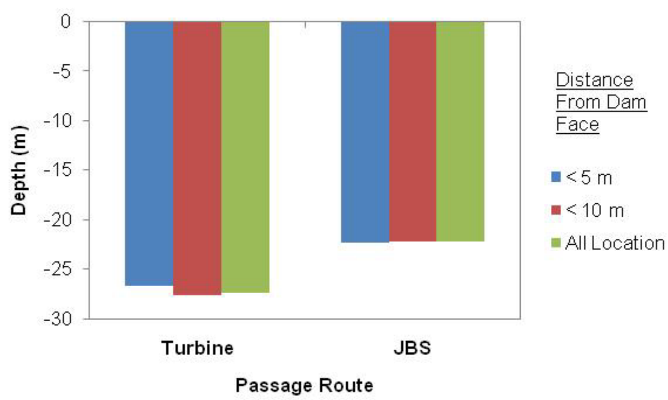

Figure 3.70. Subyearling Chinook Salmon Median Last-Detection Depths for Turbine- and JBS-Passed Fish

3.5.4.4 Travel Times and Forebay Residence Times

During summer 2009, acoustic-tagged CH0 had a median travel time between the release station and the JDA forebay array of 31.3 hours (Table 3.35). For tagged CH0 detected on the forebay array, the median travel time until passage through JDA was 3.8 hours. Median travel time from the JDA face to the tailrace egress array 10 km downstream of the dam was 0.5 hours. The median travel time from the JDA egress array to TDA forebay array was 15.4 hours. The median travel time from the TDA forebay to the Bonneville Dam forebay array was 33.1 hours. Subyearling Chinook salmon travel times were longest for powerhouse routes and shortest for the spillway (bays 2–14) at JDA during summer 2009.

Table 3.35. Distance of Travel and Median Travel Time (±1/2 95% CI) for CH0 Smolts Passing Through Specific River Reaches Between Roosevelt, Washington, and the BON Forebay

Reach	Distance (km)	Median Travel Time (h)	Mean Travel Time (h)	1/2 95% CI
Roosevelt to JDA Forebay	39.4	31.3	36.2	0.3
JDA Forebay to JDA Passage	2			
Project		3.8	7.2	0.2
JBS		3.8	8.2	0.8
Turbine		4.6	9.0	0.6
Spill2-14		3.6	6.7	0.2
JDA Passage to JDA Tailwater	2.6			
Project		0.5	1.4	0.1
JBS		3.1	7.3	0.6
Turbine		1.0	1.1	0.1
Spill2-14		0.4	0.5	0.0
JDA Passage to JDA Tailwater 30% Spill	2.6			
Project		0.5	1.7	0.1
JBS		3.9	7.4	0.7
Turbine		0.9	1.2	0.1
Spill2-14		0.4	0.5	0.0
JDA Passage to JDA Tailwater 40% Spill	2.6			
Project		0.5	1.1	0.1
JBS		2.1	7.1	1.2
Turbine		1.1	1.1	0.0
Spill2-14		0.4	0.5	0.0
JDA Tailwater to TDA Forebay	34.6	15.4	15.9	0.1
TDA Forebay to BON Forebay	75.4	33.1	35.6	0.3

The median residence times of CH0 were similar to those of CH1 and STH. Fish approaching and passing through the dam at the spillway had the shortest residence times (< 10 minutes) (Figure 3.71). Tagged CH0 approaching the spillway but passing at the powerhouse had the longest residence times (~130 minutes). Fish approaching and passing at the powerhouse had a short residence times (< 20 minutes). On the other hand, fish approaching the powerhouse but passing at the spillway had residence times of over 100 minutes.

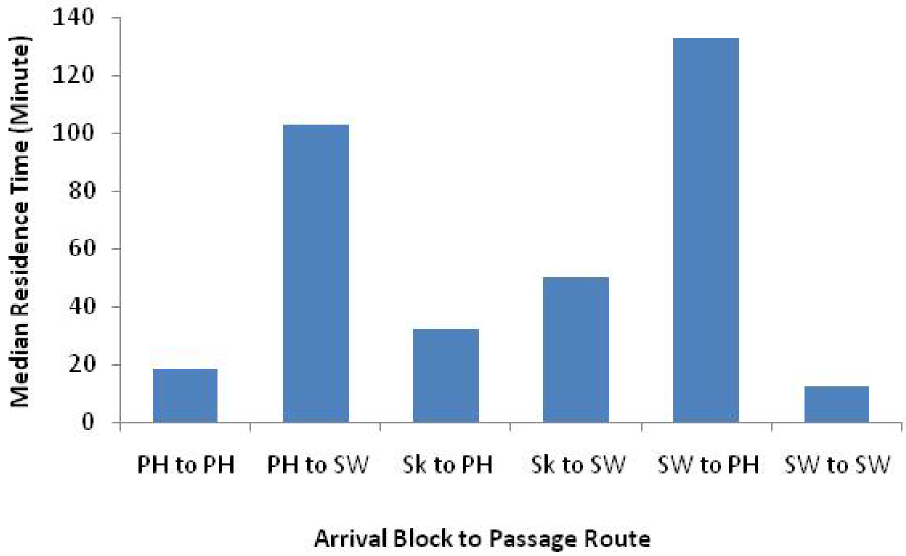

Figure 3.71. Median Residence Times of CH0 at JDA, 2009

The median residence time of smolts arriving at the powerhouse but passing through the dam at the spillway at night was over four times longer than that of smolts exhibiting the same behavior during the day (Figure 3.72). Day/night differences for other behavior patterns were not distinct.

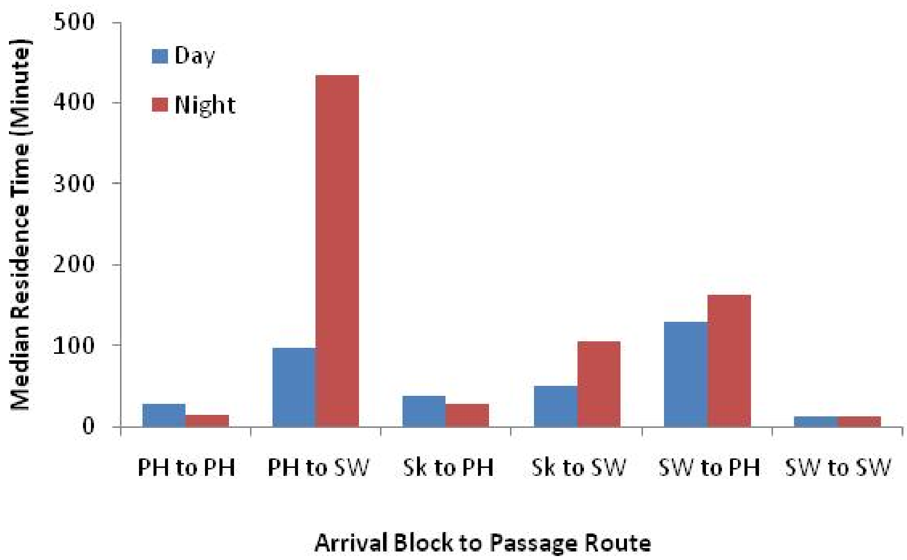

Figure 3.72. Subyearling Chinook Salmon Day/Night Median Passage Times at JDA, 2009. Abbreviations are as follows: PH = powerhouse; SW = spillway; Skeleton = skeleton bays.

4.0 Discussion, Conclusions, and Recommendations

In this section, we assess study integrity, compare 2009 results with previous survival and passage studies at JDA, and discuss the performance of the prototype TSW SFO. The section closes with 2009 study conclusions and recommendations.

4.1 Study Integrity

The 2009 acoustic telemetry study at JDA provided reliable data on fish survival rates, passage rates, and behavior, as substantiated by the following facts.

The tagged fish populations reasonably represented the respective runs-at-large in terms of run timing and length frequency. The goal of tagging the middle 80% of each of the CH1, STH, and CH0 runs was well met (Figures 3.5, 3.6, and 3.7). The median length of tagged fish was slightly longer than that of untagged fish of the same stock (2 mm for CH1 and STH; 3 mm for CH0) (Figures 3.8, 3.9, and 3.10). The 95-mm minimum length requirement on candidate fish for tagging did not restrict the lengths of fish that could be tagged in the spring and excluded only about 6.7% of the run-of-river subyearlings from tagging in 2009. 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. In 2008, about 9% of the CH0 run-at-large was too small to be tagged (Weiland et al. 2009).

Detection probabilities for the dam-face cable arrays were excellent. The combined probability of detection for the two independent arrays was 96% for CH1 and STH and 98% for CH0 (Table 3.5).

Detection probabilities for autonomous arrays above and below BON were acceptable. Detection rates for CH1, STH, and CH0 were greater than 90% for the autonomous arrays (Figure 3.11). Multi-node detections for arrays above BON were greater than 93% (Figure 3.13). Below BON, percent detection on two or more nodes of the BON primary array near Camas, Washington, was just 68% for CH1 and STH and 85% for CH0. This improved performance over 2008 is a result of increased node densities in the arrays below BON.

Tag life did not affect study results. All acoustic tags in the tag-life study were active for the required 23 days (Figure 3.15). Mean tag life was 30 days and ranged from 24 to 49 days.

Two testable assumptions of the survival models were met. There were few significant results of Burnham et al. (1987) Test 2 or Test 3. In fact, most of the Burnham Test could not be calculated because of exceptionally high detection probabilities on JDA survival arrays, and of those that could be calculated, none was significant at $\alpha = 0.1$. Note, there were no tests of arrival distributions in 2009 because there were no reference releases of fish to compare to treatment releases.

4.2 Comparison of Survival Rates and Passage Efficiencies for 30% versus 40% Spill Operations

Estimates of survival rates and passage efficiencies for the 30% and 40% spill treatments were reasonably consistent between 2008 and 2009 (Figure 4.1). One distinction was that SPE was higher for the 2009 40% treatment than the other treatment/year combinations. As a result, FPE was highest for this treatment/year. In contrast, however, dam survival rates were lower for 40% spill during 2009 compared to the others. TSWE for CH1 was 5–10 percentage points higher for 30% than 40% spill during both years; the opposite was true for STH. The 40% spill condition did not significantly increase survival rates or passage efficiencies for CH1, STH, or CH0 over 30 % spill.

Even though the 40% treatment provided one-third more spilled water than the 30% condition, perhaps a bigger difference in the treatment condition would reveal any relationship between survival and spill percentage. For example, a comparison of 20% vs 40%, 10% vs 30%, or 30% vs 50% spill might be considered for future studies, after due diligence examination of the tailrace hydraulics in a physical scale model.

Survival rates were likely also influenced by the large number of predatory birds feeding on fish passing through the spillway, mainly the TSW and adjacent bays in spring. In summer when the TSW and spillbays 17–20 were closed, in an attempt to reduce the hydraulic influence that was making access to the fish easier, the birds shifted their feeding north to spillbays 2–14. This resulted in lower spillway survival in 2009 relative to 2008.

4.3 Performance of the Prototype TSW Surface Flow Outlet

The prototype TSW SFO tested at JDA during 2009 performed comparably to other SFOs on the main stem Columbia and Snake rivers (Table 4.1). In fact, SFO passage efficiency and effectiveness for the JDA TSW were similar to those of the McNary TSW. Neither SFOperformed as well as the SFOs at Wells Dam or the BON B2. The JDA TSW out-performed the Lower Granite Dam and Ice Harbor Dam removable spillway weirs for STH, but not for CH1 or CH0. 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.

Because JDA 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 JDA 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 the case for about one-half to two-thirds of the tagged fish. This is an important finding given the huge size of the JDA powerhouse. This effect possibly could be enhanced by locating the TSWs closer to the powerhouse, perhaps at spill bays 18 and 19.

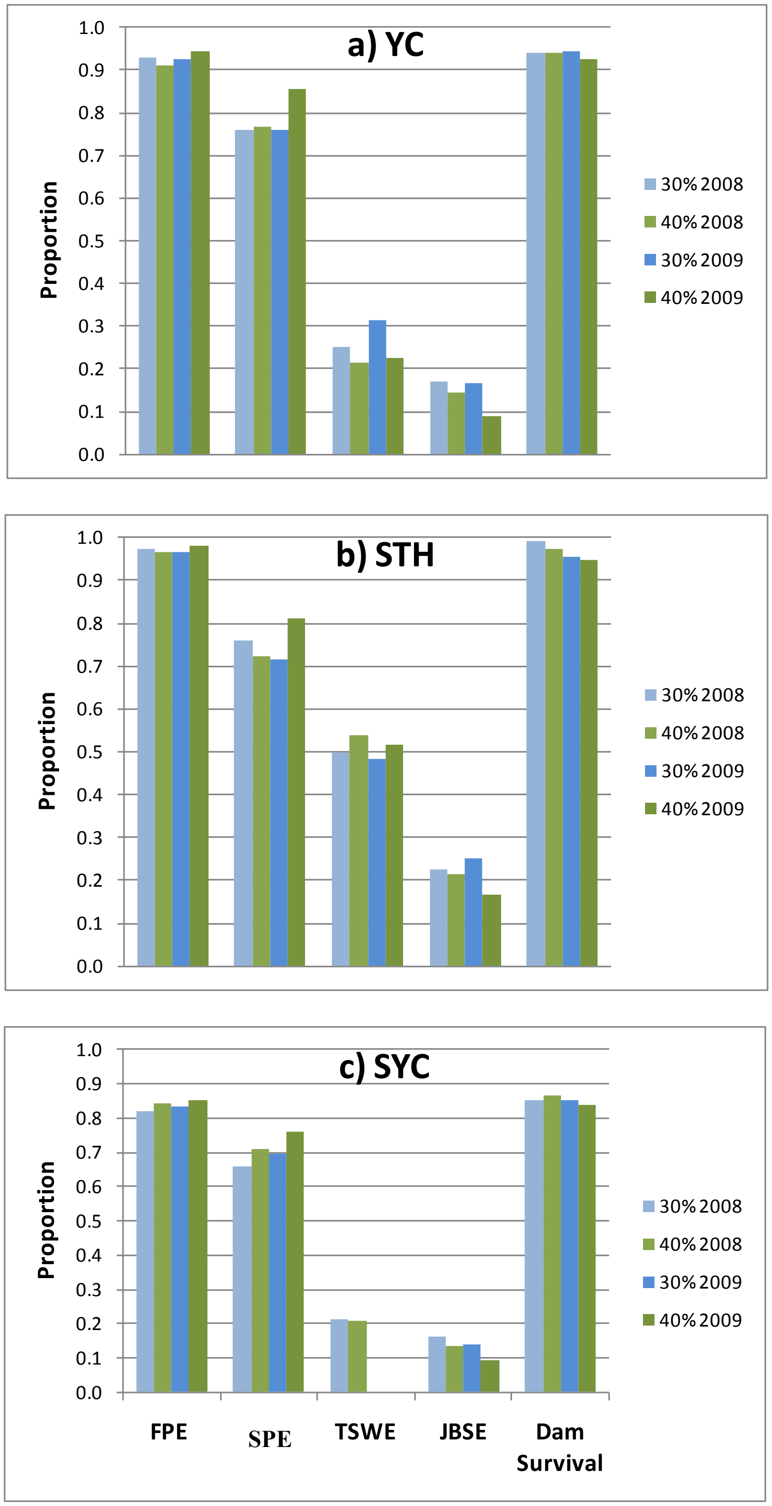

Figure 4.1. Comparison of Passage and Survival Proportions for 30% and 40% Spill Conditions During 2008 and 2009. Data for 2008 are from Weiland et al. (2009). FPE is fish-passage efficiency; SPE is spillpassage efficiency; TSWE is Top-spill weir efficiency; JBSE is juvenile bypass system-passage efficiency. Dam survival from the single-release model with virtual release at the dam-face arrays includes mortality during passage and in the tailwater to the first downstream detection array.

A primary goal of the TSW SFOs at JDA is to reduce turbine passage, the worst survival route at the dam, and thereby improve overall survival rates for downstream migrants. This report provides estimates of survival rates and passage efficiencies that indicate the goal is being met. For the purpose of further discussion of this topic, the effect of the TSWs on turbine passage was enhanced by synthesizing data from pre- and post-TSW studies at JDA. The proportion of fish passing the turbines is about 50% lower post-TSW than pre-TSW (Figure 4.2). It is possible other factors influenced this result. However, the 30–40% spill proportions during post-TSW years (2008 and 2009) were higher than some pre-TSW years (1999, 2000, 2002, and 2003) but lower than others. Outflow post-TSW was not distinctly higher or lower than pre-TSW. Extended-length submersible screens were in place each year. One piece of evidence, though, does not support the contention that the TSWs reduce turbine passage—the turbine passage proportion for CH0 during summer 2008 when the TSWs were operated was only 1 percentage point lower than during summer 2009 when the TSWs were off. Further research during 2010 will be applied to this matter.

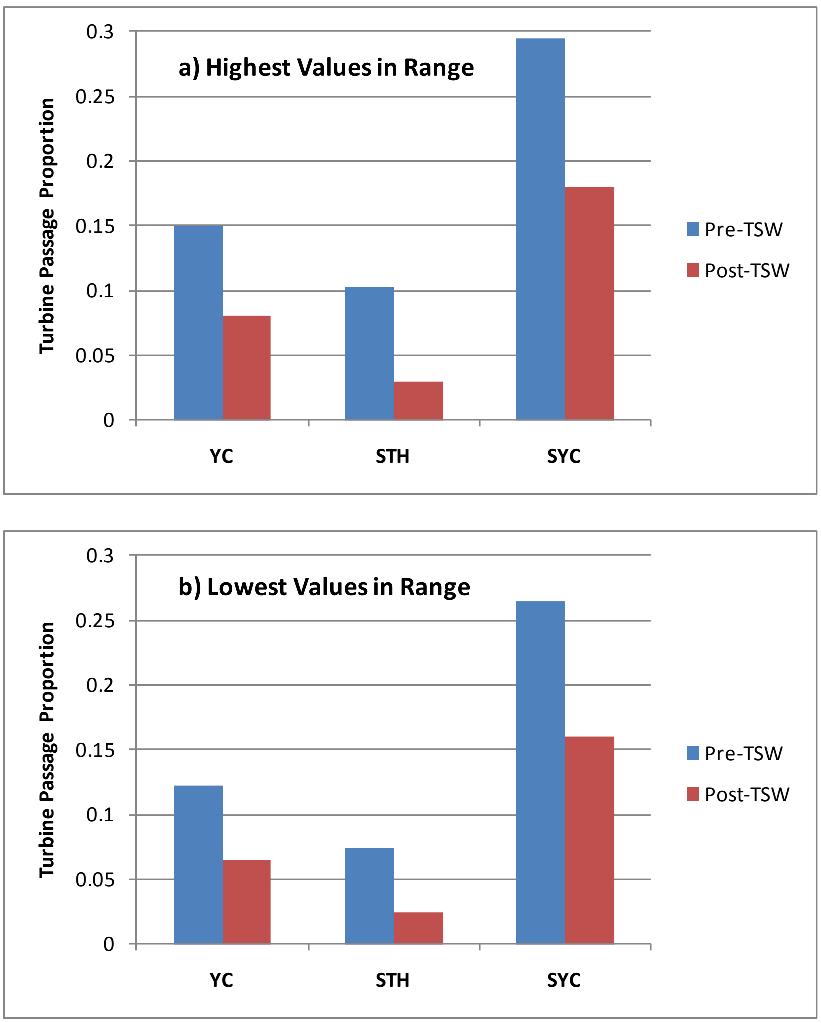

Figure 4.2. Turbine Passage Proportions Pre- and Post-TSW. Data are average across years of telemetry studies: pre-TSW during 1999, 2000, 2002, 2003 and post-TSW during 2008 and 2009 (Tables 1.2, 3.14, 3.25, and 3.35).

In addition to assessing the fish collection efficiency and effectiveness of SFOs, 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 (95% and 96% for CH1 and STH, respectively; the TSW was not operated during the 2009 CH0 migration), 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.

Table 4.1. Comparison of Performance for Various Surface-Flow Outlets in the Pacific Northwest

			SFO Efficiency			SFO Effectiveness		
Year	Dam	SFO Type	CH1	STH	CH0	CH1	STH	CH0
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	TSW	0.24	0.50	0.21	3.4	7.2	3.1
2009[(i)]	JDA	TSW	0.23	0.44	0.21	3.7	6.8	NA

(a) Skalski et al. 1996.
(b) Run-at-large in spring comprised of CH1 and STH.
(c) Counihan et al. 2006a and 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) Weiland et al. (2009)
(i) 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
CH0 = subyearling Chinook salmon.
WEL = Wells Dam
CH1 = yearling Chinook salmon.

4.4 Conclusions

The main conclusions from the acoustic telemetry evaluation of survival rates, fish-passage efficiencies and distributions, fish behavior, and effects of spill condition for CH1, STH, and CH0 at JDA during 2009 are as follows.

- Survival Rates
  - For 2009, single-release estimates of JDA-to-TDA forebay-passage survival rates for CH1 (0.927 ± 0.010[1]) and STH (0.953 ± 0.008) in spring and estimates for CH0 were (0.839 ± 0.014) in summer. Due to the study design being single release estimates and encompassing TDA pool down to the TDA forebay the performance standards outlined in the 2008 BiOp could not be applied here.
  - The passage route with the highest survival rate is the JBS (0.908 to 0.975). In terms of survival, the turbines are the worst route (0.749 to 0.851).
  - Bird predation, especially at the spillway, affected survival estimates.
- Passage Efficiencies and Distributions
  - Fish-passage efficiency was generally highest for STH and lowest for CH0. Proportionately more CH0 than CH1 or STH pass the dam via turbines.
  - Fish-passage rates at individual turbine units are strongly, positively correlated with unit-specific discharge.
- Fish Behavior
  - Spill and TSW operations attracted downstream migrant juvenile salmonids to the spillway. 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, relatively few smolts approaching the spillway passed at the powerhouse.
  - Fish approaching the spillway had the shortest median residence time of all approach paths (4 to 20 minutes, depending on fish run). The longest residence time was for fish approaching the powerhouse and then passing through the dam at the spillway or vice versa (2 to 7 hours).
  - Downstream migrants are surface-oriented, being distributed in the upper portion of the water column (< 5–7 m) on approach to the dam.
- Effect of Spill Condition (30% versus 40% spill)
  - Survival was significantly higher for CH1 at 30% spill for the five blocks meeting the treatment spill rates and at 30% spill for STH when all seven blocks were tested. There is no statistically significant increase in survival for the 40% spill treatments. Survival estimates, passage efficiencies, and fish behaviors are similar between the two spill conditions. The increase in spill discharge from 30% to 40% of total water discharged through the dam basically serves to pass incrementally more fish at non-TSW bays and incrementally fewer fish at the TSW bays.
- TSW Performance
  - In terms of fish collection, the TSWs perform well when they are operated. At about 20 kcfs, the TSW bays passed half of the STH and a quarter of the CH1 of the respective totals passing through JDA.

[1] ± ½ 95% confidence interval.

– As intended in the TSW design and operation, the TSW surface flows appeared to attract, or 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 at night, which is consistent with observations at many other SFOs (Johnson and Dauble 2006; Sweeney et al. 2007).

4.5 Recommendations

Based on the 2009 results, recommendations include the following:

- Assuming there would be no adverse impact on tailrace passage conditions, the TSWs should be moved closer to the powerhouse to maximize the collection of fish approaching and passing through the powerhouse and thereby minimizing turbine passage.
- To date, there is only 1 year (2008) of TSW evaluation for CH0. Performance of the TSW during summer for CH0 should be addressed in future studies.
- After due diligence examination of tailrace hydraulics in a physical scale model, a comparison of 20% versus 40% or 10% versus 30% spill might be considered for future studies.

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Appendix A

Tagging Tables

Appendix A

Tagging Tables

Table A.1. Yearling Chinook Salmon and Steelhead Tagged at the JDA SMF and Released near Roosevelt, Washington, in Spring 2009

Tag Date	Release Date	Number Tagged	Species	Number Released
4/26/2009	4/27/2009	229	Steelhead	115
			Yearling Chinook	114
4/27/2009	4/28/2009	232	Steelhead	116
			Yearling Chinook	116
4/28/2009	4/29/2009	231	Steelhead	115
			Yearling Chinook	116
4/29/2009	4/30/2009	231	Steelhead	116
			Yearling Chinook	115
4/30/2009	5/1/2009	225	Steelhead	110
			Yearling Chinook	115
5/1/2009	5/2/2009	231	Steelhead	116
			Yearling Chinook	115
5/2/2009	5/3/2009	237	Steelhead	120
			Yearling Chinook	117
5/3/2009	5/4/2009	232	Steelhead	116
			Yearling Chinook	116
5/4/2009	5/5/2009	232	Steelhead	116
			Yearling Chinook	116
5/5/2009	5/6/2009	232	Steelhead	116
			Yearling Chinook	116
5/6/2009	5/7/2009	229	Steelhead	115
			Yearling Chinook	114
5/7/2009	5/8/2009	231	Steelhead	116
			Yearling Chinook	115
5/8/2009	5/9/2009	230	Steelhead	115
			Yearling Chinook	115
5/9/2009	5/10/2009	233	Steelhead	116
			Yearling Chinook	117
5/10/2009	5/11/2009	230	Steelhead	115
			Yearling Chinook	115
5/11/2009	5/12/2009	232	Steelhead	116
			Yearling Chinook	116
5/12/2009	5/13/2009	230	Steelhead	115
			Yearling Chinook	115

Table A.1. (contd)

Tag Date	Release Date	Number Tagged	Species	Number Released
5/13/2009	5/14/2009	232	Steelhead	116
			Yearling Chinook	116
5/14/2009	5/15/2009	219	Steelhead	104
			Yearling Chinook	115
5/15/2009	5/16/2009	235	Steelhead	120
			Yearling Chinook	115
5/16/2009	5/17/2009	234	Steelhead	120
			Yearling Chinook	114
5/17/2009	5/18/2009	235	Steelhead	118
			Yearling Chinook	117
5/18/2009	5/19/2009	234	Steelhead	116
			Yearling Chinook	118
5/19/2009	5/20/2009	232	Steelhead	116
			Yearling Chinook	116
5/20/2009	5/21/2009	230	Steelhead	115
			Yearling Chinook	115
5/21/2009	5/22/2009	231	Steelhead	116
			Yearling Chinook	115
5/22/2009	5/23/2009	224	Steelhead	113
			Yearling Chinook	111
5/23/2009	5/24/2009	238	Steelhead	118
			Yearling Chinook	120
5/24/2009	5/25/2009	239	Steelhead	119
			Yearling Chinook	120
5/25/2009	5/26/2009	231	Steelhead	116
			Yearling Chinook	115
Totals	Totals	6941	Steelhead	3471
			Yearling Chinook	3470

Table A.2. Subyearling Chinook Salmon Tagged at the JDA SMF and Released near Roosevelt, Washington, in Summer 2009

Tag Date	Release Date	Number Tagged	Number Released
6/15/2009	6/16/2009	114	114
6/16/2009	6/17/2009	117	117
6/17/2009	6/18/2009	115	115
6/18/2009	6/19/2009	115	115
6/19/2009	6/20/2009	113	113
6/20/2009	6/21/2009	116	116
6/21/2009	6/22/2009	115	115
6/22/2009	6/23/2009	118	118
6/23/2009	6/24/2009	116	116
6/24/2009	6/25/2009	117	117
6/25/2009	6/26/2009	115	115
6/26/2009	6/27/2009	116	116
6/27/2009	6/28/2009	115	115
6/28/2009	6/29/2009	116	116
6/29/2009	6/30/2009	115	115
6/30/2009	7/1/2009	116	116
7/1/2009	7/2/2009	114	114
7/2/2009	7/3/2009	116	116
7/3/2009	7/4/2009	115	115
7/4/2009	7/5/2009	113	113
7/5/2009	7/6/2009	114	114
7/6/2009	7/7/2009	119	119
7/7/2009	7/8/2009	115	115
7/8/2009	7/9/2009	116	116
7/9/2009	7/10/2009	94	94
7/10/2009	7/11/2009	120	120
7/11/2009	7/12/2009	118	118
7/12/2009	7/13/2009	120	120
7/13/2009	7/14/2009	118	118
7/14/2009	7/15/2009	120	120
Totals	Totals	3461	3461

Appendix B

Hydrophone and Autonomous Node Deployment Tables

Appendix B

Hydrophone and Autonomous Node Deployment Tables

Table B.1. 2009 John Day Dam-Face Hydrophone Deployment

System	Pier Nose	Elevation Category	Trailer	Y-Block Color	Channel	Y-Block Location	Beldon Cable (ft)	Deck Cable (ft)	Nod e SN	Northing	Easting	Elevation (MSL)
P0	0	S	PH South	Green	1	0	150	250	12	745714.97	8153831.93	259.64
	0	S		Blue	2		150		100	745762.90	8153797.32	259.50
	C1	FOREBAY		Yellow	3		150		183	746016.31	8153759.87	
	C2	FOREBAY		Red	4		150		209	746352.82	8153513.46	
P1	0-1	S	PH South	Green	1	1-2	150	250	18	745814.84	8153758.42	255.23
	1-2	D		Blue	2		150		19	745890.46	8153711.93	169.54
	2-3	S		Yellow	3		150		39	745959.26	8153654.16	255.34
	3-4	D		Red	4		350		20	746036.31	8153606.67	169.46
P2	0-1	D	PH South	Green	1	2-3	350	250	24	745819.01	8153763.51	169.42
	1-2	S		Blue	2		150		13	745886.29	8153706.83	255.34
	2-3	D		Yellow	3		150		152	745963.43	8153659.25	169.54
	3-4	S		Red	4		150		15	746032.14	8153601.58	255.27
P3	4-5	S	PH South	Green	1	5-6	150	500	130	746104.93	8153548.78	255.26
	5-6	D		Blue	2		150		174	746182.24	8153501.22	169.40
	6-7	S		Yellow	3		150		226	746251.01	8153443.52	255.62
	7-8	D		Red	4		350		239	746328.24	8153395.89	169.43
P4	4-5	D	PH Unit 8	Green	1	6-7	350	350	137	746109.10	8153553.88	169.45
	5-6	S		Blue	2		150		17	746178.07	8153496.13	255.21
	6-7	D		Yellow	3		150		241	746255.18	8153448.61	169.56
	7-8	S		Red	4		150		142	746324.07	8153390.80	255.49
P5	8-9	S	PH Unit 8	Green	1	9-10	150	250	42	746397.01	8153338.14	255.39
	9-10	D		Blue	2		150		155	746473.96	8153290.39	169.49
	10-11	S		Yellow	3		150		223	746542.78	8153232.56	255.56
	11-12	D		Red	4		350		233	746620.13	8153184.99	169.46

Table B.1. (contd)

System	Pier Nose	Elevation Category	Trailer	Y-Block Color	Channel	Y-Block Location	Beldon Cable (ft)	Deck Cable (ft)	Nod e SN	Northing	Easting	Elevation (MSL)
P6	8-9	D	PH Unit 8	Green	1	10-11	350	500	238	746401.18	8153343.24	169.33
	9-10	S		Blue	2		150		154	746469.79	8153285.30	255.54
	10-11	D		Yellow	3		150		240	746546.95	8153237.66	169.50
	11-12	S		Red	4		150		151	746615.96	8153179.90	255.51
P7	12-13	S	PH Unit 8	Green	1	13-14	150	750	227	746688.83	8153127.26	255.59
	13-14	D		Blue	2		150		243	746766.00	8153079.59	169.35
	14-15	S		Yellow	3		150		157	746834.78	8153022.15	255.41
	15-16	D		Red	4		350		218	746911.90	8152974.45	169.43
P8	12-13	D	PH Unit 8	Green	1	14-15	350		234	746693.00	8153132.36	169.53
	13-14	S		Blue	2		150	750	175	746761.83	8153074.49	255.40
	14-15	D		Yellow	3		150		242	746838.95	8153027.24	169.36
	15-16	S		Red	4		150		188	746907.73	8152969.35	255.49
P9	16-17	S	PH Unit 19	Green	1	17-18	150	850	115	746980.62	8152916.49	255.60
	17-18	D		Blue	2		150		177	747057.69	8152868.87	169.36
	18-19	S		Yellow	3		150		123	747126.39	8152811.13	255.47
	19-20	D		Red	4		350		138	747203.50	8152763.54	169.46
P10	16-17	D	PH Unit 19	Green	1	18-19	350	500	140	746984.79	8152921.59	169.54
	17-18	S		Blue	2		150		111	747053.52	8152863.77	255.42
	18-19	D		Yellow	3		150		136	747130.56	8152816.22	169.41
	19-20	S		Red	4		150		126	747199.33	8152758.45	255.52
PS11	20-ph	S	PH Unit 19	Green	1	20-20	150	250	128	747273.24	8152705.03	255.52
	20 sp	D		Blue	2		150		48	747297.22	8152677.93	232.53
	19-20 sp	S		Yellow	3		150		30	747346.71	8152641.53	259.78
	18-19 sp	D		Red	4		246		217	747397.02	8152605.21	232.61
PS12	20-ph	D	PH Unit 19	Green	1	19-20 SP	350	600	135	747277.41	8152710.12	169.46
	20 sp	S		Blue	2		150		36	747297.22	8152677.93	259.70
	19-20 sp	D		Yellow	3		150		213	747346.71	8152641.53	232.61
	18-19 sp	S		Red	4		150		112	747397.02	8152605.21	259.78

Table B.1. (contd)

System	Pier Nose	Elevation Category	Trailer	Y-Block Color	Channel	Y-Block Location	Beldon Cable (ft)	Deck Cable (ft)	Nod e SN	Northing	Easting	Elevation (MSL)
S13	17-18	S	PH Unit 19	Green	1	16-17	150	500	23	747447.22	8152568.92	259.93
	16-17	D		Blue	2		150		127	747497.65	8152532.55	232.45
	15-16	S		Yellow	3		150		187	747548.01	8152496.25	259.35
	14-15	D		Red	4		250		216	747598.24	8152459.90	232.35
S14	17-18	D	PH Unit 19	Green	1	15-16	250	500	29	747447.22	8152568.92	232.76
	16-17	S		Blue	2		150		45	747497.65	8152532.55	259.62
	15-16	D		Yellow	3		100		228	747548.01	8152496.25	232.18
	14-15	S		Red	4		150		178	747598.24	8152459.90	259.52
S15	13-14	S	PH Unit 19	Green	1	12-13	150	750	133	747648.47	8152423.58	259.71
	12-13	D		Blue	2		100		225	747698.84	8152387.29	232.44
	11-12	S		Yellow	3		150		28	747748.83	8152350.94	259.87
	10-11	D		Red	4		250		119	747799.16	8152314.60	232.38
S16	13-14	D	PH Unit 19	Green	1	11-12	250	750	134	747648.47	8152423.58	232.54
	12-13	S		Blue	2		150		180	747698.84	8152387.29	259.61
	11-12	D		Yellow	3		100		164	747748.83	8152350.94	232.70
	10-11	S		Red	4		150		60	747799.16	8152314.60	259.55
S17	9-10	S	SP North	Green	1	8-9	150	600	47	747849.50	8152278.53	259.81
	8-9	D		Blue	2		100		229	747899.71	8152242.06	232.70
	7-8	S		Yellow	3		150		109	747949.84	8152205.89	259.86
	6-7	D		Red	4		250		231	748000.70	8152169.33	232.62
S18	9-10	D	SP North	Green	1	7-8	250	558	132	747849.50	8152278.53	232.64
	8-9	S		Blue	2		150		32	747899.71	8152242.06	259.87
	7-8	D		Yellow	3		100		237	747949.84	8152205.89	232.69
	6-7	S		Red	4		150		148	748000.70	8152169.33	259.79
S19	5-6	S	SP North	Green	1	4-5	150	500	16	748050.73	8152133.20	259.81
	4-5	D		Blue	2		100		46	748101.13	8152097.00	232.30
	3-4	S		Yellow	3		150		45	748151.05	8152060.87	259.76
	2-3	D		Red	4		250		179	748201.45	8152024.74	232.38

Table B.1. (contd)

System	Pier Nose	Elevation Category	Trailer	Y-Block Color	Channel	Y-Block Location	Beldon Cable (ft)	Deck Cable (ft)	Nod e SN	Northing	Easting	Elevation (MSL)
S20	5-6	D	SP North	Green	1	3-4	250	500	21	748050.73	8152133.20	232.64
	4-5	S		Blue	2		150		26	748101.13	8152097.00	259.47
	3-4	D		Yellow	3		100		153	748151.05	8152060.87	232.59
	2-3	S		Red	4		150		49	748201.45	8152024.74	259.55
S21	1-2	D	SP North	Green	1	1	150	250	244	748251.90	8151988.45	232.73
	1-2	S		Blue	2		150		118	748251.90	8151988.45	259.90
	1	South	SP North	Yellow	3		150		102	748306.74	8151947.97	259.32
	1	North		Red	4		150		105	748379.55	8151915.63	259.72
P0	C1	FOREBAY	PH South	Yellow	3		500	500	183	746016.31	8153759.87	
P0	C2	FOREBAY	PH South	Red	4		500		209	746352.82	8153513.46	
C2	C3	FOREBAY	PH Unit 19	Green	1		1000	820	110	746676.78	8153280.25	
C2	C4	FOREBAY	PH Unit 19	Blue	2		500		232	747007.46	8153040.23	
C2	C5	FOREBAY	PH Unit 19	Yellow	3		500		235	747338.71	8152798.69	
C2	C6	FOREBAY	PH Unit 19	Green	4		1000	1250	104	747630.17	8152583.15	
C3	C7	FOREBAY	SP North	Green	1		500	500	51	747916.39	8152377.01	
C3	C8	FOREBAY	SP North	Blue	2		500		144	748244.91	8152142.27	

Table B.2. Approximate Global Positioning System Coordinates of Autonomous Nodes Deployed in 2009 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 Roosevelt, Washington, 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 FB Entrance	45.731319	-120.67719	85
A1CR351_02		45.730279	-120.67585	133
A1CR351_03		45.729167	-120.67479	100
A1CR351_04		45.728181	-120.67370	115
A1CR351_05		45.727194	-120.67252	115
A1CR351_06		45.726136	-120.67133	115
A1CR351_07		45.725114	-120.67004	180
A1CR351_08		45.724074	-120.66888	100
A2CR346_01	JDA TW Egress	45.708464	-120.72577	20
A2CR346_02		45.707495	-120.72507	24
A2CR346_03		45.706436	-120.72420	42
A2CR346_04		45.705772	-120.72368	67
A3CR311_01	JDA Primary	45.629886	-121.11286	50
A3CR311_02		45.629148	-121.11175	130
A3CR311_03		45.628338	-121.11035	45
A3CR311_04		45.627708	-121.10929	42
A3CR311_05		45.627024	-121.10810	50
A4CR236_01	BON FB Entrance & JDA Secondary	45.649388	-121.92339	55
A4CR236_02		45.648956	-121.92282	73
A4CR236_03		45.648417	-121.92226	80
A4CR236_04		45.647985	-121.92174	56
A5CR192_01	JDA Tertiary; BON Primary	45.576289	-122.42849	32
A5CR192_02		45.568721	-122.42088	72
A5CR192_03		45.568105	-122.42180	64
A5CR192_04		45.567490	-122.42083	59
A5CR192_05		45.566874	-122.42186	48
A5CR192_06		45.566294	-122.42078	42
A5CR192_07		45.565751	-122.42186	32
A5CR192_08		45.565208	-122.42088	29
A5CR192_09		45.564519	-122.42186	26
A6CR113_01	BON Secondary	46.063202	-122.86923	36
A6CR113_02		46.070685	-122.88697	56
A6CR113_03		46.070067	-122.88733	53
A6CR113_05		46.069387	-122.88876	52
A6CR113_06		46.069583	-122.88973	50

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)
A6CR113_07		46.068892	-122.89035	43
A6CR113_08		46.068988	-122.89151	32
A6CR113_09		46.068473	-122.89226	32
A6CR113_10		46.068938	-122.89403	27
A7CR086_01	BON Tertiary	46.186095	-123.18056	72
A7CR086_02		46.185952	-123.17930	73
A7CR086_03		46.185175	-123.17980	60
A7CR086_04		46.184390	-123.17908	60
A7CR086_05		46.184080	-123.17789	43
A7CR086_06		46.183470	-123.17853	55

Appendix C

Survival and Detection Probabilities for Single Releases

Appendix C

Survival and Detection Probabilities for Single Releases

Table C.1. List of Excel Files on an Accompanying Compact Disc*

File	Description
Appendix C1.xlsx	Yearling Chinook Single-Release Survival Capture Histories and Detection Probabilities and Histories at JDA
Appendix C2.xlsx	Steelhead Single Releases Survival and Detection Probabilities and Histories at JDA
Appendix C3.xlsx	Subyearling Chinook Single Releases Survival and Detection Probabilities and Histories at JDA
Appendix C4.xlsx	Single Releases Survival and Detection Probabilities and Histories at TDA (1 Tab per fish run)

*A compact disc accompanying the report has __ files: A Portable Document File (PDF) of this report and comma-separated-variable files and Excel files with tagging, release, virtual release, capture-history data and Survival and Detection Probabilities for Single releases results.

Appendix D

Burnham Test Results

Appendix D

Burnham Test Results

Burnham Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture (Burnham et al. 1987). In the following tables, cells containing "NC" could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells that have P-values < 0.10 indicate a violation of model assumptions.

D.1 Yearling Chinook Salmon

Table D.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 Concrete

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	0.4964	0.0005
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	NC
5/25-5/26	NC	NC
5/27-6/07	0.1530	0.1528

Table D.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

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	0.4498	0.0004
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	NC
5/25-5/26	NC	NC
5/27-6/07	0.1583	0.1868

Table D.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 Turbines

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/27-4/31	NC	NC
5/01-5/05	NC	NC
5/06-5/10	NC	NC
5/11-5/15	NC	NC
5/16-5/20	NC	NC
5/21-5/25	NC	NC
5/21-6/07	NC	NC

Table D.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 JBS

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/27-4/31	NC	NC
5/01-5/05	NC	NC
5/06-5/10	NC	NC
5/11-5/15	0.1383	0.0316
5/16-5/20	NC	NC
5/21-5/25	NC	NC
5/21-6/07	NC	NC

Table D.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 Spillways

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	0.1858	0.0000
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	NC
5/25-5/26	NC	NC
5/27-6/07	0.1632	0.1612

Table D.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 TSW

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	0.1666	0.0008
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	NC

D.2 Steelhead

Table D.7. 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 Concrete

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	0.0314	0.0508
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	NC
5/25-5/26	NC	NC
5/27-6/07	0.6875	0.7457

Table D.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

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	0.0337	0.0189
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	0.3223
5/25-5/26	0.0996	0.2994
5/27-6/07	0.1612	0.2582

Table D.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 the John Day Dam Turbines

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/27-5/15	NC	NC
5/16-6/07	NC	NC

Table D.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 JBS

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/27-4/31	NC	NC
5/01-5/05	NC	NC
5/06-5/10	NC	NC
5/11-5/15	NC	NC
5/16-5/20	NC	NC
5/21-5/25	NC	NC
5/21-6/07	NC	NC

Table D.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 Spillways

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	0.0229	0.0812
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	NC
5/25-5/26	NC	NC
5/27-6/07	0.7333	0.7429

Table D.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 TSW

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
4/28-4/31	NC	NC
5/01-5/02	NC	NC
5/03-5/04	NC	NC
5/05-5/06	NC	NC
5/07-5/08	NC	NC
5/09-5/10	NC	NC
5/11-5/12	NC	NC
5/13-5/14	NC	NC
5/15-5/16	NC	NC
5/17-5/18	NC	NC
5/19-5/20	NC	NC
5/21-5/22	NC	NC
5/23-5/24	NC	NC
5/25-5/26	NC	NC
5/27-6/07	0.1890	0.0554

D.3 Subyearling Chinook Salmon

Table D.13. 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 Concrete

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
6/16-6/19	NC	NC
6/20-6/21	NC	NC
6/22-6/23	0.0652	0.4717
6/24-6/25	0.0515	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	0.0165	0.1833
7/08-7/09	0.0051	0.0642
7/10-7/11	NC	NC
7/12-7/13	NC	NC
7/14-7/15	NC	NC
7/16/8/21	NC	NC

Table D.14. 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

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
6/16-6/19	NC	NC
6/20-6/21	NC	NC
6/22-6/23	0.0515	0.4822
6/24-6/25	0.0487	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	0.1075	0.4064
7/08-7/09	NC	NC
7/10-7/11	NC	NC
7/12-7/13	NC	NC
7/14-7/15	NC	NC
7/16/7/29	NC	NC

Table D.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 the John Day Turbines

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
6/17-6/23	NC	NC
6/24-6/31	0.0031	NC
7/01-7/08	NC	NC
7/09-8/11	NC	NC

Table D.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 the John Day Dam JBS

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
6/17-6/23	0.1197	0.5151
6/24-6/31	NC	NC
7/01-7/08	NC	NC
7/09-7/20	NC	NC

Table D.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 Spillways

	P-Values from Fisher's Exact Test	
Virtual Release Date	Test 2.2	Test 3.1
6/16-6/19	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	0.0253	0.1903
7/08-7/09	0.0011	0.0542
7/10-7/11	NC	NC
7/12-7/13	NC	NC
7/14-7/15	NC	NC
7/16/8/21	NC	NC

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