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Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival at John Day Dam, 2010

FINAL REPORT

Pacific Northwest National Laboratory
University of Washington
Pacific States Marine Fisheries Commission

May 2013

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Preface

This study was conducted by the Pacific Northwest National Laboratory (PNNL), the University of Washington (UW), and the Pacific States Marine Fisheries Commission (PSMFC) for the U.S. Army Corps of Engineers (USACE), Portland District (CENWP). The CENWP technical lead was Mr. Brad Eppard. This report presents survival, behavioral, and fish passage results for yearling and subyearling Chinook salmon and juvenile steelhead tagged with Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic micro-transmitters as part of a survival study conducted at John Day Dam during 2010.

This study was designed to evaluate the passage and survival of yearling and subyearling Chinook salmon and juvenile steelhead to assist managers in identifying dam operations for compliance testing as stipulated by the 2008 Federal Columbia River Power System Biological Opinion and the 2008 Columbia Basin Fish Accords. Survival estimates were based on a single-release survival estimate model.

Executive Summary

Improving the survival rate of juvenile salmonids emigrating through the Federal Columbia River Power System (FCRPS) continues to be a high priority for the U.S. Army Corps of Engineers (USACE) and the fisheries managers maintaining the salmonid stocks in the Columbia River Basin. Many of these fish are from populations listed as threatened or endangered under the Endangered Species Act of 1973. Increasing the survival rates is necessary to ensure healthy salmon populations in the future and to meet performance standards set forth in the 2008 Biological Opinion (BiOp) on configuration and operation of the FCRPS. The BiOp mandates that a 96% and 93% survival rate with an associated standard error ≤1.5% be achieved for spring and summer downstream migrating juvenile salmonids, respectively. At John Day Dam (JDA), the USACE Portland District (CENWP) is evaluating surface-flow outlets (SFOs) as a means to increase dam fish passage efficiency and in turn increase fish passage survival rates by reducing turbine passage of juvenile salmonids. The goal of this study was to provide the fish passage and survival data necessary to evaluate the performance of the JDA prototype SFO, a top-spill weir (TSW), the dam as a whole relative to the performance standards outlined in the BiOp, and additional performance measures as stipulated in the Columbia Basin Fish Accords for yearling and subyearling Chinook salmon (*Oncorhynchus tshawytscha*) and juvenile steelhead (*O. mykiss*). This study was conducted to provide the CENWP and regional fisheries managers with information needed to adaptively manage the configuration and operation of JDA to maximize the survival rate for juvenile salmonids.

Researchers at the Pacific Northwest National Laboratory collaborated with the Pacific States Marine Fisheries Commission; CENWP; and the University of Washington to estimate survival rates and other performance measures of yearling and subyearling Chinook salmon and juvenile steelhead passing through JDA during spring and summer 2010.

The objectives of this acoustic telemetry (AT) study of survival and passage at JDA were to estimate the following performance measures for yearling and subyearling Chinook salmon and juvenile steelhead:

- Survival: JDA forebay to The Dalles Dam (TDA; 42 river kilometers [rkm]), JDA forebay array to JDA dam face (2 rkm) and JDA dam face to TDA (40 rkm), dam passage to TDA (40 rkm), and dam passage, by route, to TDA
- Travel times: forebay residence, tailrace egress, and project passage
- Passage metrics: fish passage efficiency, spill passage efficiency, and TSW passage efficiency
- Distributions: forebay approach distribution, forebay vertical distribution, and horizontal distribution by route and subroute.

The current study was not an official compliance test as described by the 2008 FCRPS BiOp, because passage conditions for the dam had not been finalized. This study relied on releases of live juvenile salmonids double tagged with Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic micro-transmitters (AMTs) and passive integrated transponders (PITs) in the Columbia River and used AT to evaluate the approach, passage, and survival of juvenile salmonids. The effects of two spill treatments (30% and 40% spill) on passage and survival metrics were evaluated. Researchers also evaluated the performance of two independent cabled detection arrays deployed on the upstream dam face (powerhouse and spillway) to ensure the arrays will meet detection efficiency standards for the 2011 official compliance test.

Yearling and subyearling Chinook salmon and juvenile steelhead surgically implanted with JSATS AMTs were released in the Columbia River upstream of JDA (Roosevelt, Washington; CR390) and regrouped based on cabled array detections at JDA to form virtual releases. Single-release passage-survival estimates were made for 2,287 yearling Chinook salmon and 2,288 juvenile steelhead tagged with JSATS AMTs and PITs released upstream of JDA in spring, and 2,849 subyearling Chinook salmon tagged with JSATS AMTs and PITs released in summer. These tagged fish were released to support passage-survival studies at JDA, TDA, and Bonneville Dam in 2010. The JSATS AMT model number SS130 weighing 0.438 g in air, manufactured by Advanced Telemetry Systems, and the Biomark HPT12 PIT were used in this investigation.

This report provides a comprehensive summary of 2010 results, including estimates of route-specific passage-survival rates. Dam passage survival through the JDA tailrace (3 km) could not be estimated in 2010 because there were no reference releases of fish in the tailwater or tailrace. Forebay to tailrace survival (BRZ-to-BRZ [boat-restricted zone]) could not be estimated for the same reason. The study methods and results are summarized below (Table ES.1–Table ES.5).

Table ES.1. Summary of methods and conditions at John Day Dam during 2010.

Objectives of Study: Estimate single-release dam passage survival rates and other performance measures for yearling and subyearling Chinook salmon and steelhead for 30% and 40% spill treatments.							
Unique Study Characteristics: Top-spill weirs were installed in spill bays 18 and 19 and the deflector at spill bay 20 was modified to improve egress conditions and survival for downstream migrating juvenile salmon. Also, a new avian deterrent wire array was installed above the tailrace.							
Hypothesis (H0): 30% spill passage survival ≥ 40% spill passage survival; H1: 30% < 40% 30% spill forebay residence time ≥ 40% spill residence time; H1: 30% < 40% 30% spill egress rate ≥ 40% spill egress rate; H1: 30% < 40% 30% spill passage efficiency ≥ 40% spill passage efficiency; H1: 30% < 40%							
Fish: yearling Chinook salmon (CH1), steelhead (STH), subyearling Chinook salmon (CH0)				Source: John Day Dam fish collection facility Implant Procedure: surgical			
Size (Median):	CH1	STH	CH0	Sample Size:	CH1	STH	CH0
Weight:	32.1 g	80.0 g	12.5 g	# release sites:	1	1	1
Length:	152 mm	215 mm	110 mm	# releases:	32	32	32
				Total # released:	2,287	2,288	2,849
Tag Type/Model: Advanced Telemetry Systems SS130 weight (g): 0.438 g (air)			Analytical Model: virtual/single release		Characteristics of Estimate: direct effects, relative survival estimates		
Environmental/Operating Conditions		Spring			Summer		
Study period:		April 28 through June 12			June 13 through August 5		
Daily total project discharge (kcfs):		Mean 232, min 154, max 408			Mean 225, min 112, max 363		
Spill operations:		30% versus 40% spill treatments			30% versus 40% spill treatments		
Temperature (°C):		Mean 12.7, min 10.9, max 14.8			Mean 17.9, min 14.5, max 21.7		
Total dissolved gas (tailrace):		Mean 107%, min 100%, max 114%			Mean 114%, min 112%, max 116%		
Compliance Results: This was not an official compliance test, which would have required paired reference releases.							

Table ES.2. Summary of survival and other performance metrics at John Day Dam during 2010. Travel times (median and means, respectively) are provided in hours.

Metric	CH1	STH	CH0
Survival: Dam passage to TDA	0.937 ($\widehat{SE}$ = 0.005)	0.950 ($\widehat{SE}$ = 0.005)	0.908 ($\widehat{SE}$ = 0.006)
30% spill treatment	0.940 ($\widehat{SE}$ = 0.007)	0.942 ($\widehat{SE}$ = 0.008)	0.919 ($\widehat{SE}$ = 0.008)
40% spill treatment	0.944 ($\widehat{SE}$ = 0.007)	0.975 ($\widehat{SE}$ = 0.005)	0.914 ($\widehat{SE}$ = 0.008)
Survival: Forebay entrance array to TDA	0.934 ($\widehat{SE}$ = 0.006)	0.948 ($\widehat{SE}$ = 0.005)	0.904 ($\widehat{SE}$ = 0.006)
30% spill treatment	0.935 ($\widehat{SE}$ = 0.008)	0.931 ($\widehat{SE}$ = 0.008)	0.915 ($\widehat{SE}$ = 0.008)
40% spill treatment	0.941 ($\widehat{SE}$ = 0.007)	0.962 ($\widehat{SE}$ = 0.006)	0.907 ($\widehat{SE}$ = 0.008)
Forebay Residence Time	2.15; 5.32	4.44; 13.70	1.83; 3.83
30% spill treatment	2.38; 5.28	5.10; 13.96	1.95; 4.00
40% spill treatment	1.89; 4.99	3.97; 13.42	1.76; 3.67
100-m Forebay Residence Time	0.58; 3.26	1.37; 8.12	0.29; 2.06
30% spill treatment	0.66; 2.95	1.66; 8.30	0.36; 2.30
40% spill treatment	0.52; 3.04	1.21; 7.85	0.26; 1.83
Tailrace Egress Time	0.74; 2.31	0.63; 2.49	0.62; 1.94
30% spill treatment	0.74; 2.02	0.64; 2.50	0.57; 1.60
40% spill treatment	0.74; 2.59	0.62; 2.48	0.56; 2.18
Project Passage Time (CR351 to CR346)	3.09; 7.44	5.71; 16.09	2.65; 5.55
30% spill treatment	3.30; 7.25	6.69; 16.51	2.75; 5.33
40% spill treatment	2.85; 7.47	5.05; 15.76	2.50; 5.67
Fish Passage Efficiency	0.963 ($\widehat{SE}$ = 0.004)	0.982 ($\widehat{SE}$ = 0.003)	0.883 ($\widehat{SE}$ = 0.006)
30% spill treatment	0.969 ($\widehat{SE}$ = 0.005)	0.982 ($\widehat{SE}$ = 0.004)	0.857 ($\widehat{SE}$ = 0.010)
40% spill treatment	0.958 ($\widehat{SE}$ = 0.006)	0.982 ($\widehat{SE}$ = 0.004)	0.908 ($\widehat{SE}$ = 0.008)
Spill Passage Efficiency	0.900 ($\widehat{SE}$ = 0.007)	0.888 ($\widehat{SE}$ = 0.007)	0.776 ($\widehat{SE}$ = 0.008)
30% spill treatment	0.917 ($\widehat{SE}$ = 0.009)	0.871 ($\widehat{SE}$ = 0.011)	0.741 ($\widehat{SE}$ = 0.012)
40% spill treatment	0.884 ($\widehat{SE}$ = 0.010)	0.904 ($\widehat{SE}$ = 0.009)	0.810 ($\widehat{SE}$ = 0.011)
TSW Passage Efficiency||Dam	0.568 ($\widehat{SE}$ = 0.011)	0.719 ($\widehat{SE}$ = 0.010)	0.311 ($\widehat{SE}$ = 0.009)
30% spill treatment	0.662 ($\widehat{SE}$ = 0.015)	0.752 ($\widehat{SE}$ = 0.014)	0.352 ($\widehat{SE}$ = 0.013)
40% spill treatment	0.478 ($\widehat{SE}$ = 0.015)	0.692 ($\widehat{SE}$ = 0.014)	0.272 ($\widehat{SE}$ = 0.012)
TSW Passage Efficiency||Spillway	0.632 ($\widehat{SE}$ = 0.011)	0.809 ($\widehat{SE}$ = 0.009)	0.401 ($\widehat{SE}$ = 0.011)
30% spill treatment	0.722 ($\widehat{SE}$ = 0.014)	0.864 ($\widehat{SE}$ = 0.012)	0.475 ($\widehat{SE}$ = 0.016)
40% spill treatment	0.541 ($\widehat{SE}$ = 0.016)	0.765 ($\widehat{SE}$ = 0.013)	0.335 ($\widehat{SE}$ = 0.014)
Fish Guidance Efficiency	0.631 ($\widehat{SE}$ = 0.033)	0.837 ($\widehat{SE}$ = 0.024)	0.477 ($\widehat{SE}$ = 0.021)
30% spill treatment	0.625 ($\widehat{SE}$ = 0.052)	0.857 ($\widehat{SE}$ = 0.031)	0.449 ($\widehat{SE}$ = 0.027)
40% spill treatment	0.641 ($\widehat{SE}$ = 0.042)	0.813 ($\widehat{SE}$ = 0.037)	0.514 ($\widehat{SE}$ = 0.031)
JBS Passage Efficiency	0.063 ($\widehat{SE}$ = 0.005)	0.094 ($\widehat{SE}$ = 0.006)	0.107 ($\widehat{SE}$ = 0.006)
30% spill treatment	0.052 ($\widehat{SE}$ = 0.007)	0.111 ($\widehat{SE}$ = 0.010)	0.116 ($\widehat{SE}$ = 0.009)
40% spill treatment	0.074 ($\widehat{SE}$ = 0.008)	0.078 ($\widehat{SE}$ = 0.008)	0.097 ($\widehat{SE}$ = 0.008)

Table ES.3. Survival estimates from the John Day Dam dam-face array (CR349) to The Dalles Dam (CR309) by subroute and spill treatment.

Route	CH1	STH	CH0
Spillway	0.951 ($\widehat{SE}$ = 0.005)	0.967 ($\widehat{SE}$ = 0.004)	0.927 ($\widehat{SE}$ = 0.006)
30% spill treatment	0.949 ($\widehat{SE}$ = 0.007)	0.951 ($\widehat{SE}$ = 0.008)	0.924 ($\widehat{SE}$ = 0.009)
40% spill treatment	0.953 ($\widehat{SE}$ = 0.007)	0.981 ($\widehat{SE}$ = 0.005)	0.930 ($\widehat{SE}$ = 0.008)
TSW	0.952 ($\widehat{SE}$ = 0.006)	0.972 ($\widehat{SE}$ = 0.004)	0.912 ($\widehat{SE}$ = 0.010)
30% spill treatment	0.957 ($\widehat{SE}$ = 0.008)	0.959 ($\widehat{SE}$ = 0.008)	0.910 ($\widehat{SE}$ = 0.013)
40% spill treatment	0.945 ($\widehat{SE}$ = 0.010)	0.985 ($\widehat{SE}$ = 0.005)	0.915 ($\widehat{SE}$ = 0.015)
Non-TSW	0.950 ($\widehat{SE}$ = 0.008)	0.944 ($\widehat{SE}$ = 0.012)	0.937 ($\widehat{SE}$ = 0.007)
30% spill treatment	0.927 ($\widehat{SE}$ = 0.016)	0.897 ($\widehat{SE}$ = 0.027)	0.936 ($\widehat{SE}$ = 0.011)
40% spill treatment	0.963 ($\widehat{SE}$ = 0.009)	0.965 ($\widehat{SE}$ = 0.012)	0.938 ($\widehat{SE}$ = 0.009)
Bay 20	0.933 ($\widehat{SE}$ = 0.016)	0.955 ($\widehat{SE}$ = 0.022)	0.891 ($\widehat{SE}$ = 0.027)
30% spill treatment	0.930 ($\widehat{SE}$ = 0.022)	0.924 ($\widehat{SE}$ = 0.043)	0.886 ($\widehat{SE}$ = 0.038)
40% spill treatment	0.936 ($\widehat{SE}$ = 0.024)	0.981 ($\widehat{SE}$ = 0.020)	0.896 ($\widehat{SE}$ = 0.037)
JBS	0.901 ($\widehat{SE}$ = 0.026)	0.943 ($\widehat{SE}$ = 0.017)	0.947 ($\widehat{SE}$ = 0.013)
30% spill treatment	0.930 ($\widehat{SE}$ = 0.035)	0.938 ($\widehat{SE}$ = 0.024)	0.973 ($\widehat{SE}$ = 0.013)
40% spill treatment	0.881 ($\widehat{SE}$ = 0.036)	0.948 ($\widehat{SE}$ = 0.024)	0.916 ($\widehat{SE}$ = 0.024)
Turbine	0.776 ($\widehat{SE}$ = 0.047)	0.694 ($\widehat{SE}$ = 0.074)	0.818 ($\widehat{SE}$ = 0.022)
30% spill treatment	0.698 ($\widehat{SE}$ = 0.080)	0.557 ($\widehat{SE}$ = 0.117)	0.848 ($\widehat{SE}$ = 0.027)
40% spill treatment	0.849 ($\widehat{SE}$ = 0.053)	0.811 ($\widehat{SE}$ = 0.086)	0.774 ($\widehat{SE}$ = 0.038)

Table ES.4. Summary of day and night survival and other performance metrics.

Route	CH1	STH	CH0
Survival: Dam passage to TDA	0.937 ($\widehat{SE}$ = 0.005)	0.950 ($\widehat{SE}$ = 0.005)	0.908 ($\widehat{SE}$ = 0.006)
Day	0.943 ($\widehat{SE}$ = 0.006)	0.971 ($\widehat{SE}$ = 0.005)	0.914 ($\widehat{SE}$ = 0.007)
Night	0.937 ($\widehat{SE}$ = 0.011)	0.931 ($\widehat{SE}$ = 0.011)	0.922 ($\widehat{SE}$ = 0.009)
Survival: JBS passage to TDA	0.901 ($\widehat{SE}$ = 0.026)	0.943 ($\widehat{SE}$ = 0.017)	0.947 ($\widehat{SE}$ = 0.013)
Day	0.875 ($\widehat{SE}$ = 0.049)	1.004 ($\widehat{SE}$ = 0.002)	0.931 ($\widehat{SE}$ = 0.025)
Night	0.914 ($\widehat{SE}$ = 0.030)	0.939 ($\widehat{SE}$ = 0.018)	0.955 ($\widehat{SE}$ = 0.015)
Survival: Spillway passage to TDA	0.951 ($\widehat{SE}$ = 0.005)	0.967 ($\widehat{SE}$ = 0.004)	0.927 ($\widehat{SE}$ = 0.006)
Day	0.950 ($\widehat{SE}$ = 0.006)	0.973 ($\widehat{SE}$ = 0.004)	0.923 ($\widehat{SE}$ = 0.007)
Night	0.957 ($\widehat{SE}$ = 0.011)	0.942 ($\widehat{SE}$ = 0.012)	0.940 ($\widehat{SE}$ = 0.011)
Survival: TSW passage to TDA	0.952 ($\widehat{SE}$ = 0.006)	0.972 ($\widehat{SE}$ = 0.004)	0.912 ($\widehat{SE}$ = 0.010)
Day	0.949 ($\widehat{SE}$ = 0.007)	0.975 ($\widehat{SE}$ = 0.005)	0.908 ($\widehat{SE}$ = 0.011)
Night	0.963 ($\widehat{SE}$ = 0.012)	0.958 ($\widehat{SE}$ = 0.014)	0.931 ($\widehat{SE}$ = 0.021)
TSW Passage Efficiency‖Spillway	0.632 ($\widehat{SE}$ = 0.011)	0.809 ($\widehat{SE}$ = 0.009)	0.401 ($\widehat{SE}$ = 0.011)
Day	0.612 ($\widehat{SE}$ = 0.012)	0.864 ($\widehat{SE}$ = 0.009)	0.423 ($\widehat{SE}$ = 0.013)
Night	0.720 ($\widehat{SE}$ = 0.024)	0.593 ($\widehat{SE}$ = 0.025)	0.329 ($\widehat{SE}$ = 0.021)

Table ES.5. Percentages of fish approach and passage distributions at John Day Dam in 2010.

Parameter	Percent		
	CH1	STH	CH0
Approached at the powerhouse	39.3	43.9	33.2
Approached at the powerhouse but passed at the spillway	79.9	81.9	53.4
Approached at the spillway	43.7	41.6	50.6
Approached at the spillway and passed at the spillway	98.4	96.5	95.1
Total passage at TSW bays	56.8	71.9	31.1
Total spillway passage at TSW bays	63.2	80.9	40.1

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- Advanced Telemetry Systems (ATS), Inc. manufactured the JSATS acoustic micro-transmitters.
- Autonomous and dam-mounted hydrophones were produced by Sonic Concepts, Seattle, Washington.
- Precision Acoustic Systems, Seattle, Washington, manufactured the quad channel receivers and conducted node acceptance tests for PNNL.
- Cascade Aquatics, Inc., Ellensburg, Washington, activated and delivered the acoustic micro-transmitters.

The Dalles Ironworks, The Dalles, Oregon, fabricated anchors for autonomous nodes and frames for star clusters that were deployed in the spillway forebay.

Acronyms and Abbreviations

°C	degree(s) Celsius or Centigrade
2D	two-dimensional
3D	three dimensional (or dimensions)
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
AMT	acoustic micro-transmitter
ANOVA	analysis of variance
AT	acoustic telemetry
ATLAS	Active Tag-Life Adjusted Survival
ATS	Advanced Telemetry Systems, Inc.
BiOp	Biological Opinion
BKD	bacterial kidney disease
BON	Bonneville Dam
BPSK	binary phase-shift keying
BRZ	boat restriction zone
cDNA	complementary DNA
CENWP	Corps of Engineers Northwest Portland District
CF	Compact Flash (card)
cfs	cubic feet per second
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
CI	confidence interval (1/2 95%)
cm	centimeter(s)
CSV	comma-separated variables

d	day(s)
DART	Data Access in Real Time
dB	decibel(s)
DSP+FPGA	digital signal-processing cards with field-programmable logic gate array
FCRPS	Federal Columbia River Power System
FL	fork length
FPE	fish passage efficiency
FGE	fish guidance efficiency (in-turbine screens)
ft	foot/ft
μg	microgram
g	acceleration (m/s^2)
g	gram(s)
GB	gigabyte
GPS	global positioning system
h	hour(s)
HA	hydroacoustic
IgM	immunoglobulin M
IL1-β	Interleukin-1 beta
in.	inch(es)
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
kg	kilogram(s)
kg/m^3	kilograms per cubic meter
km	kilometer(s)
L	liter(s)
LCR	Lower Columbia River
LRT	likelihood ratio test

m	meter(s)
min	minute(s)
mL	milliliter(s)
mm	millimeter(s)
mRNA	messenger ribonucleic acid
MS-222	tricaine methanesulfonate
MSL	mean sea level
NA	not applicable
NOAA	National Oceanic and Atmospheric Administration
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
PTAGIS	PIT Tag Information System
PRI	pulse repetition interval
PRT	pre-tagged
PSMFC	Pacific States Marine Fisheries Commission
PVC	polyvinyl chloride
qPCR	quantitative real time polymerase chain reaction
RAG-1	recombinase activating gene
rkm	river kilometer
ROR	run-of-river
RT	radio telemetry
µs	microsecond(s)
s	second(s)
SAS	Statistical Analysis System
SBC	sort-by-code (treatment group)
SByC	sort-by-code (system)
SD	standard deviation
SE	standard error
SEF	spill passage effectiveness
SFO	surface-flow outlet
SMF	Smolt Monitoring Facility
SMP	Smolt Monitoring Program
SPE	spill passage efficiency

STH	steelhead
STS	submersible traveling screen
SURPH	Survival Under Proportional Hazards
SW	spillway or spillway block
TDA	The Dalles Dam
TOAD	time of arrival difference
TSW	top-spill weir
TSWE	top-spill weir-passage efficiency
TSWEF	top-spill weir-passage effectiveness
USACE	U.S. Army Corps of Engineers
UW	University of Washington
wk	week(s)
WW	wet weight
χ^2	Chi Squared Test
yr	year(s)

Contents

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1.0 Introduction

In a continual effort to improve conditions for juvenile anadromous fish passing through Columbia River dams, the U.S. Army Corps of Engineers (USACE), Portland District (CENWP), has funded numerous evaluations of fish passage and survival through various structural configurations and operations at dams within the Federal Columbia River Power System (FCRPS). The goal is to improve passage conditions for various fish populations, some of which are listed as threatened or endangered under the Endangered Species Act of 1973.

This report describes research conducted using acoustic telemetry (AT) to evaluate juvenile salmonids passage and survival during 2010 at John Day Dam (JDA) (Figure 1.1). Researchers at the Pacific Northwest National Laboratory (PNNL) in collaboration with the Pacific States Marine Fisheries Commission (PSMFC), CENWP, and the University of Washington (UW), conducted this juvenile fish passage and survival study.

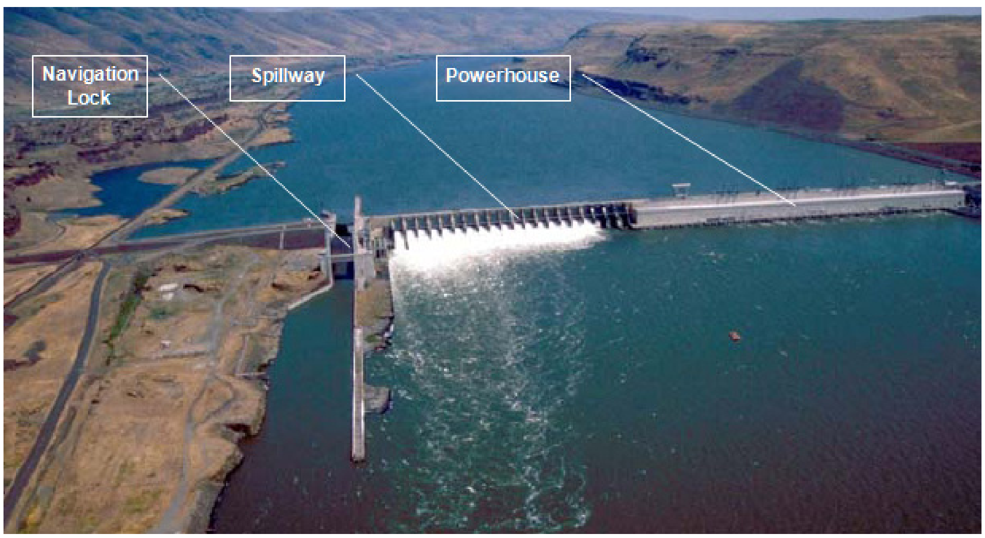

Figure 1.1. John Day Dam on the Columbia River.

The 2010 study was not an official compliance test as described by the 2008 FCRPS Biological Opinion (BiOp; NOAA Fisheries 2008) and the Columbia Basin Fish Accords (Fish Accords; 3 Treaty Tribes-Action Agencies 2008), because passage conditions for the dam had not been finalized. The primary goal of the current study was to estimate the survival of yearling (CH1) and subyearling (CH0) Chinook salmon and juvenile steelhead (STH) passing through the dam by various routes and through 40 km of tailwater using a single-release survival model. The effects of two spillway discharge treatments (30% and 40% spill) on survival rates and passage performance metrics and the performance of the JDA surface flow outlets (SFOs) on survival rates and passage performance measures were also evaluated. This study was conducted to provide the CENWP and regional fisheries managers with the information necessary to adaptively manage the configuration and operation of JDA to maximize the survival of juvenile salmonids that pass the dam. An assessment of the Juvenile Salmon Acoustic Telemetry System (JSATS) transmitter detection performance by powerhouse and spillway cabled arrays deployed for detecting and tracking fish was also conducted. This was done to ensure the arrays have sufficient detection efficiencies for an official 2011 BiOp compliance test.

1.1 Study Objectives

The overall purpose of the AT study at JDA during 2010 was to estimate juvenile salmonid survival rates and passage efficiencies under 30% and 40% spill-discharge treatments during spring and summer and evaluate the performance of top-spill weirs (TSWs) installed in spill bays 18 and 19, and evaluate the performance of a flow deflector installed at spill bay 20. During 2008 and 2009, the TSWs were installed at spill bays 15 and 16; this study examined passage metrics at the new locations closer to the powerhouse with the TSWs installed at spill bays 18 and 19. Randomized spill treatment blocks were developed for spring and summer, and each 4-d block was scheduled to begin with one 2-d treatment randomly selected to be 30% or 40% spill discharge followed by the alternate treatment. Releases of juvenile salmonids implanted (tagged) with JSATS acoustic micro-transmitters (AMTs) began on April 28, 2010, and the last fish were released on July 17, 2010. The study ended on August 5, 2010, when the batteries in 90% of the AMTs implanted in fish had failed, as estimated by the tag-life study conducted to evaluate battery life of the JSATS AMTs being implanted in fish.

The study objectives and sub-objectives outlined below were applied separately to CH1, STH, and CH0 surgically implanted with JSATS AMTs at JDA during 2010 for 30% and 40% spill treatments:

1. Estimate survival rates[1] based on a single-release survival model:
    a. JDA to TDA passage survival
    b. Survival by passage route from JDA to TDA
    c. JDA forebay survival.
2. Estimate passage efficiency metrics:
    a. Fish passage efficiency (FPE)
    b. Spill passage efficiency (SPE) (with and without the TSW)
    c. TSW passage efficiency (TSWE).
3. Estimate passage distributions:
    a. Horizontal
    b. Diel.
4. Estimate residence times:
    a. Forebay retention (forebay entry 100 m upstream of the dam to the time of dam passage)
    b. Tailrace egress (dam passage to arrival at the tailrace exit line)
    c. Project passage (forebay entry to tailrace exit).
5. Quantify the forebay approach paths of tagged fish and relate them to passage distribution:
    a. Compare forebay approach paths of turbine- vs. bypass- vs. spill- vs. TSW-passed fish.

[1] See Section 1.2 for definitions.

6. Subsample juvenile salmonids during tagging to assess population-level fitness:
   a. Characterize the fitness of in-river fish and those selected to be tagged.
   b. Compare the fitness of in-river fish and those selected to be tagged.

1.2 Definitions

For this report, we define virtual single-release survival, travel time, and passage efficiency metrics (Table 1.1). The survival metrics differ from those in the virtual paired-reference release design of Skalski (2009).

Table 1.1. Definitions of performance measures in this study.

Measure	Definition
Dam passage survival	Survival from the upstream face of the dam to the primary survival detection array located at TDA dam face 40 km downstream from JDA
Forebay to tailwater survival	Survival from a forebay array 2 km upstream of the dam to the primary survival-detection array located at TDA dam face 40 km downstream from JDA
Forebay residence time	Median and average times required for juvenile salmonids to travel from the time of first detection on the forebay entrance array 2 km upstream of the dam until the time of last detection on the dam-face array
100-m forebay residence time	Median and average times required for juvenile salmonids to travel the last 100 m of forebay until they pass through the dam
Tailrace egress time	Median and average time required for juvenile salmonids to pass through the tailrace after they pass through the dam, i.e., from time of last detection on the dam-face array until the time of last detection on the tailrace egress array 3 km downstream of JDA
Project passage time	Median and average time juvenile salmonids take to travel from first detection on the array 2 km upstream of the dam until the last detection on the tailrace exit array 3-km downstream of the dam
Spill passage efficiency	Proportion of fish passing through the dam via the spillway and TSW bays
Fish passage efficiency	Proportion of fish passing through the dam via the spillway, TSWs, and JBS

1.3 Study Area

John Day Dam, located at river kilometer (rkm) 349, is the third dam upstream from the mouth of the Columbia River. The dam comprises a powerhouse with 16 turbine units and 4 skeleton bays (bays where turbines were never installed) on the Oregon side of the river, and a 20-bay spillway on the Washington side (Figure 1.2). The skeleton bays are located between the powerhouse turbine intakes and the spillway. In 2010, TSW SFOs were installed closer to the powerhouse in spill bays 18 and 19 rather than in spill bays 15 and 16 as in previous years. This was done to optimize the diversion of fish away from the powerhouse thus minimizing turbine passage. The TSWs are weirs formed by a stop log assembly on top of the spillway crest that water flows over when the spill gates are raised (Figure 1.3). TSW discharge per bay is approximately 10,000 cfs. The TSWs create a flow field in the forebay that juvenile salmonids migrating downstream discover and follow to pass the dam in spill rather than sounding and passing through turbines. Spill, at adjacent bays, mixes with the TSW outfall discharge in the tailrace to aid in rapid movement of fish through the spillway tailrace. In addition, an avian line array was installed in the air above the JDA tailrace to reduce avian predation in the tailrace.

Figure 1.2. Aerial view of John Day Dam (Google Earth image).

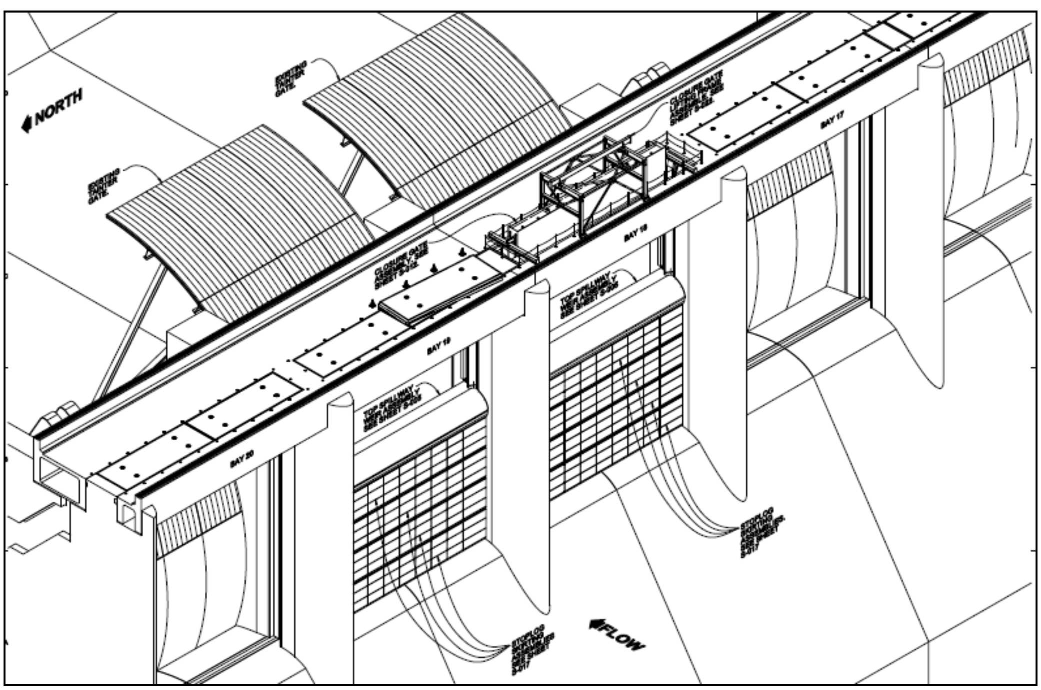

Figure 1.3. Schematic of top-spill-weirs at John Day Dam showing the location of the stoplog weirs upstream of the spill bay's tainter gates (provided by S Askelson, CENWP).

The study area for the AT evaluation of survival and passage at JDA during 2010 covered about 156 rkm of the lower Columbia River from the fish release point at Roosevelt, Washington (CR390; Columbia River (CR), rkm 390), to Bonneville Dam (tertiary array; CR234) (Figure 1.4). John Day Dam is located 41.4 rkm downstream of the fish release transect at Roosevelt, Washington. Throughout this report, we refer to locations on the river that are varying distances apart; so we created a quick reference table to provide the distances between river locations (Table 1.2).

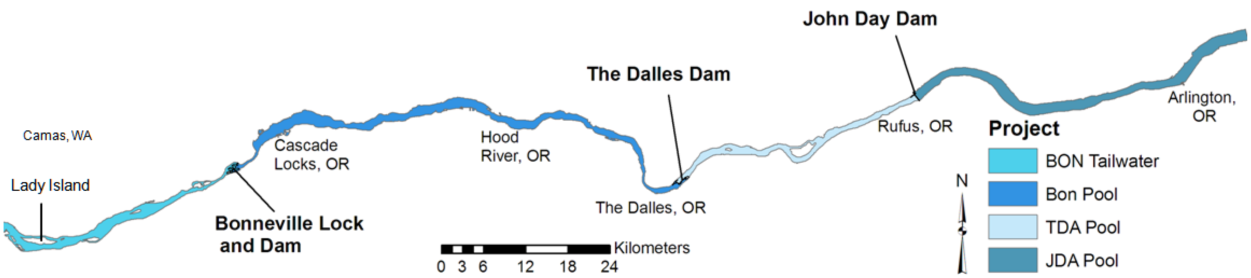

Figure 1.4. 2010 study area on the lower Columbia River from Roosevelt, Washington, to Bonneville Dam.

John Day Dam has a JBS that uses intake screens to divert fish out of turbine intakes and convey them through the dam to the tailrace. Fish are diverted by submerged traveling screens from the upper part of the powerhouse turbine intake flow into turbine gatewell slots. The diverted fish volitionally move from the gatewells through orifices in the gatewells into a bypass channel that runs the length of the powerhouse. The volume of flow through the bypass channel 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 1.2). At the SMF, diverted fish are sampled as part of the regional Smolt Monitoring Program. The SMF is where we obtained fish to tag for the 2010 JDA AT study.

Table 1.2. Distances (rkm) between locations referenced in this study.

Location	Study Function	Distance Upstream of Columbia River Mouth (km)	Roosevelt, WA	A1CR351	JDA	D1CR309	D2CR275	D3CR234
			390	351	349	309	275	234
Roosevelt, Washington	Spring Release	390	0	39	41	81	115	156
A1CR351	Forebay Virtual Release	351		0	2	42	76	117
JDA	Effects	349			0	40	74	115
D1CR309	TDA JDA Primary ($\hat{S}$)	309				0	34	75
D2CR275	Hood River JDA Secondary ($\hat{S}$)	275					0	41
D3CR234	BON JDA Tertiary (λ)	234						0

1.4 Report Contents

Additional project background is provided in Chapter 2.0. The ensuing chapters of this report then describe the methods used to estimate the survival and observe the behavior of juvenile salmonids passing JDA (Chapter 3.0), followed by a description of the environmental conditions during the study period (Chapter 4.0) and JSATS performance and survival model findings (Chapter 5.0). Results for survival, travel time, passage efficiency, and distributions for CH1, STH, and CH0 are found in Chapters 6.0, 7.0, and 8.0, respectively. Discussion of study results (Chapter 9.0), conclusions (Chapter 10.0), and references (Chapter 11.0) complete the main body of the report. In the appendices we provide the fish condition report (Appendix A); autonomous node and hydrophone deployment tables (Appendix B); assessment of survival model assumptions (Appendix C); capture histories (Appendix D); and tagging tables summarizing fish releases (Appendix E).

2.0 Background

Radio telemetry (RT) 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 JDA (Hansel et al. 2000). For CH1, STH, and CH0 previously studied at JDA using AT and RT, estimates of survival rates tended to be higher for fish passing at the spillway than at the powerhouse (Table 2.1). Differences in survival rates between the powerhouse and spillway were greater for CH1 and CH0 than for STH for RT studies. However, AT studies performed in 2008 and 2009 displayed greater differences in survival rates for STH and CH0 than for CH1 when comparing spillway and powerhouse passage. These data indicate that some of the BiOp performance standards would not be met under previous dam operating conditions.

Table 2.1. Estimates of survival rates for three salmonid stocks passing routes at John Day Dam using radio telemetry during 2000, 2002, and 2003, and acoustic telemetry during 2008 and 2009. The ranges are for point estimates under different treatments. Point estimates ±½ 95% confidence intervals were provided for 2008 and 2009.

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 (Dam)	95.7 ± 1.3%	98.6 ± 1.7%	86.1 ± 1.7%	Weiland et al. (2009)
2008 (Non-TSW Spill Bays)	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%	100.2 ± 1.9%	97.3 ± 5.7%	Ibid
2009 (Dam)	92.7 ± 1.0%	95.3% ± 0.8%	83.9 ± 1.4%	Weiland et al. (2011)
2009 (Non-TSW Spill Bays)	91.3 ± 1.4%	93.6 ± 1.6%	84.7 ± 1.6%	Ibid
2009 (TSW Spill Bays)	95.1 ± 1.4%	96.3 ± 1.0%	---	Ibid
2009 (Turbine)	85.1 ± 4.7%	82.4% ± 8.0%	74.9 ± 3.9%	Ibid
2009 (JBS)	97.5 ± 1.6%	96.6 ± 1.4%	90.8 ± 3.1%	Ibid

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

At least seven previous studies have estimated FPE and SPE at JDA (Table 2.2). Radio telemetry studies indicated that FPE ranged from 82% to 92% for CH1, 88% to 94% for STH, and from 70% to 75% for CH0. More recent AT studies estimated passage efficiency ranging from 91% to 94% for CH1, 97% to 98% for STH, and 81% to 86% for CH0. A hydroacoustic study in 2002 estimated a similar range of FPE for spring stocks; however, the estimated range for CH0 (88% to 92%) was higher than RT and AT estimates. Estimates of SPE for the three fish stocks were highly variable among years. Most recently, AT telemetry studies estimated SPE from 74% to 82% for CH1, 72% to 78% for STH, and 66% to 75% for CH0.

Table 2.2. Radio telemetry (RT), acoustic telemetry (AT), and hydroacoustic (HA) estimates of fish passage efficiency and spill passage efficiency for John Day Dam. See Section 1.2 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)[a]	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%	82 to 84%	Weiland et al. (2009)
2009 (AT)	93 to 94%	97 to 98%	83 to 85%	Weiland et al. (2011)
Spill Passage Efficiency				
1999 RT	53 to 66%	45 to 53%	---	Hansel et al. (2000)
2000 RT	75 to 86%	61 to 83%	---	Beeman et al. (2003)
2002 RT	48 to 57%	54 to 64%	42 to 58%	Beeman et al. (2006)
2002 HA[a]	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)
2009 AT	76 to 85%	72 to 81%	70 to 76%	Weiland et al. (2011)

(a) Hydroacoustic study – does not allow species differentiation.

Surface flow outlets are one of the structural modifications being evaluated to protect juvenile salmonids in the FCRPS. Sweeney et al. (2007) provide a compendium on SFO development in the Pacific Northwest. Engineering and model studies examining skeleton bays as potential SFO sites were conducted in the 1990s (Montgomery Watson et al. 2000).

Although the Portland and Walla Walla District Corps of Engineers SFO program for juvenile salmonids commenced in 1994 (USACE 1995), SFO development is in its early stages at JDA. To support SFO development at JDA, baseline biological data on fish distribution were summarized by Giorgi and Stevenson (1995) and Anglea et al. (2001). Generally, spring migrants approach the dam along the Washington side of the forebay, and CH0 approach using migration pathways near both shorelines in the summer. In addition, tagged fish have been observed traversing the forebay laterally before passing through the dam (Anglea et al. 2001).

Studies conducted in a physical hydraulic model of JDA at the USACE Engineering, Research, and Development Center showed that a 20,000-cfs SFO in a skeleton bay created strong forebay flow nets, suggesting a potential for fish to discover the SFO flow. However, this effort was discontinued, because of concerns about cost and potential issues with tailrace egress caused by a large eddy seen in the model that formed in the spillway stilling basin adjacent to the SFO outfall plume.

Field work on prototype spillway SFOs was conducted at JDA in 1997 when "over/under" weirs were placed at spill bays 18 and 19. BioSonics, Inc. (1999) found that spring passage through the bays was higher when the weirs were removed than when weirs were in place. Conversely, 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.

The CENWP identified SFO development as a priority in the JDA 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 the winter of 2007/2008, the CENWP installed prototype TSWs at spill bays 15 and 16. A bulkhead on top of the weir provided hydraulic control, thereby creating a critical entrance flow condition. The weir, discharging approximately 10,000 cfs per bay, was designed to minimize the angle of SFO jet impact on the spill bay ogee. The intent was to increase the FPE and passage survival rates of downstream-migrating juvenile salmonids at JDA.

Acoustic telemetry studies conducted in 2008 and 2009 (Weiland et al. 2009, 2011) showed survival rates of CH1 (>95%), STH (>96%), and CH0 (>92%) were high through the TSWs, second only to rates for juvenile salmonids passing through the juvenile bypass system (JBS) during both years. About half of the total number of tagged STH and nearly a quarter of the total number of tagged CH1 passed through the TSW bays during 2008 and 2009. In 2008, a fifth of the tagged CH0 passed at the TSW bays; the TSWs were not operated during the summer of 2009 because of increased bird predation due to altered hydraulic conditions. As was the intent of the design, TSW surface flows appeared to attract, or at least provide a surface outlet opportunity, for fish that had originally arrived at the dam in the powerhouse forebay. In particular, of the three stocks studied, STH that approached the powerhouse displayed the greatest tendency to pass at the TSW bays. Passage at the TSW bays was higher during the day than it was at night, particularly for STH.

Weiland et al. (2009, 2011) showed no significant difference in survival rates between the 30% and 40% spill treatments at JDA for both STH and CH0 in 2008 and 2009, and for CH1 in 2008. However, in 2009, CH1 survival rates were significantly higher during the 30% spill treatment compared to the 40% spill treatment. Only a small percentage of tagged CH1 (≤8%), STH (≤3%), and CH0 (≤17%) passed through turbines during the 2008 and 2009 studies (Weiland et al. 2009, 2011). Of the tagged fish that arrived at the dam in the powerhouse and skeleton bays' forebay, over half passed at the spillway or through the TSWs. This behavior was also observed when the TSWs were closed in the summer of 2009, when 58% of CH0 that approached the powerhouse ended up passing at the spillway. In contrast, few juvenile salmonids (<5%) approaching the spillway passed at the powerhouse, and fish approaching and passing at the spillway generally had the shortest median residence times. The longest residence time was for fish approaching the powerhouse and then passing at the spillway or vice versa.

3.0 Methods

Study methods include environmental conditions; tagged fish release-recapture experimental design; tag-life evaluation; fish collection, tagging, and release procedures; tagged fish detection; environmental conditions; acoustic signal processing; and the statistical approach to data analysis. The primary research tool was the JSATS (McMichael et al. 2010).

3.1 Environmental Conditions

Environmental conditions assessed include river water temperature, river discharge, and forebay and tailwater water surface elevations.

3.1.1 Water Discharge and Temperature

Project discharge data for each spill bay and turbine unit, in addition to forebay and tailwater elevations, were acquired in 5-min increments by automated data-acquisition systems maintained by the CENWP at JDA and provided weekly by the CENWP. Average discharge and forebay water temperature data from 2000 through 2009 were downloaded from the UW DART (Data Access in Real Time) website (http://www.cbr.washington.edu/dart). The 5-min discharge data for the entire dam and spillway were averaged by day and plotted together with daily averages for the previous 10-yr period to provide a historical context for 2010 observations.

3.1.2 Spill Treatments

The effects of 30% and 40% spill treatments on fish passage and survival rates during spring and summer study periods were evaluated using a randomized block experimental design (Figure 3.1 and Figure 3.2, respectively). The design called for 4-d blocks, each block consisting of a 2-d treatment randomly chosen to be 30% or 40% spill, followed by 2 d of the alternate treatment. Treatment changes were made at 0600 h. The first treatment spill discharge for both the spring and summer season was in place prior to the first study block; a small number of fish arrived before the first treatment began but passed under the same spill condition that was assigned to the first treatment. Similarly, the last treatment each season continued for more than 2 d and late-arriving fish experienced the same spill condition as the last 2-d treatment. Fish passage performance metrics estimated included FPE, SPE, TSWE, FGE, JBSE, and estimates of dam passage survival. Survival estimates were based on a single-release dam passage survival model from the JDA dam face to the TDA dam-face array. Differences in survival estimates and passage metrics (e.g., JDA dam face to TDA survival for 30% and 40% spill conditions) were assessed by comparing ½ 95% confidence intervals (CIs). A Shapiro-Wilk normality test was performed to determine if the data were normally distributed and subsequent one-tailed, paired t-tests ($\alpha = 0.05$) were used to compare survival and passage metrics where noted.

The spring data collection period was designed to be from April 28 to June 12, 2010, but 30% and 40% spill treatments were only realized between April 28 and June 3, 2010. The summer data collection period was designed to be from June 13 to August 5, 2010, and the realized 30% and 40% spill treatments occurred from June 13 to July 19, 2010.

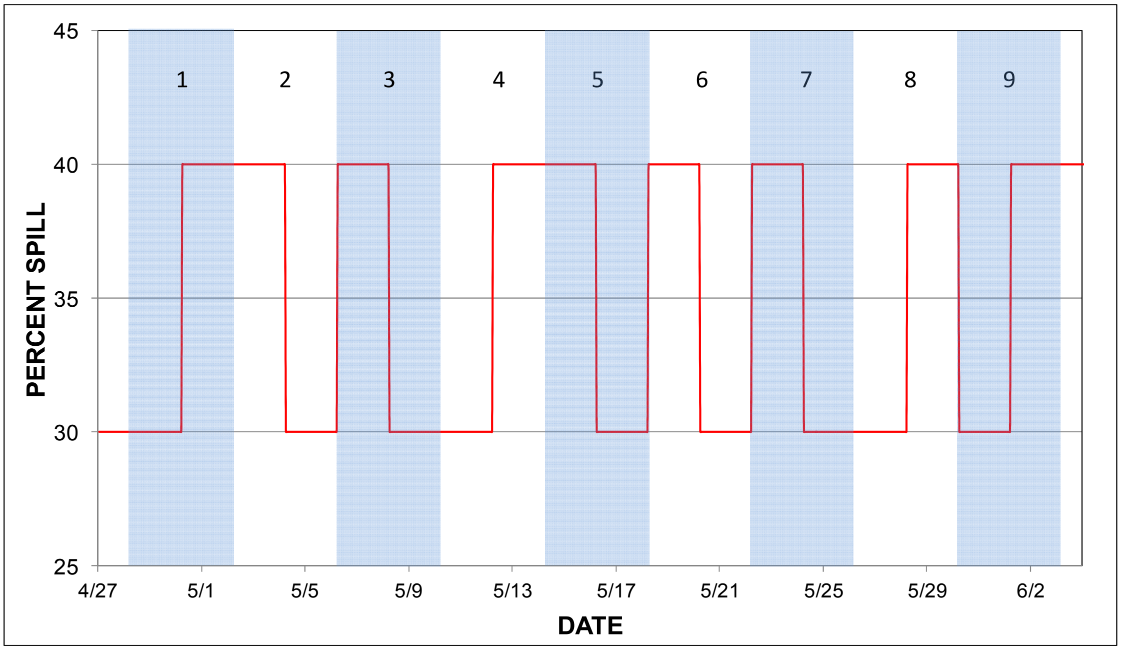

Figure 3.1. Spill treatment schedule for the spring season (April 28–June 3, 2010) at John Day Dam. The design calls for nine treatment blocks (numbered) with two treatments (30 or 40 percent spill) per block.

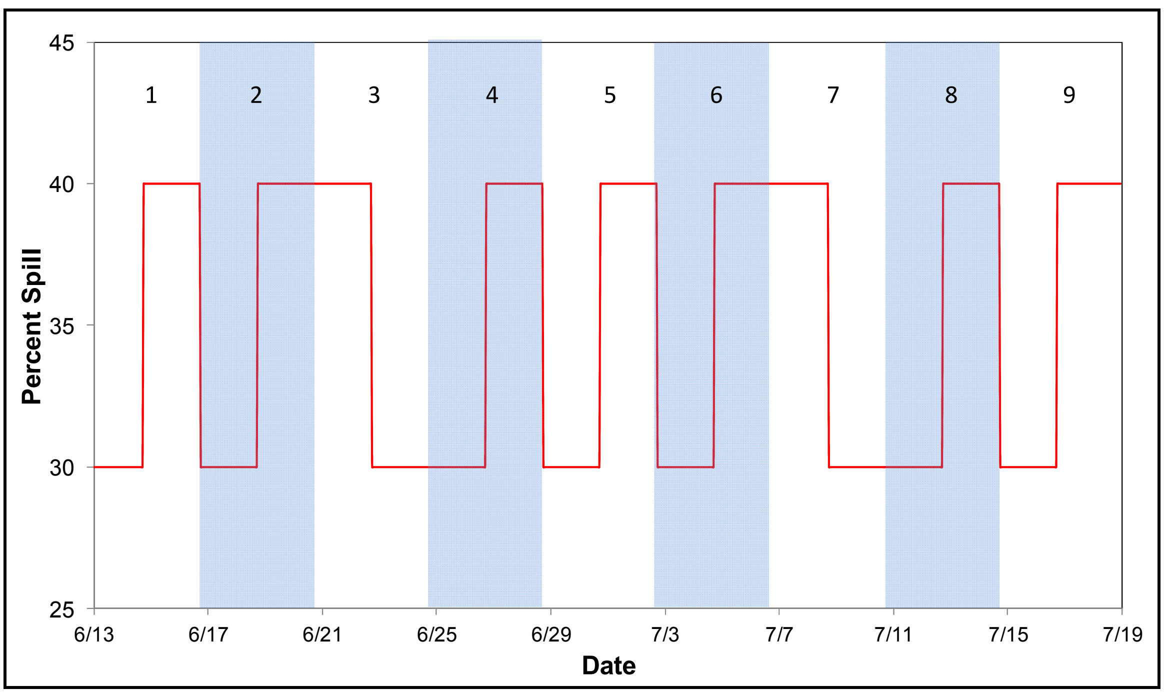

Figure 3.2. Spill treatment schedule for the summer season (June 13–July 19, 2010) at John Day Dam. The design calls for nine treatment blocks (numbered) with two treatments (30 or 40 percent spill) per block.

3.2 Release-Recapture Design and Sample Sizes

The release-recapture experimental design used to estimate dam passage survival at JDA was based on a single-release model (Figure 3.3). Releases of tagged fish near Roosevelt, Washington (CR390) were combined to form virtual-release groups of fish known to have arrived alive at the forebay entrance array (V_1; CR351) or at the face of JDA (V_2; CR349). By releasing the fish far enough upstream, they should acclimate to the river environment and arrive at the dam in a spatial pattern typical of run-of-river (ROR) fish. These virtual-release groups were then used to estimate survival of fish passing through the forebay, dam, and 40 km of river downstream of the dam or just the dam and 40 km of tailwater. We were unable to distinguish between mortalities of tagged fish that occurred in the tailrace immediately downstream of the dam and the tailwater down to TDA because there were no paired releases of fish below JDA. The release sample sizes of the fish tagged with AMTs used for the dam passage survival estimates are given in Table 3.1.

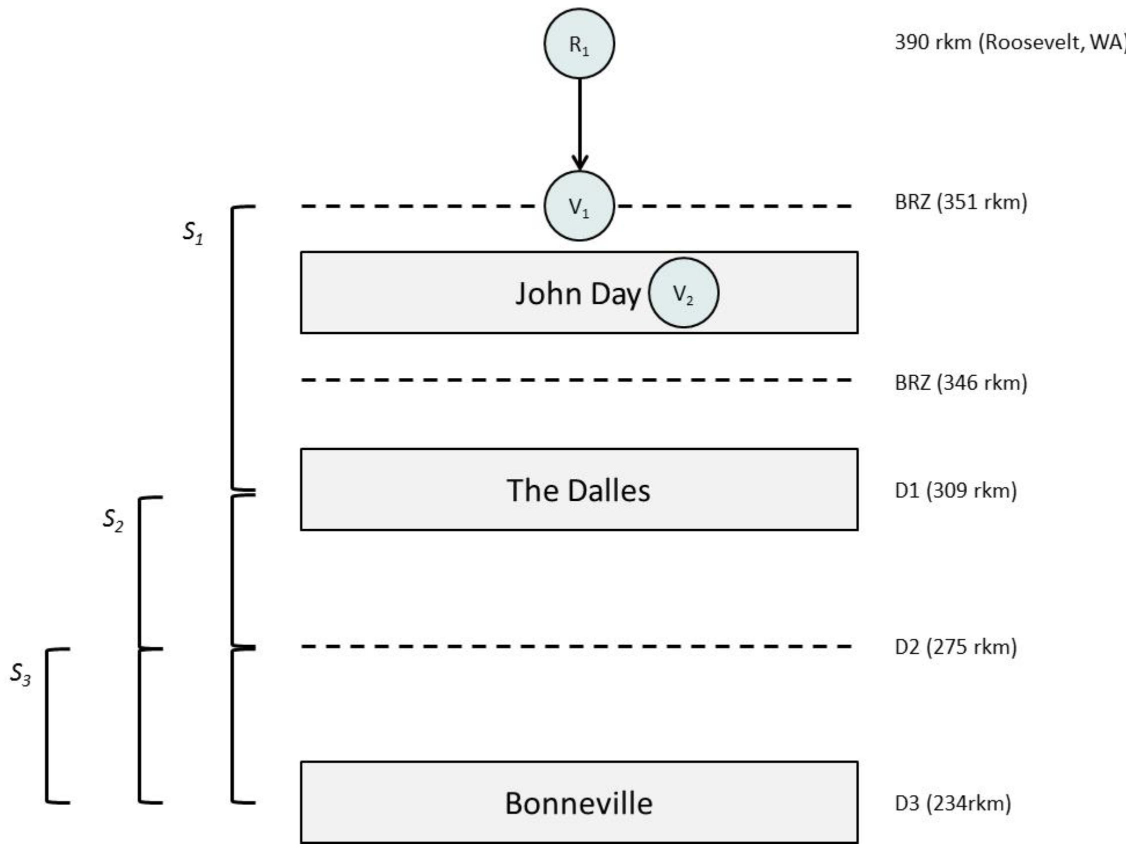

Figure 3.3. Schematic of the single-release design for estimating survival at John Day Dam. The diagram shows the release (R_1) site of fish that were regrouped to form virtual releases at the forebay entrance array (V_1) or dam-face array (V_2) and subsequently detected or not detected on three downstream arrays (D_1, D_2, D_3) to estimate single-release survival rates down to the primary array (D_1).

Table 3.1. Sample sizes of juvenile salmonids tagged with acoustic micro-transmitters released for the 2010 survival study at John Day Dam.

Species	Total Released	Virtual Release	
		30% Spill	40% Spill
Yearling Chinook salmon	2,287	1,060	1,104
Juvenile steelhead	2,288	973	1,164
Subyearling Chinook salmon	2,849	1,291	1,344

3.3 Handling, Tagging, and Release Procedures

Fish obtained from the JDA SMF were surgically implanted with JSATS AMTs and passive integrated transponders (PITs), and then transported and released above JDA, as described in the following sections. The SMF is situated on the south side of JDA at the downriver edge of the JBS where bypassed juvenile salmonids and other fishes are routed through a series of flumes and dewatering structures. Juvenile salmonids can be diverted into the SMF for routine juvenile salmonid monitoring (Martinson et al. 2006) or returned to the river through an outfall pipe located in the JDA tailrace downstream of the SMF. Juvenile salmonids processed at the SMF were returned to the river through the tailrace outfall pipe after examination unless they were selected for tagging as part of this survival study.

3.3.1 Acoustic Micro-Transmitters and Passive Integrated Transponders

The AMTs used in the 2010 study were manufactured by Advanced Telemetry Systems® (ATS) (Figure 3.4). Each AMT, model number SS130, measured 12.02 mm long, 5.21 mm wide, 3.72 mm thick, and weighed 0.438 g in air (0.290 g in water). The AMTs had a nominal transmission rate of 1 pulse every 3 s. Nominal tag life of the AMT was expected to be approximately 25 d. Each AMT was acoustically activated by Cascade Aquatics, Inc., using a Pinger Dish II designed by ATS to activate and deactivate AMTs. Each pulse from an activated JSATS AMT contains a complex phase-encoded signal that uniquely identifies the transmitting AMT. The PIT used in the study was the Biomark HPT12 with a length of 12.5 mm.

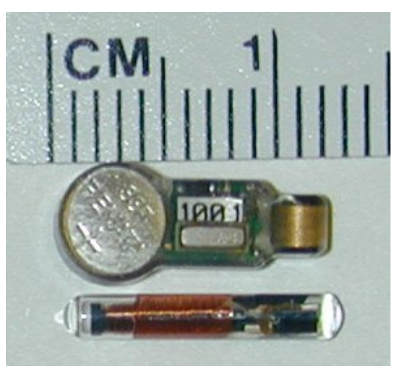

Figure 3.4. JSATS Model SS130 acoustic micro-transmitter (top) and Biomark HPT12 passive integrated transponder (bottom) that were surgically implanted in CH1, CH0 and STH at John Day Dam in 2010.

3.3.2 Fish Source

The collection site, record-keeping required to meet fish use permit requirements for fish collection and handling, sampling methods, JSATS AMT and PIT implantation, fish recovery and holding, and subsequent transportation and release are described in the following sections.

3.3.2.1 Federal and State Permitting

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 19-10-PNNL40). The Oregon Department of Fish and Wildlife authorized take for this study under permit number 15340. The federal and Oregon permits were both authorized under the 2004 FCRPS BiOp (NOAA 2004). All requirements and guidelines of both permits were met and reports of collection and release were reported to both agencies. Records were kept of all juvenile salmonids handled and collected (both target and non-target species) for permit accounting purposes. Collection of fish for tagging was 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 the separate federal and state permits issued for this study.

3.3.2.2 Collection and Sampling Procedures

Juvenile salmonids were diverted from the JBS and routed into a 6,795 L holding tank in the SMF. On average 150 to 200 juvenile salmonids 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) then fish were anesthetized with 60 mL of a stock tricaine methanesulfonate (MS-222) solution with a concentration of 50 g/L. Once anesthetized, fish were routed into an examination trough for identification and enumeration. Technicians added MS-222 as needed to maintain sedation and 5 to 10 mL of PolyAqua™ to limit handling damage and reduce fish stress. Water temperatures were monitored in the main holding tank and examination trough, and water in the trough was refreshed with main holding tank water to maintain water temperature within 2°C of that in the main tank.

Once in the examination trough, juvenile salmon were evaluated for use in the tagging study using the following acceptance and rejection criteria:

- Qualifying (acceptance) criteria
  - size ≥95 mm
  - visible elastomer tag(s) present or absent
  - adipose-fin clipped or unclipped
  - presence of trematodes, copepods, leeches
  - short operculum
  - healed (moderate) injuries (e.g., bird strikes)
  - ≤3% body coverage fungal patch

- minor fin blood
- partial descaling (<20%)
- STH with eroded pectoral or ventral fins (likely hatchery STH)

- Disqualifying (rejection) conditions
  - ≥20% descaling
  - body punctures with 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
  - emaciated
  - holdovers (fish not CH1, STH, or CH0)
  - PIT-, RT- or AT-tagged or other post-surgery fishes
  - notable operculum damage (except short operculum)
  - presence of columnaris or furuncles
  - injured caudal peduncles
  - injured caudal fins
  - fin hemorrhage.

Fish meeting acceptance criteria were counted and transferred to six 303-L pre-surgery holding tanks, where they were held for 18 to 30 h before surgery. The pre-surgery holding duration depended on the time of collection and the time of tagging on the next day. Fish excluded and rejected from the tagging study for various reasons were released to the river through the SMF bypass system after a 30-min recovery period.

3.3.3 Tagging Procedures

The tagging team followed the most recent guidelines for surgical implantation of AMTs and PITs in juvenile salmonids (Axel et al. 2011). Numerous steps were taken to minimize the handling impacts of the collection and surgical procedures. Because many juvenile salmonids used for tagging were part of the routine collection for SMF monitoring, fewer additional fish needed to be collected to meet tagging requirements.

Prior to surgery, the fish to be tagged were anesthetized in an 18.9-L "knockdown" bucket with fresh river water and MS-222 (tricaine methanesulfonate; 80 mg/L). Anesthesia buckets were refreshed repeatedly with new water to maintain the temperature in the buckets within ±2°C of river water temperature. Once an anesthetized fish lost equilibrium, it was transferred to a processing table in a small container of river water and anesthetic. Species and run type, whether the adipose fin was intact or clipped, and fork length (±1 mm) 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 and an activated AMT. Length, weight, species and run type, tag codes, surgeon, and fin clip were all added automatically into the tagging database by the 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 photo table. Photographs were taken of both sides of the fish while they were in the transfer container and then they were given to the assigned surgeon for tag implantation.

During surgery, each fish was placed ventral side up and a gravity-fed supply line delivering "maintenance" anesthesia and fresh river water was placed into the fish's mouth (Figure 3.5). The concentration of the "maintenance" anesthesia used during surgery was 40 mg/L. Using a #15 surgical blade or a Micro-Sharp stab scalpel with a 5-mm blade (dependent on the surgeon's preference), a 6- to 8-mm incision was made ventrally in the body cavity, 3 mm from and parallel to the mid-ventral line and equidistant from the pelvic girdle and pectoral fin. A PIT was inserted followed by an AMT. Both tags were inserted toward the anterior end of the fish. Two interrupted sutures of 5-0 monofilament were used to close the incision using an RB-1 needle. After the surgical incision was closed, the fish were placed in 18.9-L aerated recovery buckets and closely monitored until equilibrium was reestablished. Each bucket held one to five fish depending on fish size and the number of tagged fish to be released at each site. Buckets were carried to a large holding tank (Figure 3.6) supplied with a continuous flow of river water. Fish were held in these tanks for 18 to 24 h before being transported for release into the river.

Figure 3.5. Surgical implantation of tags at JDA SMF.

All surgical instruments were sterilized daily in an autoclave and each surgeon rotated four sets of instruments for tagging each day. When a set was not being used, it was placed in a 70% ethanol solution for approximately 10 min. The instruments were then transferred to a distilled water bath for 10 min, 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 and recovery buckets were kept within 2°C of river water temperature.

Figure 3.6. Post-surgery holding tank with recovery buckets.

Tested and validated protocols were used during the tagging process to minimize the impact of handling on tagged fish. The number of personnel available to move the fish through the tagging process was managed to ensure that all tagged fish were handled efficiently with as little disturbance to the fish as possible. A team of eight to nine people conducted the tagging process. One individual was responsible for anesthetizing fish and delivering them to be weighed and measured; two were responsible for weighing, measuring, and recording data; one was responsible for taking lateral photographs with a high-resolution digital camera; three performed surgeries to implant tags in the fish; and one or two were responsible for moving tagged fish into the post-surgery holding tanks.

3.3.4 Fish Transportation and Release

Tagged fish were transported from JDA by truck to the release location at Roosevelt, Washington, 41 rkm upstream of JDA, near rkm 390. A ¾-ton truck was outfitted with one 681-L Bonar insulated tote and one 265-L Bonar insulated tote to transport tagged fish. The 681-L tote could hold ten 18.9-L fish buckets, and the 265-L tote could hold four 18.9-L fish buckets. The totes had snug-fitting lids and extra space inside so that ice could be added to keep the water in the tote cool on hot days. 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. During transport, a network of valves and plastic tubing delivered oxygen to the totes from a 2,200-psi oxygen tank. A YSI meter was used to monitor the dissolved oxygen and temperature of the water in the totes before and during transportation to ensure they were within acceptable limits. If the water temperature in the totes exceeded the threshold, ice was added to cool the water.

Upon arrival at the release site, the buckets containing tagged fish were transferred to a boat for transport to the in-river release locations. There were five release locations equidistant across the river and equal numbers of fish were released at each location. During both spring and summer, releases occurred for 35 consecutive days (from April 28 to June 1, 2010 and from June 13 to July 17, 2010, respectively). Releases alternated daily between day and night over the course of the study. The timing of the releases was staggered to help facilitate downstream mixing (Table 3.2).

Just before fish were released into the river, the buckets were opened and checked for dead fish. Dead fish found were removed and scanned with a BioMark portable transceiver PIT scanner to identify the implanted PIT code. The associated AMT code was identified later from tagging data, which documented the paired codes of all PITs and AMTs implanted in fish. Dead fish were returned to the tagging facility and released once a week from the JDA spillway to determine if dead fish could be detected on downstream survival-detection arrays to verify the survival model assumptions were being met. Post-tagging, pre-release mortalities were low for each run of fish studied in 2010 (CH1 = 0.10%; STH = 0.10%; CH0 = 0.35%)

Table 3.2. Release time of fish tagged with JSATS acoustic micro-transmitters released at rkm 390 near Roosevelt, Washington.

	Release Time	
Release Location	Daytime Start	Nighttime Start
R_1 (rkm 390)	Day 1: 0900 h	Day 2: 2000 h

3.4 Tagged Fish Detection

Two types of JSATS receivers, cabled and autonomous, were deployed to detect fish bearing JSATS AMTs as they moved downstream through the study reach between Roosevelt, Washington at rkm 390 and Bonneville Dam (BON) at rkm 234 (Table 3.3). The JDA forebay array (rkm 351) was used to create virtual-release groups of fish, known to have survived since release into the river and to have entered the forebay 2 km upstream of JDA, to estimate dam passage survival and forebay residence time. The JDA dam-face array (CR349) was used to create virtual-release groups of fish known to have passed JDA and make observations of the location and time of the last detection of tagged fish prior to dam passage. The virtual-release groups were used to estimate JDA dam passage survival rates and route-specific passage survival rates based on three-dimensional (3D) tracking of tagged fish and observations of the location of the last detection of tagged fish prior to dam passage. The 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 last detection by the JDA tailwater egress array (rkm 346) minus the time of last detection on the dam-face array provided an estimate of egress time. The Dalles Dam dam-face array (rkm 309) was the primary array for estimating the survival rate for tagged juvenile salmonids passing through JDA. The Hood River, Oregon, array (rkm 275) was used as the secondary array for estimating the dam passage survival rate at JDA. The BON dam-face array (rkm 234) was used as the tertiary array for estimating the product of survival and detection rates (λ) for tagged juvenile salmonids passing through JDA.

Table 3.3. Description, location, name, and survival model function of arrays deployed in 2010.

Array Description	Location	rkm	Array Function
JDA forebay	2 km upstream JDA	351	Regroup fish for virtual releases
JDA dam face	JDA	349	Regroup fish for virtual releases
JDA tailwater egress	JDA tailrace	346	JDA egress
TDA dam face	TDA	309	JDA primary
Hood River	Hood River	275	JDA secondary
BON dam face	BON	234	JDA tertiary

3.4.1 Cabled Dam-Face Arrays

The cabled dam-face receivers were designed by PNNL for the CENWP using an off-the-shelf user-build system design. Each cabled receiver system includes a computer, data-acquisition software, digital signal-processing cards with field-programmable logic gate array (DSP+FPGA), global positioning system (GPS) card, four-channel signal-conditioning receiver with gain control, hydrophones, and cables (Figure 3.7). The software that controls data acquisition and signal processing is the property of the CENWP and is made available by the CENWP as needed.

A modular, time-synchronized JSATS cabled array was deployed along the upstream face of JDA to detect JSATS-tagged juvenile salmonids approaching the dam. The dam-face cabled array consisted of 23 cabled receivers each supporting up to four hydrophones. The receivers were housed in trailers on the forebay deck. The four possible hydrophones per cabled receiver were deployed on trolleys in pipes attached to the main piers at the powerhouse and spillway (Figure 3.8) in a known fixed geometry. Trolley pipes at the powerhouse were 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. 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 161 ft above MSL. One hydrophone on each pier was deployed at a shallow elevation (at 252 ft above MSL – approximate 13-ft depth) and another was deployed at a deep elevation (at 165 ft above MSL – approximate 100-ft depth) to provide acceptable geometries for tracking fish tagged with AMTs in three dimensions and assigning a route of passage through the dam (Figure 3.9).

At the spillway, hydrophones were mounted on trolleys that were deployed in 40-ft-long 8-in.-diameter slotted pipes installed previously for RT studies. At each spillway pier, one hydrophone was deployed at a shallow elevation (256 ft above MSL – approximate 9-ft depth) and the other at a deep elevation (229 ft above MSL – approximate 36-ft depth). 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 3.10).

The cabled dam-face array deployed at JDA allowed fish behavior and route of passage to be assessed via 3D tracking of JSATS-tagged fish. Assigning spatial locations using acoustic tracking is a common technique in bioacoustics based on time-of-arrival differences (TOADs) among different hydrophones. Usually, the process requires a three-hydrophone array for two-dimensional (2D) tracking and a four-hydrophone array for 3D tracking. The detailed 3D tracking system is described by Deng at al. (2011).

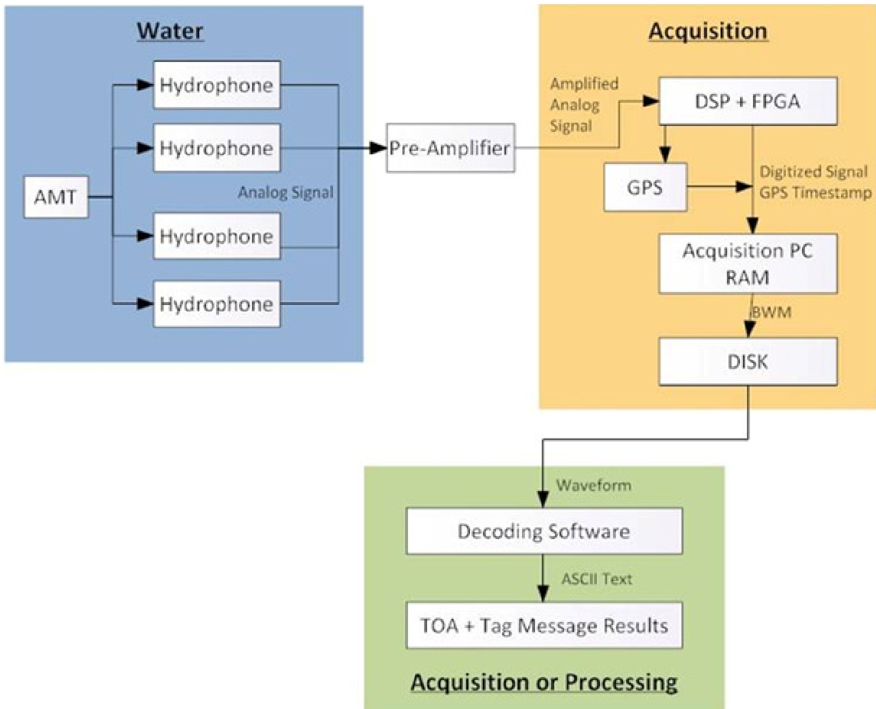

Figure 3.7. Schematic of dam-face modular receiver system showing the main components and direction of signal acquisition and processing. (AMT = acoustic micro-transmitter implanted in fish; DSP = digital signal processing card; FPGA = field programmable logic gate array; GPS = global positioning system; PC = personal computer; RAM = random access memory; BWM = binary waveform; TOA = time of arrival.)

Figure 3.8. Trolley pipe mounted on a main pier of the John Day Dam powerhouse showing the cone used as a guide for trolley insertion.

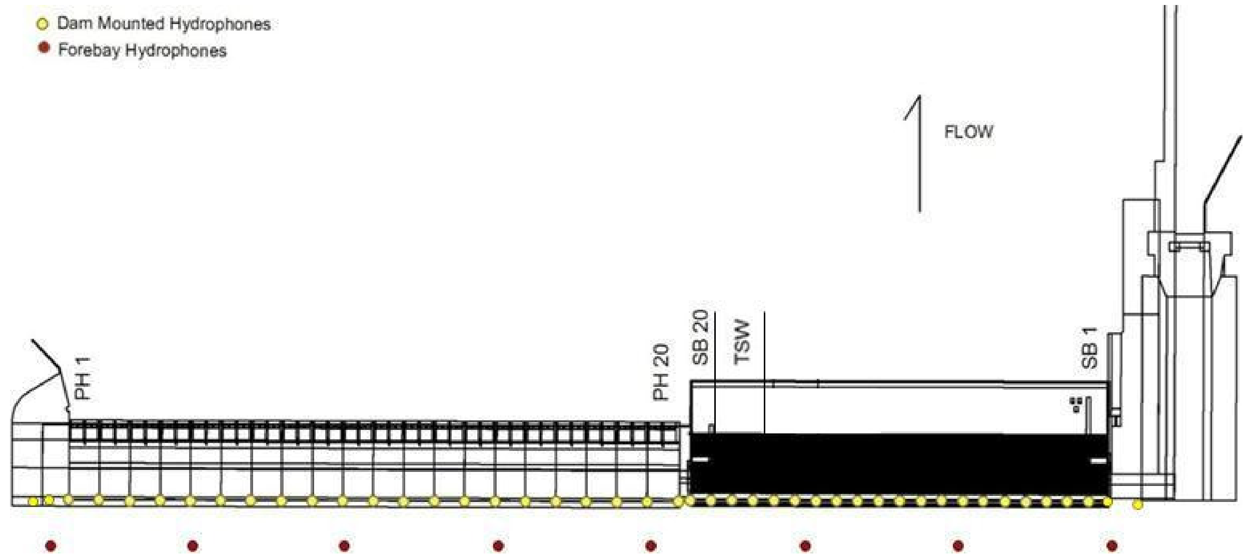

Figure 3.9. Location of hydrophones on the dam face and in the forebay of John Day Dam, 2010. The red dots show the relative location of forebay deployed cabled-array receivers located about 75 m upstream of the dam and the yellow dots show the relative location of dam-face hydrophones on JDA at rkm 349.

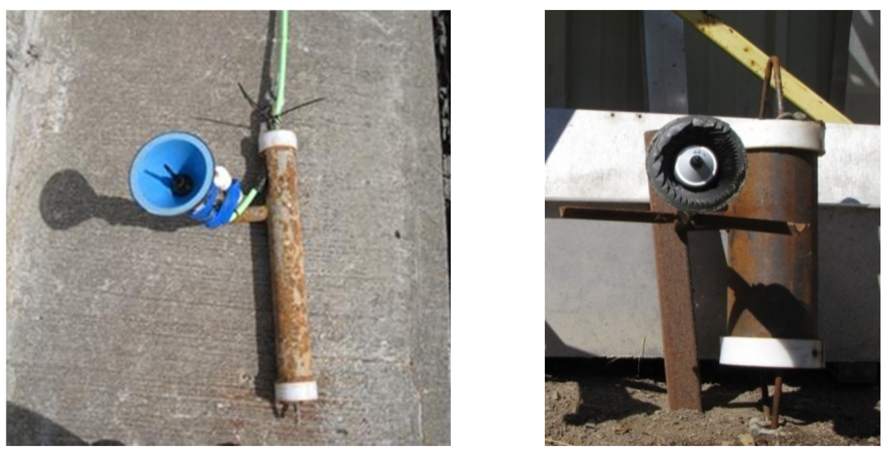

Figure 3.10. Trolleys used to deploy hydrophones at the JDA powerhouse and spillway, 2010. A 4-in.-diameter trolley with hydrophone (left) for slotted pipes on powerhouse piers and an 8-in.-diameter trolley with hydrophone (right) for slotted pipes on spillway piers. Each trolley had a steel arm to support a hydrophone that was surrounded by a plastic cone lined with anechoic material to prevent sound reception from a downstream direction.

3.4.2 Autonomous Receiver Arrays

The autonomous AT receiver, manufactured by Sonic Concepts, Bothell, Washington, (hereafter referred to as an autonomous node or simply node) used in this study consisted of two coupled parts. The top was made from 10.16-cm-diameter Schedule 40 polyvinyl chloride (PVC) pipe that was capped at the top and had a fitting with male threading at the bottom (Figure 3.11). The cap was modified for watertight seating of a hydrophone, and the body below the cap housed the analog and digital boards for processing detected tag signals. A lubricated rubber O-ring was fitted over the lower threaded end so that it would form a watertight seal when the node top was screwed to the bottom. The node bottom was made from approximately 1 m of 10.16-cm-diameter PVC pipe and the upper end had a fitting with female threads for coupling it to the node top. The lower end of the node bottom was capped and a stainless-steel harness was located just below the upper fitting so the node could be attached to an anchor system, which is described later. An acoustic beacon, transmitting an acoustic signal once every 15 s, was attached to the outside of the battery housing just below the threaded end. This beacon was used to determine the location of a node if it didn't surface after it was acoustically released from an anchor. Beacons also could be used to determine when an adjacent node disappeared.

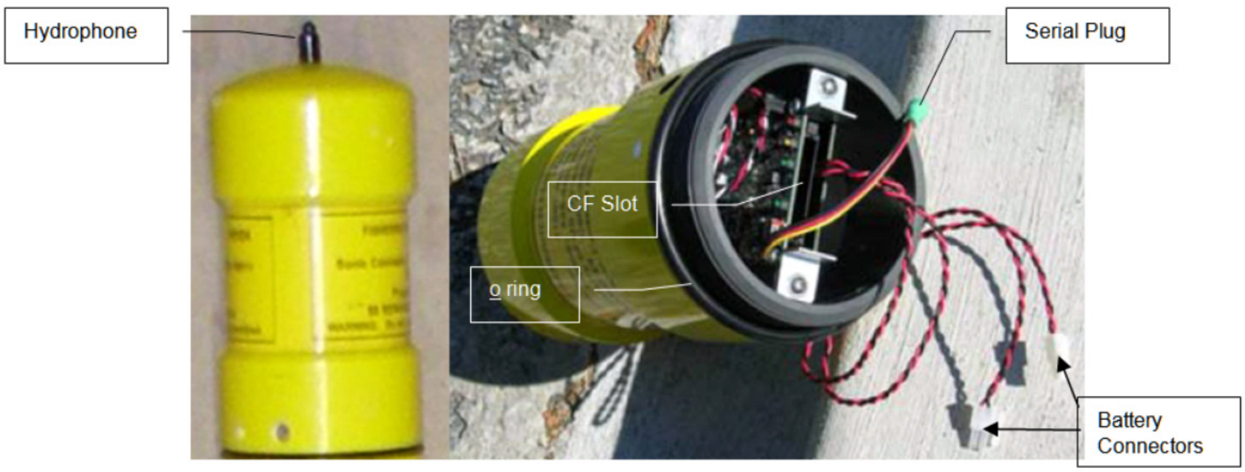

Figure 3.11.   Side (left) and bottom (right) views of the top of an autonomous node.

Before deployment, 28-d lithium-ion batteries were lowered into the node bottom and secured in place with a battery-retention device. Wires from the batteries were attached to connectors from the analog board in the node top. One end of a serial cable was connected to a plug from the board set in the node top and the other end was plugged into a laptop computer so that staff could communicate with the node, set its date and time, and verify detection of a beacon tag. Next, a 1-GB SanDisk Extreme III CompactFlash (CF) card was mounted in a slot on the board set, and the node top and bottom were screwed together until beveled edges of each piece compressed the O-ring to form a watertight seal. Prior to putting the node into the water, staff verified that a light-emitting diode on the node top housing was flashing, indicating that the node was functioning properly and data would be written to the CF card. In the water, air space within the sealed node provided positive buoyancy, while the batteries in the node bottom provided ballast to help keep the node upright.

The length of autonomous node rigging varied with water depth at deployment sites. A 1.5-m section of line with three 2.72-kg buoyancy floats was attached to a strap half way between the node tip and node bottom (Figure 3.12). An acoustic release (InterOcean Systems, Inc. Model 111 or Teledyne Benthos Model 875-T) was attached to the other end of the 1.5-m line. The length of the 0.48-cm-diameter wire rope anchor line deployed varied with water depth, from 0.3- to 2-m long. One end of the anchor line was connected to a 76.2-mm ring that fit into the mechanical latch end of the acoustic release and the other end was shackled to a 34-kg anchor. In water <5.5 m deep, the node, float line, and acoustic release were bound together with 1-m-long zip-ties and a short (0.3-m) anchor line was used to maintain a rigging length of less than 1.5 m.

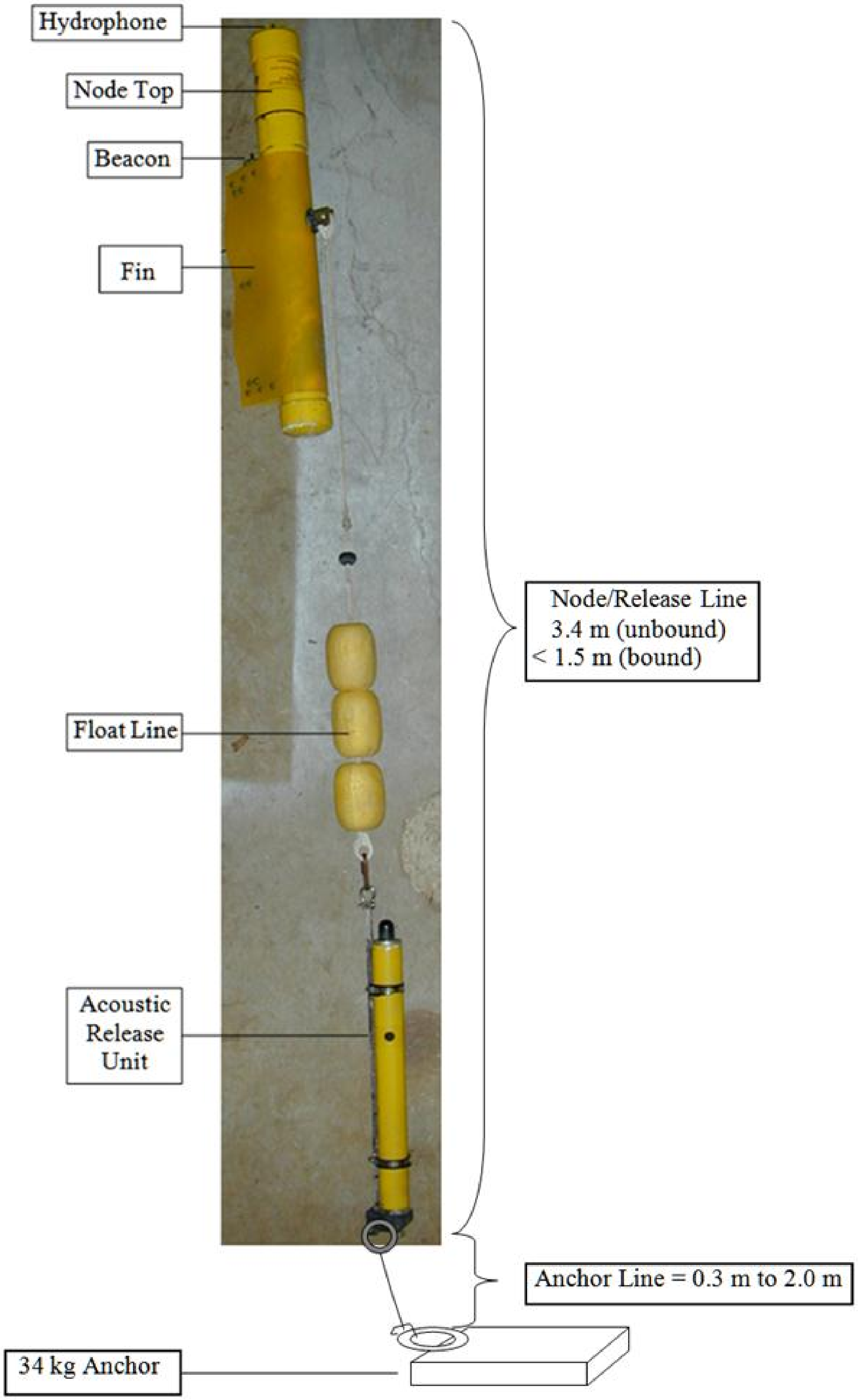

Figure 3.12. Autonomous node rigging.

Autonomous nodes were deployed in cross-sectional arrays in the river to detect tagged fish migrating downstream through the study area. Most autonomous node arrays were designed with individual autonomous receivers deployed with a spacing of no more than 122 m apart and within 76 m of the shoreline. Deployments of autonomous node arrays included two arrays for calculating project passage travel times in the JDA forebay and tailrace near rkm 351 (CR351) and rkm 346 (CR346), respectively; a cabled array at TDA near rkm 309 (CR309); an autonomous node array near Hood River, Oregon (rkm 275 [CR275]); and a cabled array used for survival detection and calculations at BON (rkm 234 [CR234]) (Figure 3.13).

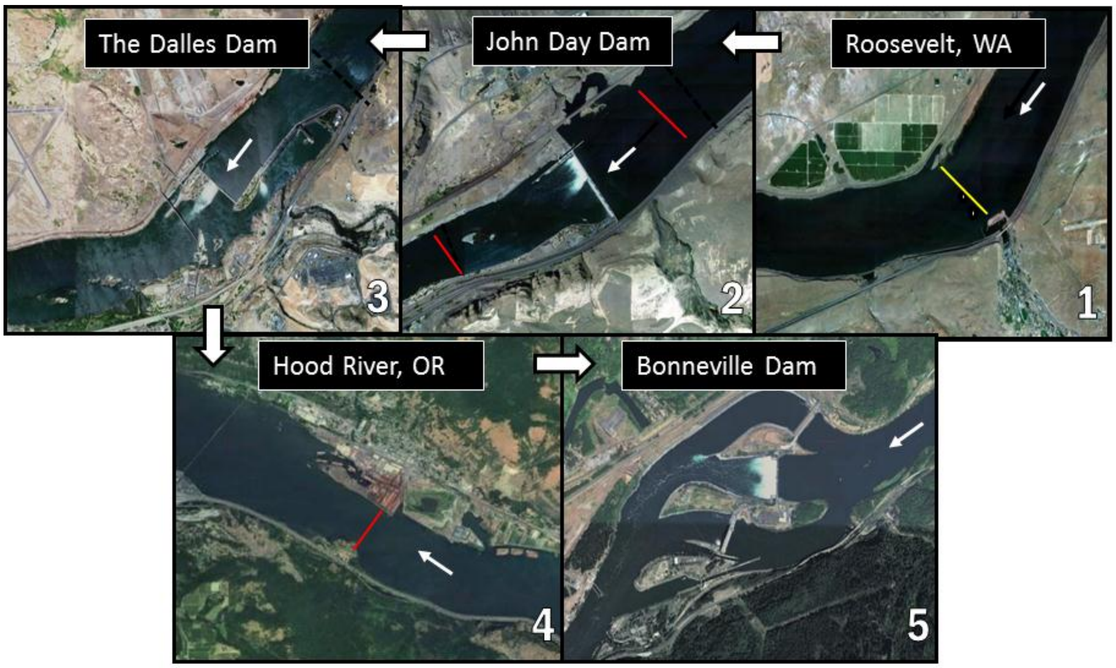

Figure 3.13. Location of the fish-release transect (yellow line) at Roosevelt, Washington, for the 2010 study and locations of autonomous node arrays (red lines) deployed to detect fish tagged with acoustic micro-transmitters migrating downstream. White arrows between Google Earth images indicate the order of images from upstream to downstream and the direction of water flow within each image. 1) Fish-release location, R_1, near Roosevelt, Washington, at CR390; 2) JDA forebay (right; CR351), dam (middle; CR349) and tailrace (left; CR346) arrays; 3) TDA dam-face array (CR309); 4) Hood River array (CR275); and 5) BON dam-face array (CR234).

3.4.3 Node Retrieval, Servicing, and Redeployment

Autonomous nodes were deployed and serviced from April 26 until August 5, 2010. They were retrieved every 2 wk to download data and batteries were replaced every 28 d before redeployment. The first step in servicing a node was to trigger its acoustic release from the anchor. Staff entered a release-specific code into a topside command transceiver that 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 node rigging from the anchor so that it would surface and could be retrieved by staff in the boat (Figure 3.14). The next step was to dry the node with a towel, remove the node top, eject the CF card, and download data from the card to a laptop computer. Each file was checked to verify that data were collected during the 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 in Seattle, Washington, for repair. The most common problem was damage to the hydrophone tip.

Figure 3.14. Autonomous node retrieval.

3.5 Acoustic Signal Processing

Acoustic signal processing included decoding binary waveform data files, filtering the decoded signals, and tracking fish movements using the decoded data.

3.5.1 Signal Decoding

Acoustic signals detected by the JSATS-cabled hydrophones were encoded and saved as candidate messages in binary time-domain waveform files (Figure 3.15). Binary waveform files were processed by a decoding utility (Waveform Utilities developed by the CENWP and PNNL) that identifies valid tag signals and computes the tag code and time of arrival using binary phase-shift keying (BPSK), 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.

JSATS tag-code transmissions received on cabled and autonomous hydrophones were recorded in raw data files and processed using standardized methods by two independent groups of PNNL staff located at North Bonneville and Richland, Washington.

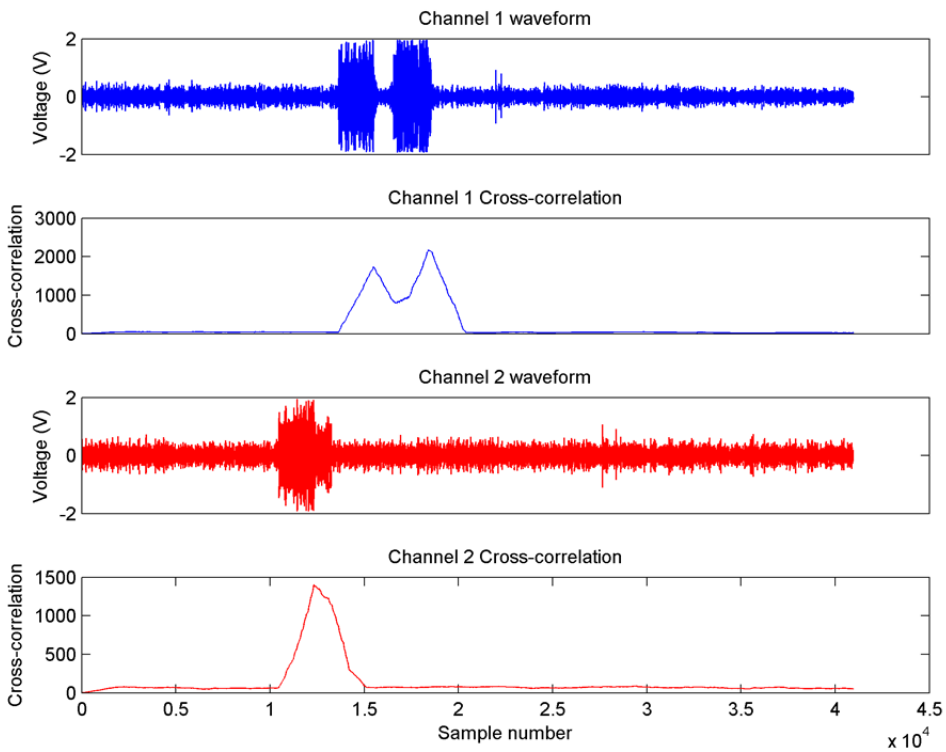

Figure 3.15. Example of time-domain waveforms and corresponding cross-correlations acquired at the John Day Dam spillway. The message portion was 1,860 samples (744 μs long). Note that multipath components were present in both channels. Decodes from the multipath components were filtered out in post-processing.

3.5.2 Filtering Decoded Data

Receptions of tag codes within raw data files were processed to produce a data set of accepted tag-detection events. For cabled arrays, detections from all hydrophones at the dam were combined for processing. The following three filters were used for cabled array data:

- Multipath filter: For data from each individual cabled hydrophone, all tag-code receptions that occur within 0.156 s after an initial identical tag code reception were deleted under the assumption that closely lagging signals are multipath. Initial code receptions were retained. The delay of 0.156 s was the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and was computed as 2(PRI_Window+12×PRI_Increment). Both PRI_Window and PRI_Increment were set at 0.006, which was chosen to be slightly larger than the potential rounding error in estimating PRI to two decimal places.
- Multi-detection filter: Receptions were retained only if the same tag code was received at another hydrophone in the same array within 0.3 s, because receptions on separate hydrophones within 0.3 s (about 450 m of range) were likely from a single tag transmission.
- PRI filter: Only those series of tag-code receptions (or "messages") consistent with the pattern of transmissions from a properly functioning JSATS AMT were retained. Filtering rules were evaluated for each tag code individually, with the assumption that only a single tag would be transmitting that

code at any given time. For the cabled system, the PRI filter operated on a message that included all receptions of the same transmission on multiple hydrophones within 0.3 s. Message time was defined as the earliest reception time across all hydrophones for that message. Detection required that at least six messages were received with an appropriate time interval between the leading edges of successive messages.

Like cabled-array data, receptions of JSATS tag codes within raw autonomous node data files are processed to produce a data set of accepted tag detection events. One single file is processed at a time, and no information about receptions at other nodes is used. The following two filters are used during processing of autonomous node data:

- Multipath filter: Same as for the cabled-array data.
- PRI filter: Only the series of receptions of a tag code (or "hits") that were consistent with the pattern of transmissions from a properly functioning JSATS AMT were retained. Each tag code was processed individually, and it was assumed that only a single tag would be transmitting that code at any given time.

The output of the filtering processes for both cabled and autonomous hydrophones was a data set of events that summarized accepted tag detections for all times and locations where hydrophones were operating. Each unique event record included a basic set of fields that provided the unique identification number of the fish, the first and last detection time for the event, the detection location, and the number of messages detected within the event. This list was combined with accepted tag detections from the autonomous arrays and PIT-tag detections for additional quality assurance/quality control analysis prior to survival analysis. Additional fields capture specialized information, where available. One such example was route of passage, which was assigned a value for those events that immediately preceded passage at a dam based on spatial tracking of tagged fish movements to a location of last detection. Multiple receptions of messages within an event can be used to triangulate successive tag positions relative to hydrophone locations.

An important quality control step was to examine the chronology of detections of every tagged fish on all arrays above and below the dam-face array to identify any detection sequences that deviated from the expected upstream to downstream progression through arrays in the river. Apparent upstream movements of tagged fish between arrays that were more than 5 km apart or separated by one or more dams were very rare (<0.015%) and probably represented false positive detections on the upstream array. False positive detections usually will have close to the minimum number of messages and were deleted from the event data set before survival analysis.

3.6 Statistical Methods

The statistical methods include tests of analysis model assumptions and estimation of dam passage survival, forebay and dam passage survival, travel times, passage efficiencies, and distributions.

3.6.1 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. The *Statistical Design for the Lower Columbia River Acoustic-Tag Investigations of Dam Passage Survival and Associated Metrics* by Skalski (2009) provide the assumptions of the virtual-single-release model. Table 3.4 lists survival model assumptions and subsequent sections describe testing conducted in 2010.

Table 3.4. Survival model assumptions.

Assumption	Test
A1. Individuals marked for the study are a representative sample from the population of inference.	Compare run timing distributions for the test fish versus the juvenile salmonids monitoring data by species. Compare fish size and other fitness measures between tagged fish and run-at-large.
A2. All sampling events are "instantaneous." That is, sampling occurs over a negligible distance relative to the length of the intervals between sampling events.	No test; the time a tagged fish spends at a sampling array is relatively brief compared to the time of travel between arrays.
A3. The fate of each tagged individual is independent of the fate of all others.	No test; commonly accepted as true in tagging studies.
A4. All tagged individuals alive at a sampling location have the same probability of surviving until the end of that event.	Tests 2 and 3 of Burnham et al. (1987) can be used to assess whether upstream detection has an effect on downstream survival.
A5. All tagged individuals alive at a sampling location have the same probability of being detected on that event.	No test; this assumption is satisfied by placing hydrophone arrays across the breadth of the river so that all fish, regardless of location, have the same probability of detection. Lab-derived tag-life and tag-expulsion data will be used to assess this assumption.
A6. All tags are correctly identified and the status of juvenile salmonids (i.e., alive or dead), correctly assessed.	Releases of dead tagged fish at the dams will be used to confirm the absence of false positive detections due to fish dying during dam passage but being detected downriver. Further, if dead fish are detected at the first detection array downstream of the dam, deployment of multiple additional arrays will allow flexibility to select arrays farther downstream to ensure this assumption is not violated. In addition, because tag loss or failure would violate the assumption, we will perform laboratory tag-life assessments.
A7. Survival in the lower river segment of the first reach is conditionally independent of survival in the upper river segment.	Comparison of the survival estimates through the two downstream reaches, formed by the three below-dam hydrophone arrays for the three release groups, can therefore be used to help assess the validity of assumption. Laboratory tagging affects research using ROR untagged, PIT-only, and AT+PIT groups collected at the time of tagging and through the sort-by-code systems will be used to assess this assumption. Survival by release location and river reach will be assessed to test for tagging effects.
A8. The virtual-release group is constructed of tagged fish known to have passed through the dam.	A cabled array on the forebay dam face increases detection probabilities close to 1.0 and will be used to test for homogeneous detection rates.
A10. All fish arriving at the dam have an equal probability of inclusion in the virtual-release group, independent of passage route through the dam.	This assumption is met by having very high detection probabilities (~1.00) on dam-face arrays. Thus, we will estimate array detection probabilities.

3.6.1.1 Probability of Detection

Detection probabilities are an integral part of the survival estimation. For any particular passage route the following variables are defined (Figure 3.16):

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

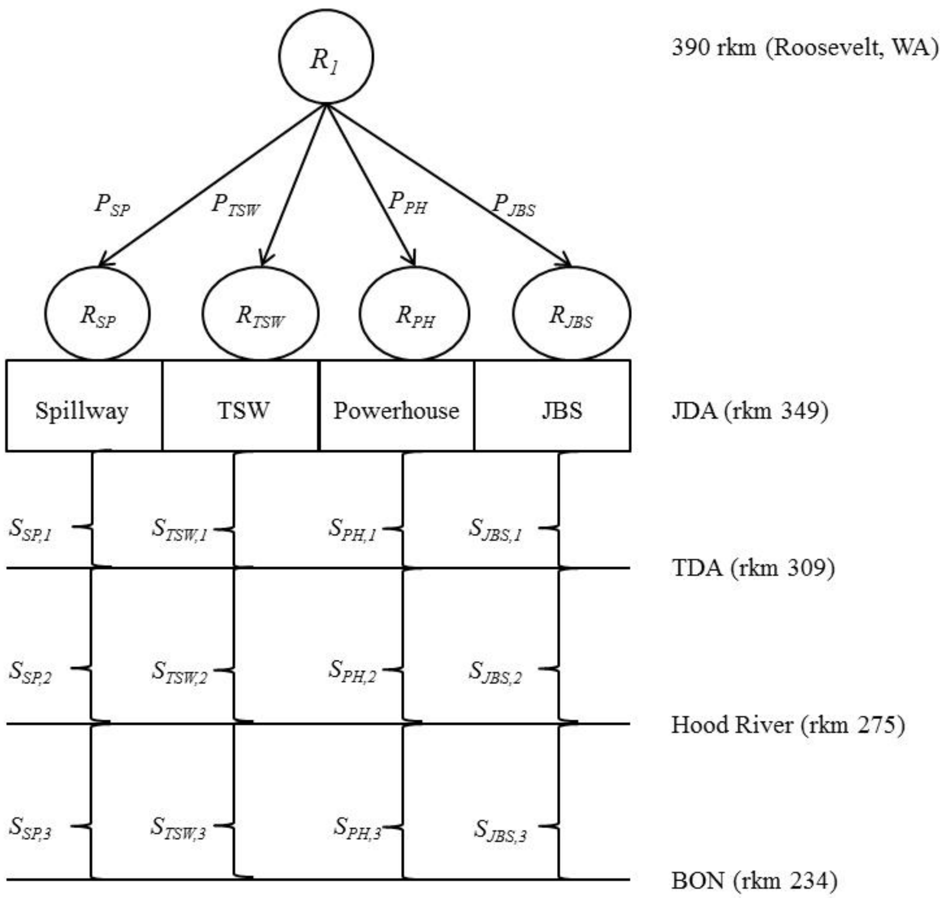

Figure 3.16. Schematic of route-specific passage and downstream recoveries for virtual releases at the spillway (R_{SP}), TSW (R_{TSW}), powerhouse (R_{PH}), and JBS (R_{JBS}).

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

$$\hat{N} = \frac{(n_{10} + n_{11} + 1)(n_{01} + n_{11} + 1)}{(n_{11} + 1)} - 1 \qquad (3.1)$$

or

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{(n_{11}+1)} - 1 \tag{3.2}$$

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

$$\widehat{\mathrm{Var}}(\hat{N}) = \frac{(n_1+1)(n_2+1)(n_1-n_{11})(n_2-n_{11})}{(n_{11}+1)^2(n_{11}+2)} \tag{3.3}$$

The estimated probability of detection $\left(\hat{p}_1\right)$ in the first array is calculated as

$$\hat{p}_1 = \frac{n_{11}}{n_2} \tag{3.4}$$

and the probability of detection $\left(\hat{p}_2\right)$ in the second array as

$$\hat{p}_2 = \frac{n_{11}}{n_1} \tag{3.5}$$

The overall probability of a juvenile salmonid being detected on the cabled array is given by

$$\hat{P} = 1 - \left(1-\hat{p}_1\right)\left(1-\hat{p}_2\right) = \frac{n_{11}\left(n_1+n_2+n_{11}\right)}{n_1 n_2} \tag{3.6}$$

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 juvenile salmonids passing through the powerhouse ($\hat{P}_{PH}$) was estimated as follows

$$\hat{P}_{\mathrm{PH}} = \frac{\hat{N}_{\mathrm{PH}}}{\hat{N}_{\mathrm{PH}} + \hat{N}_{\mathrm{SP}} + \hat{N}_{\mathrm{TSW}} + N_{\mathrm{JBS}}} \tag{3.7}$$

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

$$\widehat{\mathrm{Var}}\left(\hat{P}_{\mathrm{PH}}\right) = \frac{\hat{P}_{\mathrm{PH}}\left(1-\hat{P}_{\mathrm{PH}}\right)}{\hat{N}} + \hat{P}_{\mathrm{PH}}^2\left(1-\hat{P}_{\mathrm{PH}}\right)^2 \cdot \left[\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{PH}}\right)}{\hat{N}_{\mathrm{PH}}^2} + \frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{SP}}\right) + \widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{TSW}}\right) + \widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{JBS}}\right)}{\left(\hat{N}_{\mathrm{SP}} + \hat{N}_{\mathrm{TSW}} + N_{\mathrm{JBS}}\right)^2}\right], \tag{3.8}$$

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 (3.7) and associated variances were estimated analogously to Equation (3.9). Note that for N_{JBS}, $Var(N_{\text{JBS}}) = 0$.

3.6.1.2 Burnham et al. (1987) Tests

Tests 2 and 3 of Burnham et al. (1987) have been used to assess whether upstream detection history has an effect on downstream survival. Such tests are most appropriate when fish are physically recaptured or segregated during capture as in the case with PIT-tagged fish going through the JBS. However, AT studies do not use physical recaptures to detect fish. Consequently, there is little or no relevance of these tests in AT studies. Furthermore, the very high detection probabilities present in AT studies frequently preclude calculation of these tests. For these reasons, these tests were not performed.

3.6.1.3 Tests of Mixing

Evaluation of homogeneous arrival of release groups at downriver detection sites was based on graphs of arrival distributions. The graphs were used to identify any systematic and meaningful departures from mixing. Ideally, the arrival distributions should overlap one another with similarly timed modes.

3.6.1.4 Tagger Effects

Subtle differences in handling and tagging techniques can have an effect on the survival of AMT-tagged juvenile salmonids used in the estimation of dam passage survival. For this reason, tagger effects were evaluated using the *F*-test. The single release-recapture model was used to estimate reach survivals for fish tagged by different individuals. The analysis evaluated whether any consistent pattern of reduced reach survivals existed for fish tagged by any of the tagging staff.

For *k* independent reach survival estimates, a test of equal survival was performed using the *F*-test

$$F_{k-1,\infty} = \frac{s_{\hat{S}}^2}{\left(\dfrac{\sum_{i=1}^{k} \text{Var}\left(\hat{S}_i \middle| S_i\right)}{k} \right)}, \tag{3.9}$$

where $s_{\hat{S}}^2 = \dfrac{\sum_{i=1}^{k}\left(\hat{S}_i - \hat{\bar{S}}\right)^2}{k-1}$ and $\hat{\bar{S}} = \dfrac{\sum_{i=1}^{k}\hat{S}_i}{k}$.

3.6.2 Tag-Life Study

To meet survival model assumptions (see Assumption Testing above), a tag-life study was conducted. All tags for the spring season were delivered prior to April 23, 2010, and tags from all manufacturing dates were randomly mixed prior to the use of any tags. After mixing, 49 tags were randomly selected for a spring tag-life assessment. Similarly, all tags for summer deployments were delivered prior to the tagging of any fish during the summer tagging season and 50 tags were removed randomly for a summer tag-life assessment. The possibility of AMT failure depends on travel time relative to battery life. Tag-life curves were constructed for the spring and summer tags. These curves and the cumulative percent of tags passing survival-detection arrays downstream of the dam were plotted together as a function of time since tag activation. Tag-life corrections were made to survival estimates, as described in the next section, based upon the method described by Townsend et al. (2006).

3.6.3 Estimation of Survival Rates

3.6.3.1 Study Design

The 2010 study was a virtual-single-release-recapture design in which fish released upstream at CR390 were regrouped, if detected, on either the forebay entrance array or the dam-face array and entered into a virtual-release group specific to one of those arrays. Tagged fish detected by the JDA forebay entrance array (CR351) were pooled over periods of several days to define virtual releases for estimating single-release forebay and dam passage survival rates. Fish detected on the dam-face array (CR349) were also pooled over periods of several days to define virtual releases for estimating single-release dam- and route-specific passage survival rates. The dam- and route-specific passage survival rates at JDA were estimated using subsequent detection histories at arrays located at TDA upstream dam face (CR309; primary survival array), Hood River, Oregon (CR275; secondary survival array), and BON upstream dam face (CR234; tertiary survival array) as diagramed in Figure 3.3. Differences in survival estimates for spill treatments (i.e., 30% and 40%) and time periods (i.e., day and night) were assessed by comparing ½ 95% CIs. Paired-release estimates could not be made in 2010 because no tagged fish were released in the JDA tailrace.

The design for estimating survival for fish passing through 2 km of forebay, the dam, and 40 km of tailwater or through just the dam and 40 km of tailwater is illustrated in Figure 3.3. Fish detections assigned to the virtual release at the dam face, along with subsequent capture histories on three survival detection arrays downstream of the dam, were further divided by route of passage assignments or spill treatment to estimate route- or treatment-specific survival rates. During the spring and summer seasons, data were also divided into day (0600 to 2159 h) and night (2200 to 0559 h) for comparisons of passage survival rates during these periods.

3.6.3.2 Processing Software and Approach

We used TagPro software, an AMT data preprocessor for Active Tag-Life_Adjusted Survival (ATLAS) and Survival Under Proportional Hazards (SURPH) software (http://www.cbr.washington.edu/analysis.html), to select fish release and detection sites from the 2010 three-dam database. TagPro data files were loaded into ATLAS Version 1.2.1 to create virtual-single-release capture-history files for a virtual-single-release design. The three downstream survival detection arrays produced 16 (2^4) possible capture histories for each release group (i.e., 1111, 0111, 1011, 0011, 1101, 0101, 1001, 0001, 1110, 0110, 1010, 0010, 1100, 0100, 1000, 0000), where a 1 indicates detection, and a 0 indicates no detection. For example, "1111" indicates detection on all four arrays, whereas "0100" indicates detection on the second array but not on the first, third, or fourth arrays. The ATLAS User Manual (see Section 3.3, pages 34–40, in Lady et al. [2010]) describes in detail analyses for several study designs including the virtual-single-release design used in this study. Tags detected on the dam-face array and then detected or not detected on the three downstream survival detection arrays were in a single TagPro file used to estimate dam passage survival rates for a specific run of fish studied. Those files were divided into smaller files according to route-of-passage criteria (turbines, spillway, or TSWs) using the Statistical Analysis System (SAS). The resulting route-specific detection histories were analyzed separately in ATLAS using the virtual-single-release option to obtain route-specific survival estimates for each run of fish. Similarly, we used SAS to divide large dam passage TagPro detection files into smaller files according to the spill treatment at which each tagged fish passed the dam, which allowed estimates for each spill treatment to be made. We also divided the summer dam passage data by spill block and treatment.

3.6.3.3 Tag-Life Corrections to Survival Rates

A virtual-release group is composed of fish known to have arrived alive at an acoustic array during a specific period of time. These fish may include individuals from multiple release groups upstream. As such, they may have different times in-river and require different tag-life corrections. Assuming all fish in a virtual release have the same downstream survival and detection processes, their subsequent capture histories may be modeled by joint likelihood (see pages 71 and 72 in Lady et al. [2010]). The tag corrections for the virtual-release site are the "unconditional" tag survival probabilities from the actual release site to the virtual-release site. Corrections for downstream survival detection arrays are "conditional" tag survival probabilities, given that the tags were alive at the virtual-release site. Tag-life corrections for each release of fish detected at a virtual-release site are used to calculate subsequent tag corrections at downstream arrays but are not used to directly adjust survival rates.

3.6.4 Route-Specific Survival Estimates

The hydrophone array on the JDA dam face was used to three-dimensionally track and identify fish known to have passed through the spillway, powerhouse, and TSWs (spill bays 18 and 19).

Juvenile salmonids known to have passed through the various routes at JDA were detected by JSATS receivers on downstream arrays to obtain their capture histories. To estimate survival, you first must quantify the number of juvenile salmonids passing by various routes, as follows:

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

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

$$RS_{\text{SP/PH}} = \frac{\left(\frac{n_{\text{SP}}}{R_{\text{SP}}}\right)}{\left(\frac{n_{\text{PH}}}{R_{\text{PH}}}\right)} \tag{3.10}$$

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

$$\widehat{\text{Var}}\left(\widehat{RS}_{\text{SP/PH}}\right) = \widehat{RS}^{2}_{\text{SP/PH}}\left[\frac{1}{n_{\text{PH}}} - \frac{1}{R_{\text{PH}}} + \frac{1}{n_{\text{SP}}} - \frac{1}{R_{\text{SP}}}\right]. \tag{3.11}$$

The estimators of relative survival rates for the other three routes are analogous to Equation (3.10) and their variances are analogous to Equation (3.11).

Using the juvenile salmonids known to have passed through a specific route at the dam, absolute survival rates from the dam entrance to the tailrace detection array location were estimated using a single release-recapture model. 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 Cormack-Jolly-Seber algorithms programmed in ATLAS.

3.6.5 Estimation of Forebay-to-Tailrace Survival

The same virtual-single-release methods used to estimate dam passage were also used to estimate forebay-to-tailrace survival. The only distinction was the virtual-release group (V_1) was composed of fish known to have arrived at the JDA forebay array (CR351) instead of at the dam-face array (Figure 3.3).

3.6.6 Estimation of Travel Times

Travel times associated with forebay residence and tailrace egress were estimated using arithmetic averages, i.e.,

$$\bar{t} = \frac{\sum_{i=1}^{n} t_i}{n}, \tag{3.12}$$

with the variance of $\bar{t}$ estimated by

$$\widehat{\text{Var}}(\bar{t}) = \frac{\sum_{i=1}^{n}\left(t_i - \bar{t}\right)^2}{n(n-1)}, \tag{3.13}$$

and where t_i was the travel time of the i^{th} fish $(i = 1, \ldots, n)$. Median, minimum, and maximum travel times were also computed and reported.

Travel time estimates were calculated as follows:

- Forebay residence time was calculated by subtracting the time of last detection on the dam-face array from the time of first detection on the forebay entrance array.
- 100-m forebay residence time was calculated by subtracting the time of last detection at the dam face from the time of first detection 100 m upstream of the dam face.
- Tailrace egress time was calculated by subtracting the time of last detection at the dam-face array from the time of last detection at the tailrace exit array downstream of the dam.
- Project passage time was calculated by subtracting the time of first detection on the forebay entrance array from the time of last detection on the tailrace egress array.

3.6.7 Estimation of Passage Efficiencies

Fish passage was characterized by estimating various passage efficiencies (e.g., SPE and TSWE). One-tailed, paired t-tests (α = 0.05) were used to compare passage metrics where noted. Fish passage efficiency 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:

$$\widehat{\text{FPE}} = \frac{\hat{N}_{NTSW} + \hat{N}_{TSW} + \hat{N}_{JBS}}{\hat{N}_{NTSW} + \hat{N}_{TSW} + \hat{N}_{JBS} + \hat{N}_{TUR}} \tag{3.14}$$

with associated variance estimator

$$\widehat{\text{Var}}\left(\widehat{\text{FPE}}\right) = \frac{\widehat{\text{FPE}}\left(1-\widehat{\text{FPE}}\right)}{\hat{N}} + \widehat{\text{FPE}}^2\left(1-\widehat{\text{FPE}}\right)^2 \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{\text{PH}}\right)}{\hat{N}_{\text{PH}}^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{\text{SP}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{TSW}}\right) + \widehat{\text{Var}}\left(\hat{N}_{\text{JBS}}\right)}{\left(\hat{N}_{\text{SP}} + \hat{N}_{\text{TSW}} + \hat{N}_{\text{JBS}}\right)^2}\right]. \tag{3.15}$$

Spill passage efficiency is defined as the proportion of fish that pass through the spillway (i.e., TSW and non-TSW spill bays). It was estimated by the sum

$$\widehat{\text{SPE}} = \frac{\hat{N}_{NTSW} + \hat{N}_{TSW}}{\hat{N}_{NTSW} + \hat{N}_{TSW} + \hat{N}_{TUR} + \hat{N}_{JBS}} \tag{3.16}$$

with associated variance estimator

$$\mathrm{Var}\left(\widehat{\mathrm{SPE}}\right)=\frac{\widehat{\mathrm{SPE}}\left(1-\widehat{\mathrm{SPE}}\right)}{\sum_{i=1}^{4}\hat{N}_i}+\widehat{\mathrm{SPE}}^2\left(1-\widehat{\mathrm{SPE}}\right)^2 \cdot\left[\frac{\mathrm{Var}\left(\hat{N}_{NTSW}\right)+\mathrm{Var}\left(\hat{N}_{TSW}\right)}{\left(\hat{N}_{NTSW}+\hat{N}_{TSW}\right)^2}+\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{TUR}\right)+\mathrm{Var}\left(\hat{N}_{JBS}\right)}{\left(\hat{N}_{TUR}+\hat{N}_{JBS}\right)^2}\right]. \tag{3.17}$$

Top-spill weir passage efficiency is defined as the proportion of juvenile salmonids passing the dam through the TSW spill bays. For this study, the TWSE was expressed by

$$\widehat{\mathrm{TSWE}}=\hat{P}_{\mathrm{TSW}} \tag{3.18}$$

with associated variance estimator

$$\widehat{\mathrm{Var}}\left(\widehat{\mathrm{TSWE}}\right)=\frac{\hat{P}_{\mathrm{TSW}}\left(1-\hat{P}_{\mathrm{TSW}}\right)}{\hat{N}}+\hat{P}_{\mathrm{TSW}}{}^2\left(1-\hat{P}_{\mathrm{TSW}}\right)^2 \cdot\left[\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{TSW}}\right)}{\hat{N}_{\mathrm{TSW}}^2}+\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{SP}}\right)+\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{PH}}\right)+\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{JBS}}\right)}{\left(\hat{N}_{SP}+\hat{N}_{\mathrm{PH}}+\hat{N}_{\mathrm{JBS}}\right)^2}\right]. \tag{3.19}$$

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

$$\widehat{\mathrm{FGE}}=\frac{\hat{P}_{\mathrm{JBS}}}{\hat{P}_{\mathrm{TUR}}+\hat{P}_{\mathrm{JBS}}} \tag{3.20}$$

with the associated variance estimator

$$\widehat{\mathrm{Var}}\left(\widehat{\mathrm{FGE}}\right)=\frac{\widehat{\mathrm{FGE}}\left(1-\widehat{\mathrm{FGE}}\right)}{\hat{N}}+\widehat{\mathrm{FGE}}^2\left(1-\widehat{\mathrm{FGE}}\right)^2 \cdot\left[\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{JBS}}\right)}{\hat{N}_{\mathrm{JBS}}^2}+\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{SP}}\right)+\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{PH}}\right)+\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{TSW}}\right)}{\left(\hat{N}_{SP}+\hat{N}_{\mathrm{PH}}+\hat{N}_{\mathrm{TSW}}\right)^2}\right]. \tag{3.21}$$

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

$$\mathrm{JBSE}=\frac{\hat{P}_{\mathrm{JBS}}}{\hat{P}_{\mathrm{JBS}}+\hat{P}_{\mathrm{TUR}}+\hat{P}_{\mathrm{NTSW}}+\hat{P}_{\mathrm{TSW}}} \tag{3.22}$$

with the associated variance estimator

$$\widehat{\mathrm{Var}}\left(\widehat{\mathrm{JBSE}}\right)=\frac{\hat{P}_{\mathrm{JBS}}\left(1-\hat{P}_{\mathrm{JBS}}\right)}{\hat{N}}+\hat{P}_{\mathrm{JBS}}^{2}\left(1-\hat{P}_{\mathrm{JBS}}\right)^{2} \cdot\left[\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{JBS}}\right)}{\hat{N}_{\mathrm{JBS}}^{2}}+\frac{\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{PH}}\right)+\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{SP}}\right)+\widehat{\mathrm{Var}}\left(\hat{N}_{\mathrm{TSW}}\right)}{\left(\hat{N}_{\mathrm{PH}}+\hat{N}_{SP}+\hat{N}_{\mathrm{TSW}}\right)^{2}}\right]. \quad (3.23)$$

3.6.8 Spatial Trends

Based on detections on the dam-face array and 3D tracking results, the horizontal distribution of passage of each stock of fish at JDA was estimated according to the individual turbine and spill bay of passage. The same 3D tracking data set allowed evaluation of the vertical distribution of juvenile salmonids within 75 m of the dam.

For a broader picture of fish behavior in the forebay, the distribution of juvenile salmonids detected on the forebay entrance array 2 km upstream of JDA was compared to the distribution of juvenile salmonid passage at the dam. Juvenile salmonid detections on the forebay array were assigned to horizontal blocks corresponding to locations upstream of dam structures, from south to north: PH1–16 = powerhouse units 1 to 16, skeleton bays, SW20 = spill bay 20, SW18 and 19 = spill bays 18 and 19 (each with a TSW), and SW1–17 = spill bays 1 through 17. Passage locations also were grouped into blocks of routes with the same names used to describe juvenile salmonid arrivals, except that skeleton bays were dropped because they could not pass fish. This approach allowed examination of juvenile salmonid behavioral response to the dam by their avoidance or selection of passage-route blocks. Similar arrival and passage distributions would suggest that juvenile salmonid responses to forebay conditions and operations were limited, whereas substantial shifts in those distributions would indicate that juvenile salmonids were responding to forebay conditions or operations by selecting preferred blocks of routes.

4.0 Results – Environmental Conditions

This section contains a description of environmental conditions during the 2010 study, including river discharge and temperature relative to the 10-yr average, JDA forebay elevation, and realized spill discharges for the 30% and 40% spill treatments.

4.1 Water Discharge and Temperature

From the first release of tagged fish on April 28 to the retrieval of the last node (April 28 to August 5, 2010), total daily discharge through the dam ranged from 112 to 408 kcfs and averaged 229 kcfs. During the entire study period, 34.2% of total water discharged was passed through the spillways, including 8.4% TSW discharge during the spring (April 28 to June 12) and 6% TSW discharge during the summer (June 13 to August 5). Throughout the spring portion of the study, discharge was below the 10-yr average (2000 to 2009) when tagged fish were released (Figure 4.1); the daily total project discharge averaged 232 kcfs, and ranged between 154 and 408 kcfs. During the summer study period, the daily total project discharge averaged 225 kcfs and ranged between 112 and 363 kcfs. Total project discharge exceeded the 10-yr average during the summer tagged fish releases.

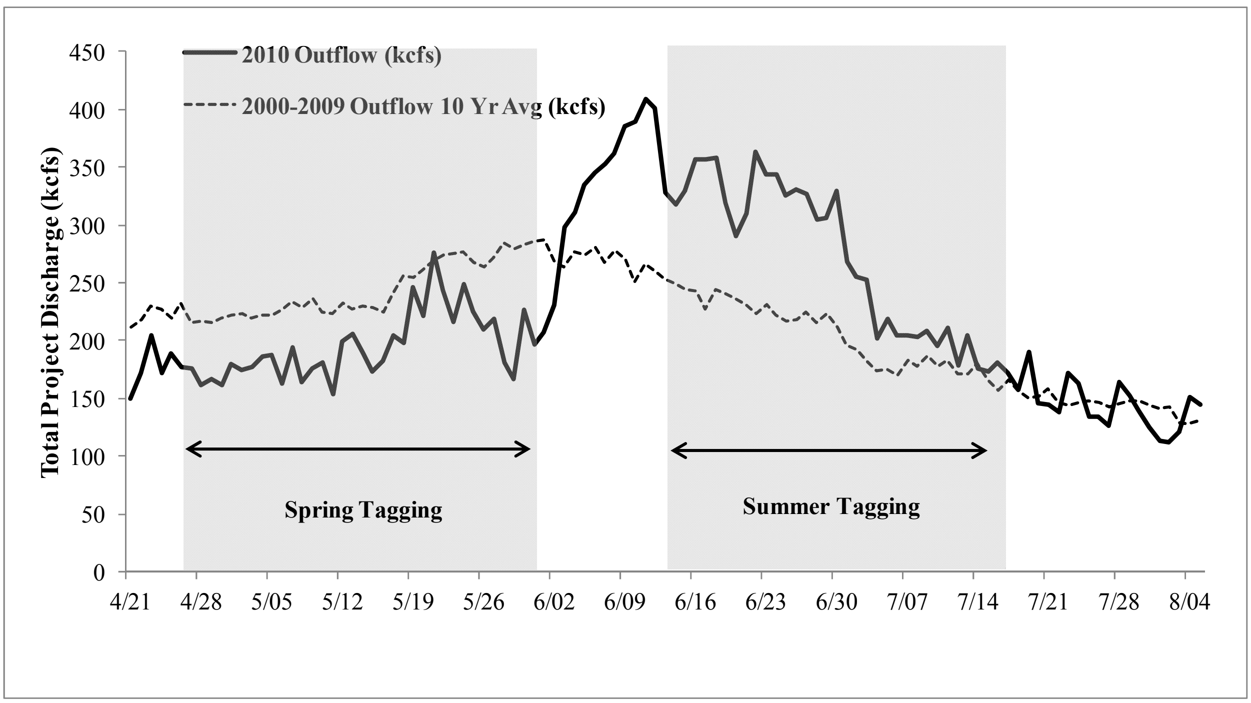

Figure 4.1. Average daily water discharge (kcfs; solid line) from JDA during the 2010 study and for the preceding 10-yr (2000 to 2009; dashed line) period.

Columbia River water temperatures in the JDA forebay were similar in 2010 to the 10-yr average. Slight variations occurred when the water temperature exceeded the 10-yr average during the early part of the spring tagging season, and then remained slightly below the 10-yr average for the duration of the study (Figure 4.2).

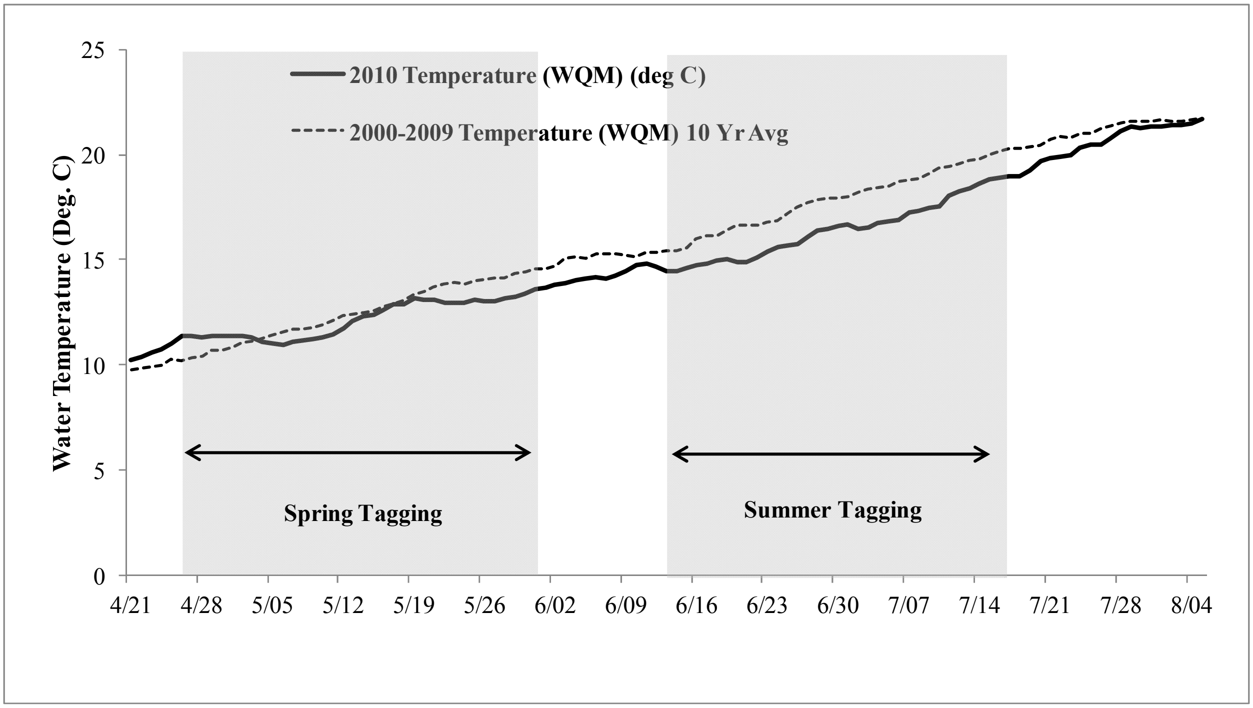

Figure 4.2. John Day Dam average daily forebay water temperatures (ºC) during the 2010 study (solid line) and for the preceding 10-yr period (dashed line) (WQM = water quality monitoring).

4.2 Forebay Elevations

During the spring and summer 2010 study periods, forebay elevation averaged 263.3 ft above MSL. The range was 0.6 ft and 0.5 ft for the spring and summer season, respectively.

4.3 Spill Treatments

During spring 2010, spill treatment conditions were well maintained at each of the designated spill levels for 2 d during each block (Figure 4.3). During Block 6, dam operations required treatments to be maintained for 4 d rather than 2 d; consequently, there were eight treatment blocks rather than nine. During summer, conditions were met for Blocks 2 through 9; however, dam operators were not able to meet prescribed conditions during the 40% spill treatment for Block 1 (Figure 4.4). Despite not meeting the 40% spill treatment during most of Block 1, the spill levels were above 35% most of the time and comparisons could still be made.

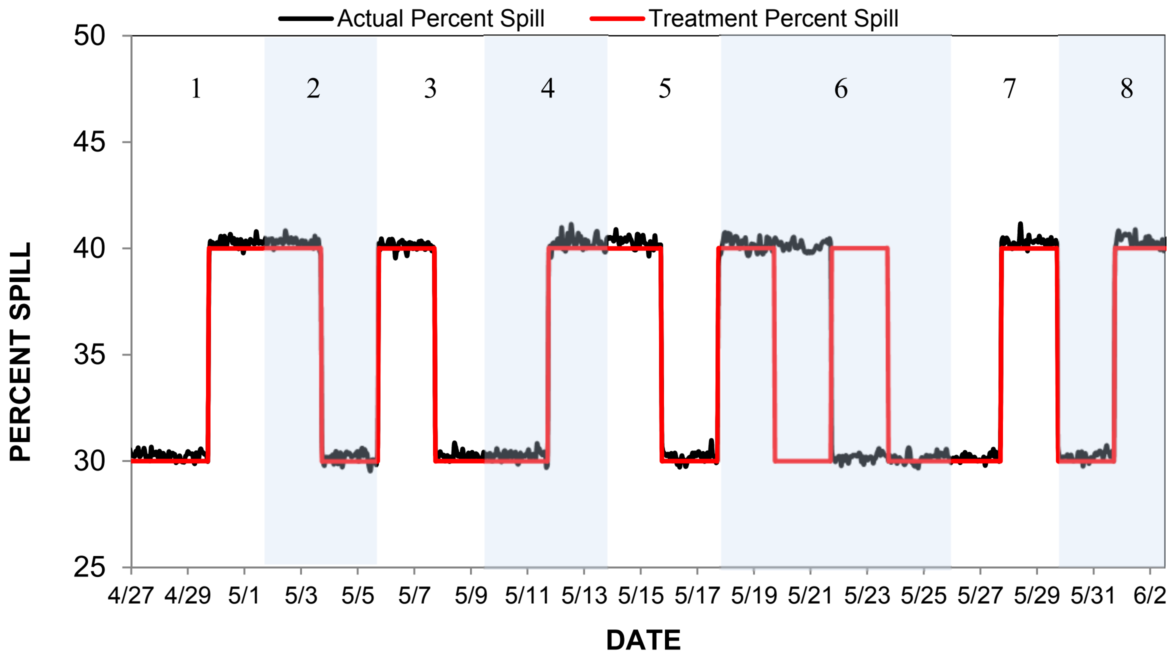

Figure 4.3. Spill treatments for the spring study at John Day Dam, April 28 through June 3, 2010. There were eight treatment blocks with two 2-d treatments per block, with the exception of Block 6, which had a 4-d treatment length.

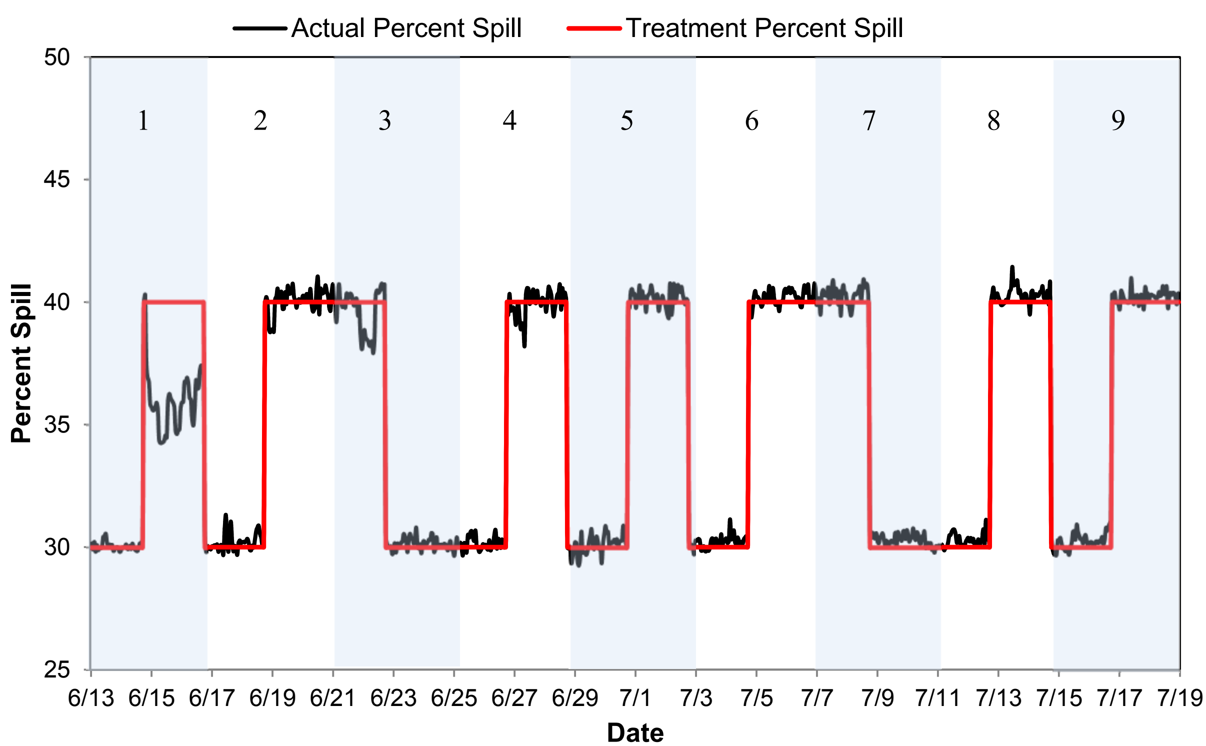

Figure 4.4. Spill treatments in summer at John Day Dam, June 13 through July 19, 2010. There were nine treatment blocks with two 2-d treatments per block; however, the 40% spill treatment for Block 1 was not met.

5.0 Results – JSATS Performance and Assessment of Survival Model Assumptions

Results derived from the validation of JSATS performance testing and adherence to survival model assumptions are presented in the following sections. A review of fish condition associated with the collection and tagging process was performed concurrently to ensure individual fish marked for the study were a representative sample from the population and is presented in Appendix A. Further examination of how experimental model criteria were met is presented in Appendix C.

5.1 JSATS Performance

JSATS performance was evaluated by assessing tagged fish detection probabilities at dam-face arrays to ensure survival model assumptions were met. The Lincoln-Peterson single mark-recapture model was used to calculate the detection efficiency of a combined dam-face array formed from two independent hydrophone arrays deployed at the JDA dam face. The GPS positions of individual dam-face hydrophones and autonomous nodes are presented in Appendix B.

5.1.1 Detection Probabilities at Dam-Face Arrays

Detection probabilities for all tagged fish passing through JDA in both spring and summer were 100% for both independent dam-face arrays, resulting in a combined detection probability of 100% (Table 5.1).

Table 5.1. Detection probabilities for dam-face arrays at John Day Dam in spring and summer 2010 (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 Passed	N11	N10	N01	Detection Probability Array 1	Detection Probability Array 2	Combined Probability
CH1	2,171	2,171	0	0	1.0000	1.0000	1.0000
STH	2,141	2,141	0	0	1.0000	1.0000	1.0000
CH0	2,636	2,594	0	0	1.0000	1.0000	1.0000

5.2 Assessment of Model Assumptions

The results of multiple experimental model assumptions are summarized in the following sections and details are provided in Appendix C.

5.2.1 Fish Size Distribution

Length frequency distributions of CH1 and juvenile STH tagged with JSATS AMTs (Appendix C, Figure C.1 and Figure C.2, respectively) were comparable to untagged, ROR fish collected at the JDA SMF during the same time period. Median lengths for tagged CH1 and juvenile STH were 152 mm and 215 mm, respectively. In contrast, the size distribution of tagged CH0 was slightly offset from run-of-river fish sampled at the JDA SMF (Appendix C, Figure C.3). Tagged CH0 had a median length of 110 mm compared to the untagged population sampled at the JDA SMF with a median of 104 mm.

5.2.2 Collected Fish Fates

We summarized the number and percent of fish collected for tagging according to their fate (Table 5.2). Most fish collected for the study were tagged and released alive. A small percentage of fish were tagged and released dead with active tags to test detection assumptions. The extra fish collected and not used for tagging due to daily quotas being met, were released to the river via the JDA juvenile bypass outfall. We also summarized information for fish collected but rejected from tagging because of maladies (Table 5.3) or excluded for other reasons (Table 5.4).

Table 5.2. Summary of the number and percent of fish that were rejected, excluded, tagged and released alive, tagged and released dead, or exceeded the daily tagging quota in 2010.

	CH1		STH		CH0		Total	
Fate	n	%	n	%	n	%	n	%
Excluded[a]	209	4.5	309	6.4	330	5.8	848	5.6
Rejected[b]	297	6.5	427	8.9	430	7.6	1,154	7.7
Tagged and Released Live	3,880	84.3	3,885	80.9	4,449	78.8	12,214	81.2
Tagged and Released Dead[c]	33	0.7	37	0.8	67	1.2	137	0.9
Extra Fish[d]	182	4.0	147	3.1	369	6.5	698	4.6
Collected	4,601	100.0	4,805	100.0	5,645	100.0	15,051	100.0

(a) Did not meet length criteria, previously tagged, dead, non-target species, mishandled.
(b) Due to maladies.
(c) Used specifically to meet detection assumptions.
(d) Collected but not tagged due to the daily tagging quota being met.

Table 5.3. Number of observed malady types that warranted rejection and percent rejected by malady type.

	CH1		STH		CH0		Total	
Malady Description	n	%	n	%	n	%	n	%
BKD[a]	2	0.7	0	0.0	2	0.5	4	0.3
Descaling (≥20%)	148	49.8	212	49.6	226	52.6	586	50.8
Emaciated	1	0.3	0	0.0	1	0.2	2	0.2
Exophthalmia	16	5.4	5	1.2	5	1.2	26	2.3
Fin Rot	5	1.7	1	0.2	5	1.2	11	1.0
Fungus	49	16.5	60	14.1	9	2.1	118	10.2
Hemorrhaging	9	3.0	2	0.5	5	1.2	16	1.4
Lacerations	25	8.4	50	11.7	69	16.0	144	12.5
Lesions	12	4.0	22	5.2	26	6.0	60	5.2
Operculum Damage	13	4.4	41	9.6	33	7.7	87	7.5
Other	8	2.7	23	5.4	4	0.9	35	3.0
Parasites	0	0.0	4	0.9	34	7.9	38	3.3
Skeletal Deformities	9	3.0	7	1.6	11	2.6	27	2.3
Total	**297**	**100.0**	**427**	**100.0**	**430**	**100.0**	**1,154**	**100.0**

(a) BKD = bacterial kidney disease.

Table 5.4. Number of juvenile salmonids excluded from tagging for other reasons and percent excluded by reason.

Reason for Exclusion	CH1 n	CH1 %	STH n	STH %	CH0 n	CH0 %	Total n	Total %
Moribund	0	0.0	0	0.0	2	0.6	2	0.2
Previously tagged	168	80.4	156	50.5	120	36.4	444	52.4
<95 or >260 mm	1	0.5	150	48.5	202	61.2	353	41.6
Wrong species	40	19.1	3	1.0	5	1.5	48	5.7
Dropped/Jumped	0	0.0	0	0.0	1	0.3	1	0.1
Total	**209**	**100.0**	**309**	**100.0**	**330**	**100.0**	**848**	**100.0**

5.2.3 Handling Mortality, Tagging Mortality, and Tag Shedding

Handling and tagging mortalities during the study were minimal and no tags were shed during the 18- to 24-h post-surgery holding period. Species-specific post-tagging mortality was 0.1% for both CH1 and STH, and 0.35% for CH0. Detailed analysis of handling and tagging mortality and tag shedding data is presented in Appendix C.

5.2.4 Run Timing

To ensure a representative sample from the population were being selected for tagging, the 10-yr smolt index average was used as an indicator of run timing to select an appropriate start date for tagging fish. The goal of tagging during the middle 80% of the outmigration (10th to 90th percentile) for each species was nearly achieved. During the spring, tagging of CH1 and STH occurred during the middle 78% and 73% of the run, respectively. During the summer, tagging of CH0 corresponded to the middle 79% of the run. Detailed analysis of run timing data is presented in Appendix C.

5.2.5 Detection of Dead Fish

The experimental model assumption that dead fish with active tags are not being detected on downstream receiving arrays and counted as alive in the survival estimate was tested by euthanizing, or using fish that died post-tagging, and releasing the sample of tagged fish downstream of the spillway of JDA. In spring, 29 tagged CH1 and 35 tagged STH were released dead in the spillway below JDA; no dead fish were detected on the JSATS receiving arrays. In summer, 58 dead CH0 were tagged and released and none were detected at the JSATS receiving arrays downstream of JDA.

5.2.6 Arrival Distribution Relative to Tag Life

For CH1 and STH mean tag life (n = 49) was 32.73 d. The earliest tag failure was at 7.8 d and the longest at 39.6 d. A total of 13.7 d was required for more than 99% of the CH1 to pass the tertiary survival-detection array, and juvenile STH required 15.0 d. The failure-time data for the AMTs was fit to a four-parameter vitality model of Li and Anderson (2009) (Appendix C). For CH0, mean tag life (n = 50) was 35.54 d. A total of 11.9 d was required for CH0 to pass the tertiary survival-detection array. A tag-life correction was not applied to estimates of survival because nearly 100% of CH0 were expected to pass the tertiary array at BON (CR234) before tag life became problematic.

6.0 Results – Yearling Chinook Salmon

This section contains estimates of survival rates, travel times, passage metrics, and distributions for CH1 at JDA during spring 2010. Capture-history data are presented in Appendix D and tagging tables summarizing fish releases are available in Appendix E.

6.1 Survival Estimates

Seasonal, route-specific, and day/night CH1 survival estimates are presented in the following sections.

6.1.1 Point Estimates

Single-release survival estimates ($\hat{S}$ [±S.E.]) were calculated for the 2,287 CH1 released at Roosevelt, Washington (CR390). Survival from JDA to TDA was similar whether fish were virtually released from the face of JDA (0.937 ±0.005; CR349) or the JDA forebay entrance (0.934 ±0.006; CR351) (Table 6.1). Route-specific passage survival for spillway-passed fish, which included TSW-passed fish, was 0.951; survival for non-TSW-passed fish was 0.950, and survival for TSW-passed fish was 0.952 (Table 6.2). Survival of CH1 that passed at spill bay 20, the location of the modified flow deflector, was 0.933. The lowest survival rate was observed with turbine-passed fish (0.776 ±0.047). Survival rates through the JBS decreased after a loose steel plate in the passage channel was repaired; however, non-overlapping ½ 95% CIs indicated the difference in survival before and after the repair was not significant (Table 6.3).

Table 6.1. CH1 passage survival from the John Day Dam forebay entrance and dam face to the dam face at The Dalles Dam.

Metric	Survival Estimate	SE
JDA dam face to TDA (CR349 to CR309)	0.937	0.005
JDA forebay entrance to TDA (CR351 to CR309)	0.934	0.006

Table 6.2. CH1 route-specific survival from the dam-face virtual release at John Day Dam to The Dalles Dam (CR349 to CR309).

Route	Survival Estimate	SE
Spillway virtual release to TDA	0.951	0.005
TSW virtual release to TDA	0.952	0.006
Non-TSW virtual release to TDA	0.950	0.008
Spill bay 20 virtual release to TDA	0.933	0.016
JBS virtual release to TDA	0.901	0.026
Turbine virtual release to TDA	0.776	0.047

Table 6.3. JBS survival of CH1 before and after repair of a loose steel plate in the bypass channel.

Metric	All Spring	SE	Prior to 5/20	SE	After 5/21	SE
JDA dam face to TDA (CR349 to CR309)	0.901	0.026	0.909	0.030	0.880	0.051

6.1.2 Day/Night Trends in Survival

During the spring season, fish passage data were divided into day (civil sunrise to civil sunset) and night (civil sunset to civil sunrise) periods and survival estimates were not significantly different when comparing ½ 95% CIs (Table 6.4). Passage efficiency of the TSW, compared with that of the spillway, appeared to be significantly lower during the day than at night (Table 6.5).

Table 6.4. Comparison of day/night single-release estimates of survival for CH1 (CR349 to CR309). Estimates were not corrected for tag life.

	Day		Night	
Survival Reach	Estimate	SE	Estimate	SE
Dam face to TDA	0.943	0.006	0.937	0.011
JBS virtual release to TDA	0.875	0.049	0.914	0.030
Spillway virtual release to TDA	0.950	0.006	0.957	0.011
TSW virtual release to TDA	0.949	0.007	0.963	0.012

Table 6.5. TSW passage efficiency of CH1 relative to the spillway.

	Day		Night	
Metric	Estimate	SE	Estimate	SE
TSWE ‖ Spillway	0.612	0.012	0.720	0.024

6.2 Spill Treatment Effects

There were no treatment fish in Block 1 for 30% spill or Block 8 for 40% spill, so these two blocks were removed from the comparison (Table 6.6). No observable differences in single-release survival estimates were observed when comparing ½ 95% CIs for 30% and 40% spill treatments within a spill block. In addition, a Shapiro-Wilk normality test determined data from 30% and 40% spill conditions were normally distributed (alpha = 0.05; $P = 0.34$) and subsequent t-tests indicated there was no significant difference in mean survival of CH1 between the two spill discharge levels tested at JDA for Blocks 2 through 7 ($P = 0.26$; Table 6.7). Furthermore, there was no significant difference in CH1 survival between 30% and 40% spill treatments when estimates were pooled over the entire season (Table 6.8). Relative to the dam and the spillway, TSWE was significantly higher during the 30% spill treatment than during the 40% treatment. Other major passage metrics did not differ significantly between the spill treatments.

Table 6.6. Estimates of JDA face to TDA forebay passage survival rates by two-day block and spill treatment for CH1 (CR349 to CR309).

Block	30% Spill	1/2 95% CI	40% Spill	1/2 95% CI
1	-	-	0.942	0.047
2	0.963	0.031	0.962	0.029
3	0.947	0.037	0.951	0.039
4	0.899	0.044	0.944	0.049
5	0.922	0.045	0.938	0.038
6	0.950	0.027	0.947	0.025
7	0.922	0.050	0.898	0.048
8	0.934	0.064	-	-

Table 6.7. Results of a one-tailed, paired t-test comparing estimates of JDA dam-face to TDA forebay passage survival rates by two-day block and spill treatment for CH1 (CR349 to CR309).

	30% Spill	40% Spill
Mean	0.934	0.940
Variance	0.0006	0.0005
Observations	6	6
Pearson Correlation	0.4935	
Hypothesized Mean Difference	0	
df	5	
t Stat	–0.6770	
P(T<=t) one-tail	0.2642	
t Critical one-tail	2.0150	
P(T<=t) two-tail	0.5285	
t Critical two-tail	2.5706	

Table 6.8. Estimates of major passage metrics by spill treatment for CH1.

	30% Spill		40% Spill		
Metric	Estimate	SE	Estimate	SE	Sig Diff[(a)]
Survival – Dam face to TDA (CR349 to CR309)	0.940	0.007	0.944	0.007	
Survival – Forebay entrance to TDA (CR351 to CR309)	0.935	0.008	0.941	0.007	
FPE || Dam	0.969	0.005	0.958	0.006	
SPE || Dam	0.917	0.009	0.884	0.010	
TSWE || Dam	0.662	0.015	0.478	0.015	*
TSWE || Spillway	0.722	0.014	0.541	0.016	*
FGE (powerhouse screen efficiency)	0.625	0.052	0.641	0.042	
JBSE || Dam	0.052	0.007	0.074	0.008	

(a) Spill treatments were compared using ½ 95% confidence intervals.

6.3 Travel Times

There were 2,166 tagged CH1 detected on the forebay array; they had a median residence time of 2.15 h (CR351 to CR349; Table 6.9). Median residence time from 100 m upstream of the dam to the JDA dam face was 0.58 h, while median travel time from the JDA dam face to the tailrace egress array was 0.74 h (CR349 to CR346). Median project passage time from the JDA forebay entrance to the JDA egress array was 3.09 h (CR351 to CR346).

Table 6.9. CH1 residence times (h) at John Day Dam, spring 2010.

Route	n	Median	Mean	Max	Min	SE
Forebay (CR351 to CR349)	2,166	2.15	5.32	247.90	0.51	0.24
100-m forebay residence time	1,424	0.58	3.26	237.32	0.04	0.28
JDA egress time (CR349 to CR346)	2,031	0.74	2.31	459.42	0.33	0.32
Project passage time (CR351 to CR346)	2,033	3.09	7.44	470.72	1.03	0.39

6.4 Estimates of Passage Efficiency

During 2010, FPE for CH1 was 96.3% and SPE was 90.0% (Table 6.10). Relative to the dam and spillway, the TWSEs were 56.8% and 63.2%, respectively; FGE was 63.1% and JBSE was 6.3%.

Table 6.10. Estimates of major passage metrics for CH1 at John Day Dam, spring 2010.

Metric	Estimate	SE
FPE || Dam[(a)]	0.963	0.004
SPE || Dam[(a)]	0.900	0.007
TSWE || Dam[(a)]	0.568	0.011
TSWE || Spillway	0.632	0.011
FGE (powerhouse screen efficiency)	0.631	0.033
JBSE || Dam[(a)]	0.063	0.005

(a) If dam route is included, proportions will not add up to 1.

6.5 Fish Passage Distributions

The following sections include CH1 horizontal distribution, forebay approach distribution, and forebay vertical distribution.

6.5.1 Horizontal Distribution

Most CH1 (89.8%) passed through the spillway and fish passed through every bay. Specifically, spill bays 17 through 20 passed the most fish; bays 18 and 19 (TSW bays) passed the largest portion of the spillway-passed fish (Figure 6.1). Discharge was also markedly higher through the TSWs (8.4% of total discharge). Passage through all spill bays generally increased proportionally to increases in percent discharge. The same trend was observed at the turbine units and the JBS, and was particularly evident at turbine units 2, 5, and 15 (Figure 6.2). Of the 10.2% of fish passed at the powerhouse, more than 60% were routed through the JBS. No tagged fish were detected passing at turbine unit 6.

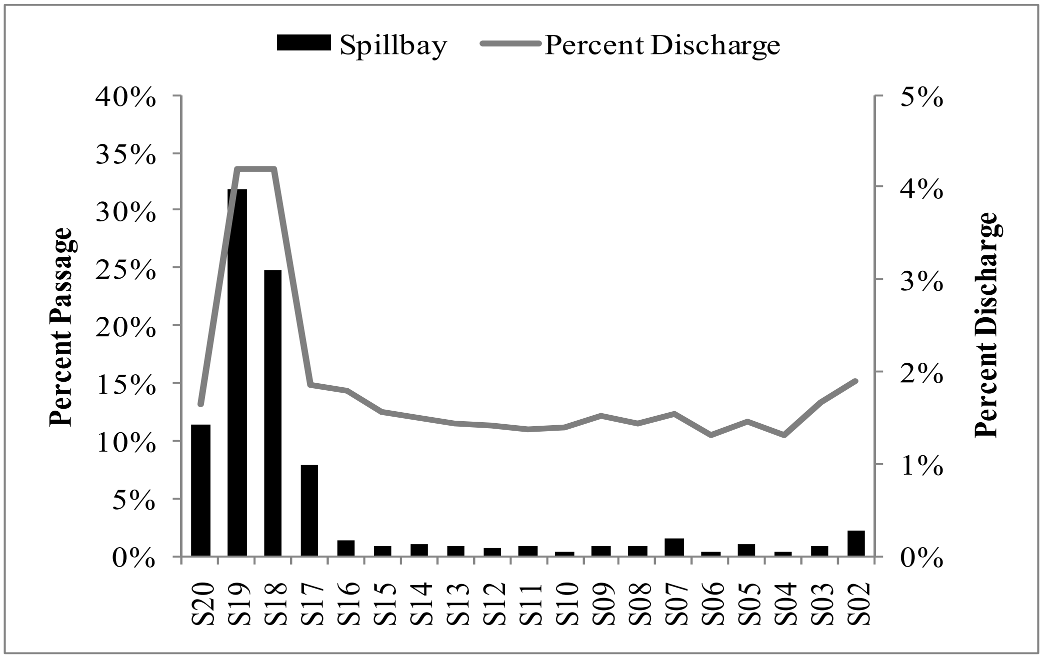

Figure 6.1. Percent passage and discharge of CH1 by spill bay (S).

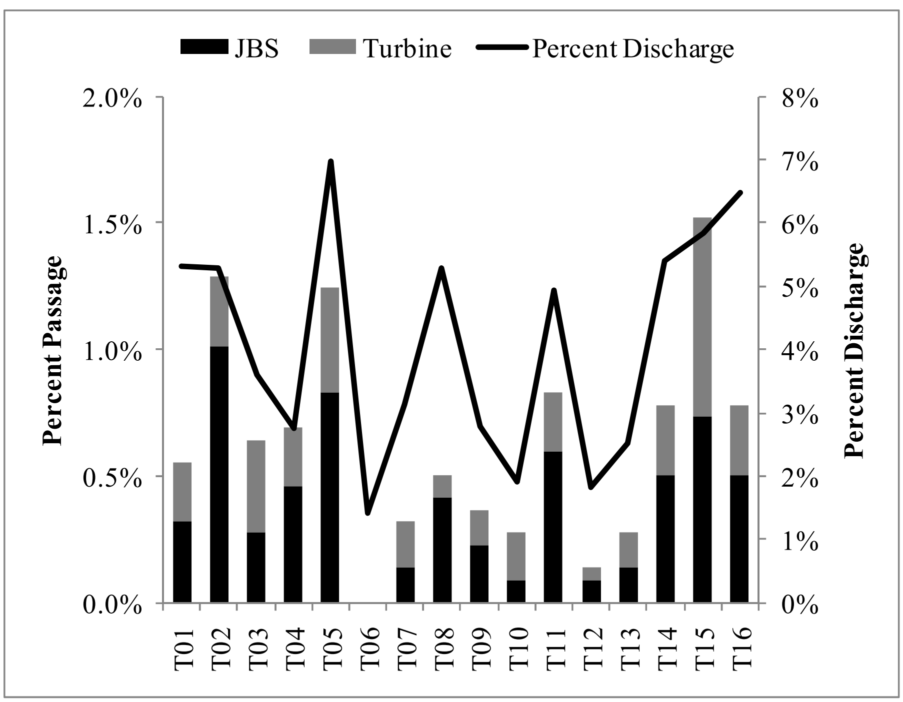

Figure 6.2. Percent passage and discharge of CH1 by juvenile bypass system (JBS) and turbine (T) unit.

6.5.2 Day/Night Forebay Approach Distribution and Residence Times

Most CH1 (≈79%) passed through JDA during the day and 44% of CH1 approached and passed through the spillway during this period (Figure 6.3). The spillway was more effective at passing juvenile salmonids during the day than at night, attracting 34% of CH1 that approached the powerhouse, and 17% that approached skeleton bays during the day. At night, 38% of CH1 approached the spillway and subsequently passed the spillway. During the night, CH1 that approached the powerhouse were just as likely to pass at the powerhouse (24%) as at the spillway (22%). Very few fish that approached the spillway had final passage at the powerhouse regardless of day or night (<2%).

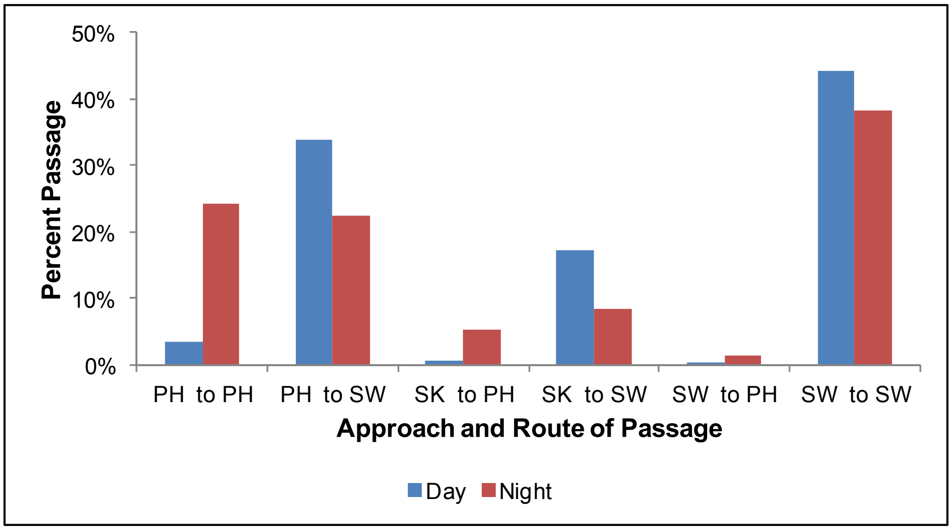

Figure 6.3. CH1 approach and passage distributions during day and night. The first abbreviation is for the approach location, and the second is for the passage location (PH = powerhouse; SK = skeleton bay; SW = spillway).

Median residence times related to approach and passage distributions were markedly higher for fish that approached either the powerhouse or spillway and passed by way of the other (i.e., powerhouse approach, spillway passage; Table 6.11). This effect was magnified at night on the order of two- to three-times longer residence times for night-passed versus day-passed fish.

Table 6.11. CH1 median residence time (h) based on approach and passage structure for day and night periods.

	Median Residence Time (h)		
Approach and Passage	All	Day	Night
Powerhouse to powerhouse	0.58	0.72	0.30
Powerhouse to spillway	1.77	1.55	3.61
Skeleton bays to powerhouse	0.51	0.71	0.45
Skeleton bays to spillway	0.29	0.26	1.19
Spillway to powerhouse	2.04	1.53	3.23
Spillway to spillway	0.20	0.18	0.35

6.5.3 Forebay Vertical Distribution

Most CH1 were vertically distributed at about 3- to 4-m depth below the shallow hydrophone (depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m (251.39 ft) above MSL, about 3 m below the surface of the water) as they approached the dam from a distance of 75 m (Figure 6.4). Median depth generally decreased for fish approaching all dam structures during the first 65 m of approach (i.e., from 75 m to 10 m from the hydrophone). A dramatic increase to over 20-m depth occurred within 5 m of the dam face for fish approaching the powerhouse. CH1 approaching the spillway were observed at depths that continually decreased within their 75-m approach to spill bays 17–20 due to the TSWs at spill bays 18 and 19. This pattern was not evident at spill bays 1–16 where fish depth had to increase to pass under the tainter gates. The CH1 moved shallower as they approached the skeleton bays, similar to their powerhouse and spillway approach, but showed an intermediate increase in depth within 5 m of the dam relative to the CH1 detected within 5 m of the dam at the spillway and the powerhouse. The same general pattern was observed for CH1 approaching JDA within the 75-m approach field during the day (Figure 6.5); however, CH1 that approached the skeleton and spill bays at night did overall have a shallower approach depth (Figure 6.6.).

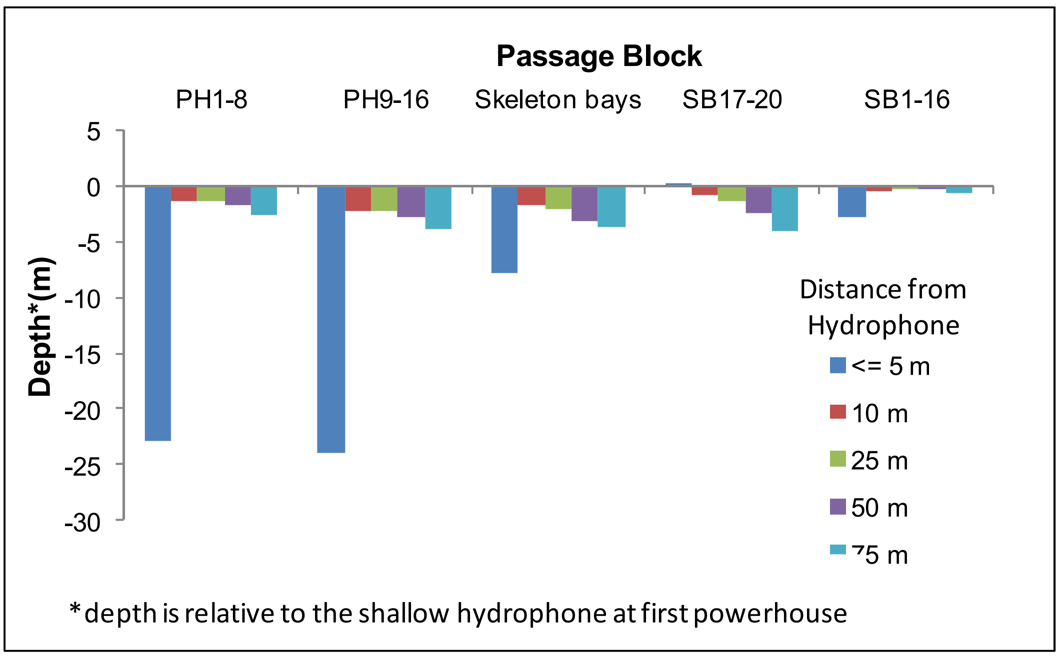

Figure 6.4. Overall median depth at last detection of tagged CH1 at JDA (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL, about 3 m below the surface of the water.

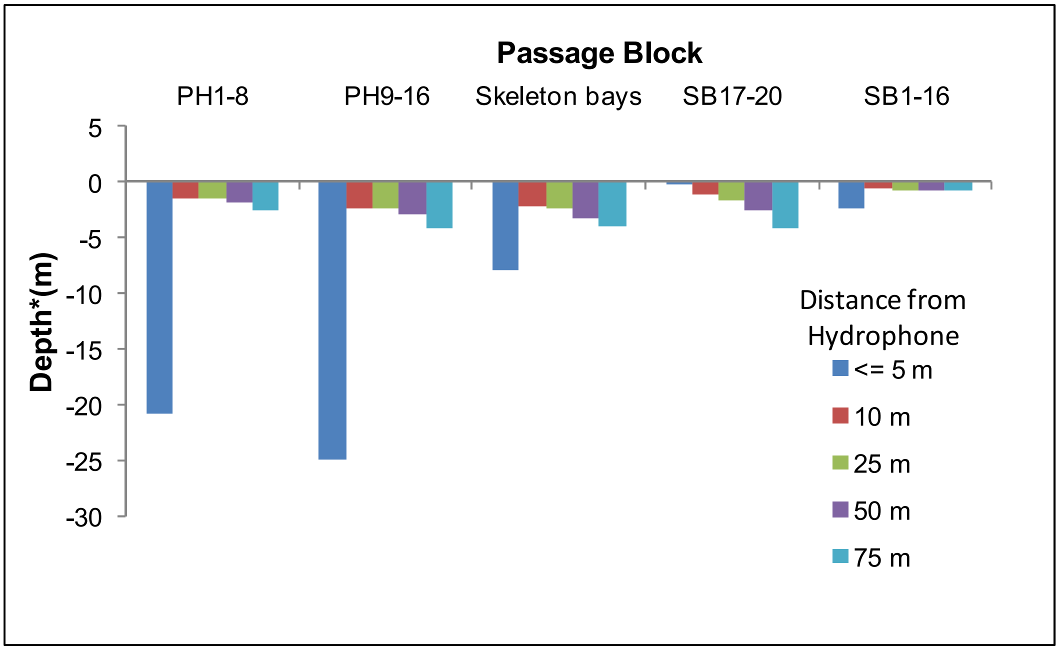

Figure 6.5. Median depth at last detection of tagged CH1 at JDA during daytime (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL, about 3 m below the surface of the water.

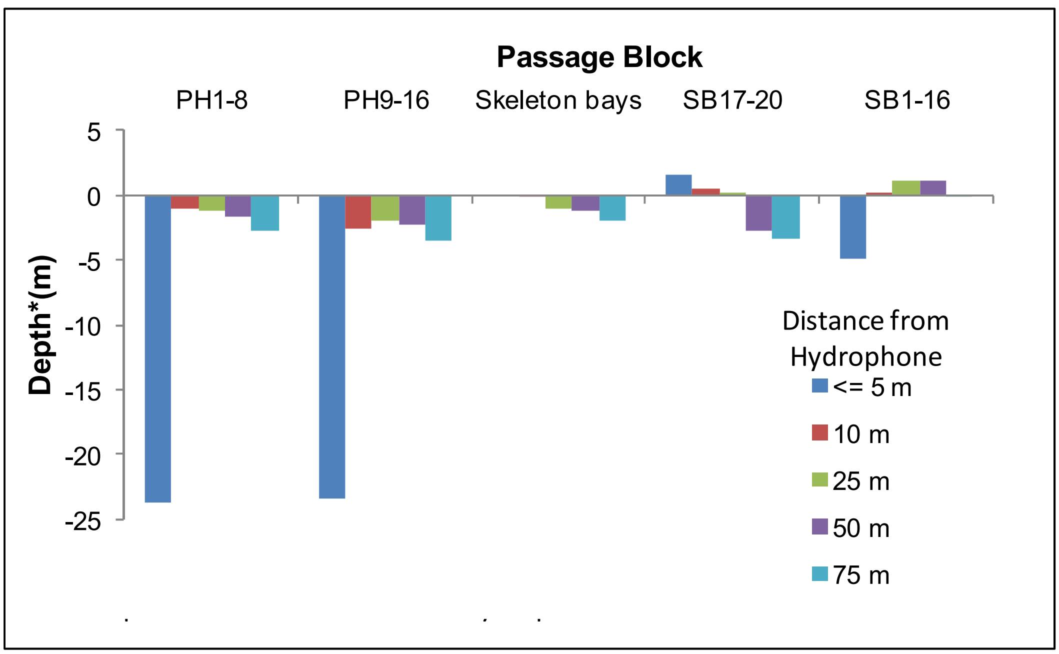

Figure 6.6. Median depth at last detection of tagged CH1 at JDA at night (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL, about 3 m below the surface of the water.

7.0 Results – Juvenile Steelhead

This section contains estimates of survival rates, travel times, passage metrics, and distributions for juvenile STH at JDA during spring 2010. Capture-history data are presented in Appendix D, and tagging tables summarizing fish releases are available in Appendix E.

7.1 Survival Estimates

Seasonal, route-specific, and day/night survival estimates for juvenile STH are presented in the following sections.

7.1.1 Point Estimates

Single-release survival estimates ($\hat{S}$ [±S.E.]) were calculated for the 2,288 STH released at Roosevelt, Washington (CR390) and regrouped at the JDA dam face (CR349) to form virtual releases. STH survival from JDA to TDA was approximately 95% for fish forming the virtual release from the JDA dam face (0.950 ± 0.005) or from the forebay entrance (0.948 ± 0.005; Table 7.1). Route-specific passage survival was approximately 97% for STH passing through the spillway (Table 7.2). Fish that passed via the two TSW bays at the spillway had greater survival rates (0.972 ± 0.004) than those that passed at non-TSW bays (0.944 ± 0.012). The survival rate was 95.5% for fish passing through spill bay 20 with the modified flow deflector. The lowest survival rate was observed for turbine-passed fish (0.694 ± 0.074). Survival rates through the JBS decreased after the repair of a loose steel plate, but the difference in survival before and after the repair was not significant (Table 7.3).

Table 7.1. STH passage survival from the JDA forebay entrance array and dam-face array to the dam face at TDA.

Route	Survival Estimate	SE
Dam face to TDA (CR349 to CR309)	0.950	0.005
Forebay entrance to TDA (CR351 to CR309)	0.948	0.005

Table 7.2. STH route-specific survival from virtual release at the JDA dam face to TDA dam face (CR349 to CR309).

Route	Survival Estimate	SE
Spillway virtual release to TDA	0.967	0.004
TSW virtual release to TDA	0.972	0.004
Non-TSW virtual release to TDA	0.944	0.012
Spill bay 20 virtual release to TDA	0.955	0.022
JBS virtual release to TDA	0.943	0.017
Turbine virtual release to TDA	0.694	0.074

Table 7.3. STH juvenile bypass system survival before and after repair of a loose steel plate in the bypass channel.

Metric	All Spring	SE	Prior to 5/20	SE	After 5/21	SE
JDA dam face to TDA (CR349 to CR309)	0.943	0.017	0.944	0.021	0.941	0.030

7.1.2 Day/Night Trends in Survival

During the spring season, data were divided into day (civil sunrise to civil sunset) and night (civil sunset to civil sunrise) periods and route-specific survival was generally higher during the day; however, only survival from the JDA dam face and JBS virtual releases to TDA were significantly different (Table 7.4). Passage efficiency through the TSW compared to total spillway passage also appeared to be significantly higher during the day than at night (86% and 59%, respectively; Table 7.5).

Table 7.4. Comparison of day/night single-release estimates of survival for juvenile STH (CR349 to CR309).

	Day		Night	
Survival Reach	Estimate	SE	Estimate	SE
Dam face to TDA	0.971[(a)]	0.005	0.931[(a)]	0.011
JBS virtual release to TDA	1.004[(a)]	0.002	0.939[(a)]	0.018
Spillway virtual release to TDA	0.973	0.004	0.942	0.012
TSW virtual release to TDA	0.975	0.005	0.958	0.014

(a) Significantly different when comparing ½ 95% CIs.

Table 7.5. TSW passage efficiency of juvenile STH relative to the spillway.

	Day		Night	
Metric	Estimate	SE	Estimate	SE
TSWE || Spillway	0.864[(a)]	0.009	0.593[(a)]	0.025

(a) Significantly different when comparing ½ 95% CIs.

7.2 Spill Treatment Effects

There were no treatment fish in 30% spill for Block 1 or 40% spill for Block 8 so these two blocks were removed from the comparison (Table 7.6). There were no significant differences in survival within individual spill treatment blocks as indicated by overlapping CIs. A Shapiro-Wilk normality test determined data from 30% and 40% spill conditions were normally distributed (alpha = 0.05: $P = 0.80$), which permitted comparisons using t-tests. There was a significant difference in mean survival estimates of STH between the 30% and 40% spill discharge levels for Blocks 2 through 7, with mean survival rates of 93.4% and 96.3%, respectively ($P = 0.02$; Table 7.7). In addition, STH survival estimates pooled over the entire season were significantly higher during the 40% spill treatment (Table 7.8). Relative to the dam, TSWE was significantly higher (*P* < 0.05) during the 30% spill treatment (75.2%) than the 40% treatment (69.2%). Relative to the spillway, TSWE was significantly higher for the 30% spill treatment when compared to the 40% spill treatment. Other major passage metrics did not differ significantly between the spill treatments.

Table 7.6. Estimates of JDA dam face to TDA forebay passage survival rates by two-day block and spill treatment for STH (CR349 to CR309).

Block	30% Spill	1/2 95% CI	40% Spill	1/2 95% CI
1	-	-	0.930	0.052
2	0.957	0.036	0.959	0.037
3	0.932	0.045	0.951	0.034
4	0.945	0.037	0.942	0.038
5	0.927	0.050	0.985	0.019
6	0.929	0.031	0.971	0.018
7	0.915	0.051	0.971	0.030
8	0.896	0.066	-	-

Table 7.7. Results of a one-tailed, paired t-test comparing estimates of JDA dam face to TDA forebay passage survival rates by two-day block for spill treatment Blocks 2-7 for STH (CR349 to CR309).

	30% Spill	40% Spill
Mean	0.9343	0.9633
Variance	0.0002	0.0002
Observations	6	6
Pearson Correlation	–0.5679	
Hypothesized Mean Difference	0	
df	5	
t Stat	–2.6527	
P(T<=t) one-tail	0.0226	
t Critical one-tail	2.0150	
P(T<=t) two-tail	0.0453	
t Critical two-tail	2.5706	

Table 7.8. Estimates of major passage metrics by spill treatment for STH.

	30% Spill		40% Spill		
Metric	Estimate	SE	Estimate	SE	Sig diff[(a)]
Survival – Dam face to TDA (CR349 to CR309)	0.942	0.008	0.975	0.005	*
Survival – Forebay entrance to TDA (CR351 to CR309)	0.931	0.008	0.962	0.006	*
FPE || Dam	0.982	0.004	0.982	0.004	
SPE || Dam	0.871	0.011	0.904	0.009	
TSWE || Dam	0.752	0.014	0.692	0.014	*
TSWE || Spillway	0.864	0.012	0.765	0.013	*
FGE (powerhouse screen efficiency)	0.857	0.031	0.813	0.037	
JBSE || Dam	0.111	0.010	0.078	0.008	

(a) Spill treatments were compared using ½ 95% CIs.

7.3 Travel Times

There were 2,138 tagged STH detected on the forebay array; they had a median residence time from the forebay entrance to the dam of 4.44 h (Table 7.9). Median residence time from 100 m upstream of the dam until passage through JDA was 1.37 h, while median travel time from the JDA dam face to the tailrace egress array (CR349 to CR346) was approximately 0.63 h. Median project passage time for STH from the JDA entrance (CR351) to the JDA egress array (CR346) was 5.71 h.

Table 7.9. Juvenile STH residence times (h) at JDA.

Route	n	Median	Mean	Max	Min	SE
Forebay (CR351 to CR349)	2,138	4.44	13.70	241.3	0.5	0.51
100-m forebay residence time	1,501	1.37	8.12	235.8	0.1	0.46
JDA egress time (CR349 to CR346)	2,072	0.63	2.49	459.0	0.3	0.33
Project passage time (CR351 to CR346)	2,072	5.71	16.09	461.1	1.0	0.62

SE = standard error.

7.4 Estimates of Passage Efficiency

During 2010, overall estimates of major passage metrics compared to the entire dam for STH included FPE of 98.2%, SPE of 88.8%, and TSWE of 71.9% (Table 7.10). The JBS had the lowest passage efficiency when compared to the entire dam at 9.4%.

Table 7.10. Estimates of major passage metrics for juvenile STH at John Day Dam.

Metric	Estimate	SE
FPE || Dam[(a)]	0.982	0.003
SPE || Dam[(a)]	0.888	0.007
TSWE || Dam[(a)]	0.719	0.010
TSWE || Spillway	0.809	0.009
FGE (powerhouse screen efficiency)	0.837	0.024
JBSE || Dam[(a)]	0.094	0.006

(a) If dam route is included, proportions will not add up to 1.

7.5 Fish Passage Distributions

The following sections present results for juvenile STH horizontal distribution, forebay approach distribution, and forebay vertical distribution.

7.5.1 Horizontal Distribution

The majority of STH (88.7 %) passed JDA via the spillway and fish were passed at every spill bay. A direct relationship was observed between the proportion of STH passing through specific bays and water discharge levels (Figure 7.1). Over 70% of all STH traveled through the TSWs (spill bays 18 and 19), where discharge was markedly higher (8.4%) compared to the other spill bays. A similar trend was observed with turbine and JBS passage, and was particularly evident at turbine units 1, 2, 5, and 15 (Figure 7.2). Of the 11.3% of fish that passed at the powerhouse, over 80% were routed through the JBS. No tagged fish were detected passing at turbine unit 6.

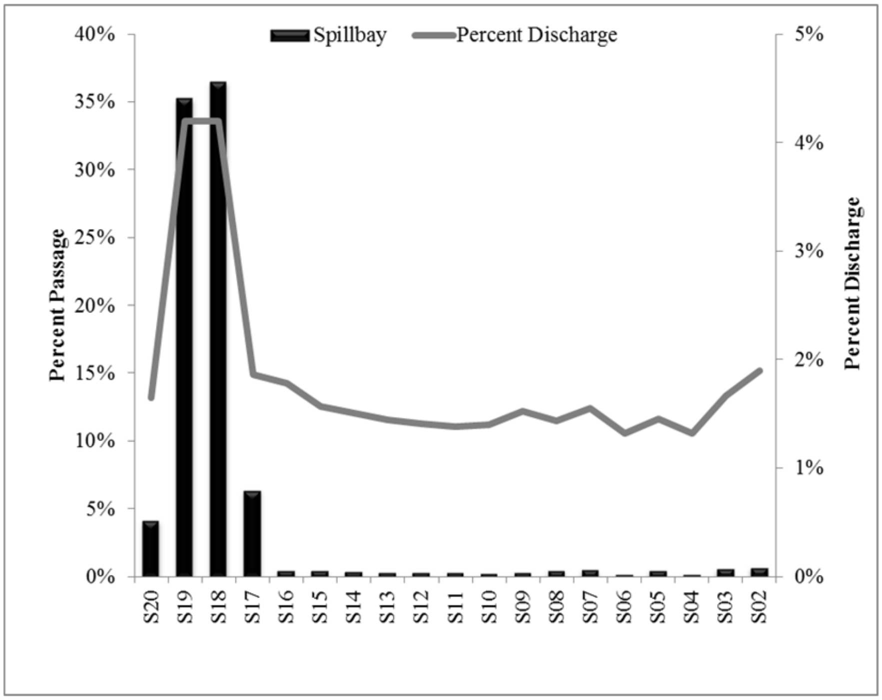

Figure 7.1. Percent passage and discharge of juvenile STH by spill bay (S).

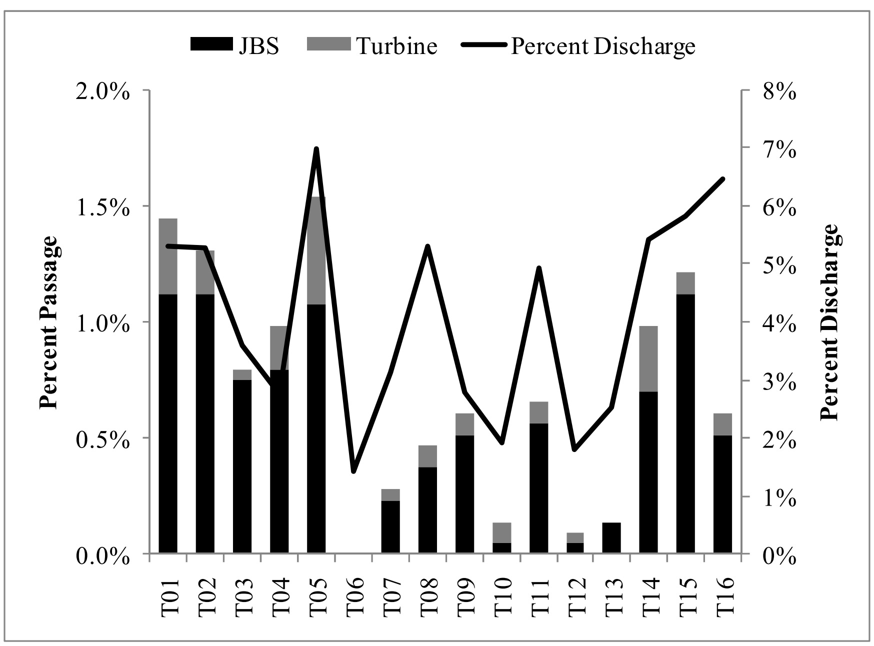

Figure 7.2. Percent passage and discharge of juvenile STH by juvenile bypass system (JBS) and turbine (T) unit.

7.5.2 Day/Night Forebay Approach Distribution and Residence Times

Most STH (≈74%) passed JDA during the day and 43% of STH approached upstream of the spillway and passed via the spillway during this period (Figure 7.3). Similar to results for CH1, the STH were attracted to the spillway in greater proportion during the day than at night; the spillway attracted 40% of STH that approached the powerhouse, and 15% of STH that approached skeleton bays during the day (Figure 7.3). At night, 32% of STH approached the spillway and passed via the spillway. STH that approached the powerhouse at night were slightly more likely to pass at the powerhouse (27%) than at the spillway (24%). Six percent of fish approaching the skeleton bay region at night passed via the powerhouse, while 7% passed via the spillway. Very few fish that first approached the spillway ended up passing at the powerhouse regardless of day or night (<6%).

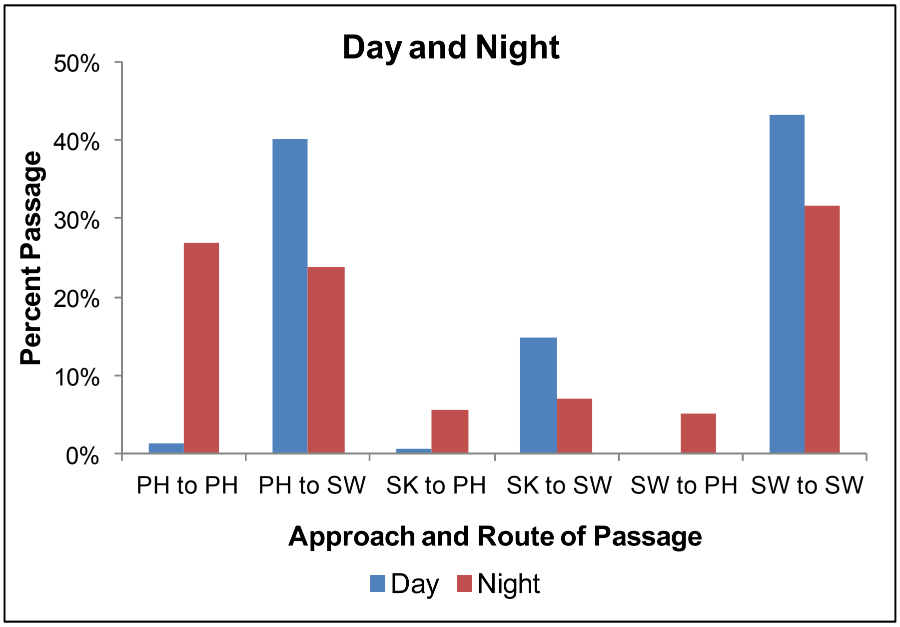

Figure 7.3. STH approach and passage distributions during day and night. The first abbreviation is for the approach location, and the second is for the passage location (PH = powerhouse; SK = skeleton bay; SW = spillway).

STH that approached the spillway and passed at the powerhouse exhibited the longest median residence times (Table 7.11) for both day and night (12.7 h and 11.4 h, respectively). Extended residence times were also noted for fish approaching the powerhouse and passing via the spillway at the night (7.6 h).

Table 7.11. STH median residence times (h) based on approach and passage structure during day and night periods.

Approach and Passage	Median Residence Time (h) All	Day	Night
Powerhouse to powerhouse	0.88	1.60	0.78
Powerhouse to spillway	2.88	2.38	7.61
Skeleton bays to powerhouse	1.64	2.85	1.46
Skeleton bays to spillway	0.57	0.53	0.94
Spillway to powerhouse	11.35	12.66	11.35
Spillway to spillway	0.43	0.47	0.36

7.5.3 Forebay Vertical Distribution

Generally, median STH approach depth was within 3 m above or below the shallow hydrophone location (the hydrophone was about 3 to 4 m below the water surface) for all passage blocks (Figure 7.4). Depth generally decreased or remained stable during the first 70 m of the approach. However, within 5 m of the dam-face STH depth increased to more than 20 m for fish passing by turbine or JBS routes. Minimal fluctuation in approach depth was evident with STH that passed via spill bays 17–20; STH migrated consistently at a depth similar to that of the shallow hydrophone. Swimming depth increased at spill bays 1–16 as STH approached within <5 m of the dam face. Daytime patterns were similar, with fish depth generally decreasing during the first 70 m of the approach (Figure 7.5). STH were generally approaching deeper during the night than during the day (Figure 7.6).

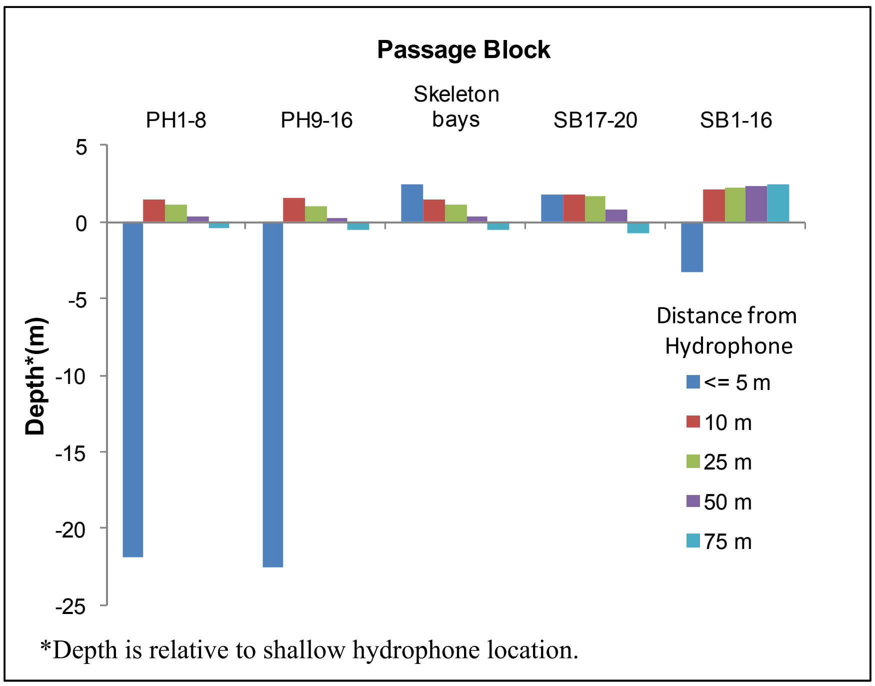

Figure 7.4. Overall median depth of last detection of tagged juvenile STH at JDA (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL.

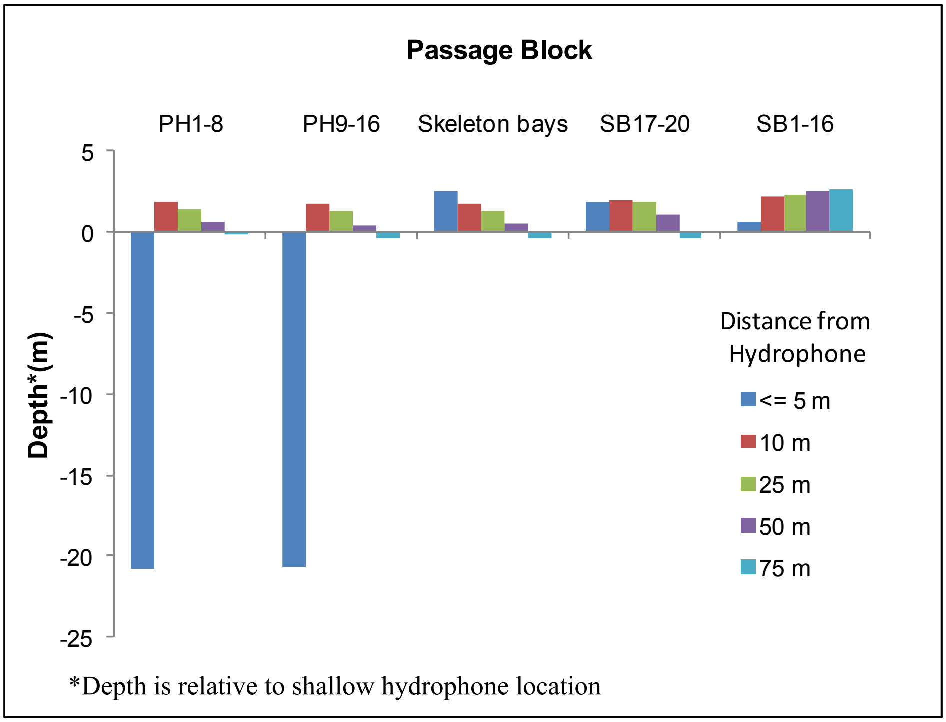

Figure 7.5. Median depth at last detection of tagged juvenile STH at JDA during daytime (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL.

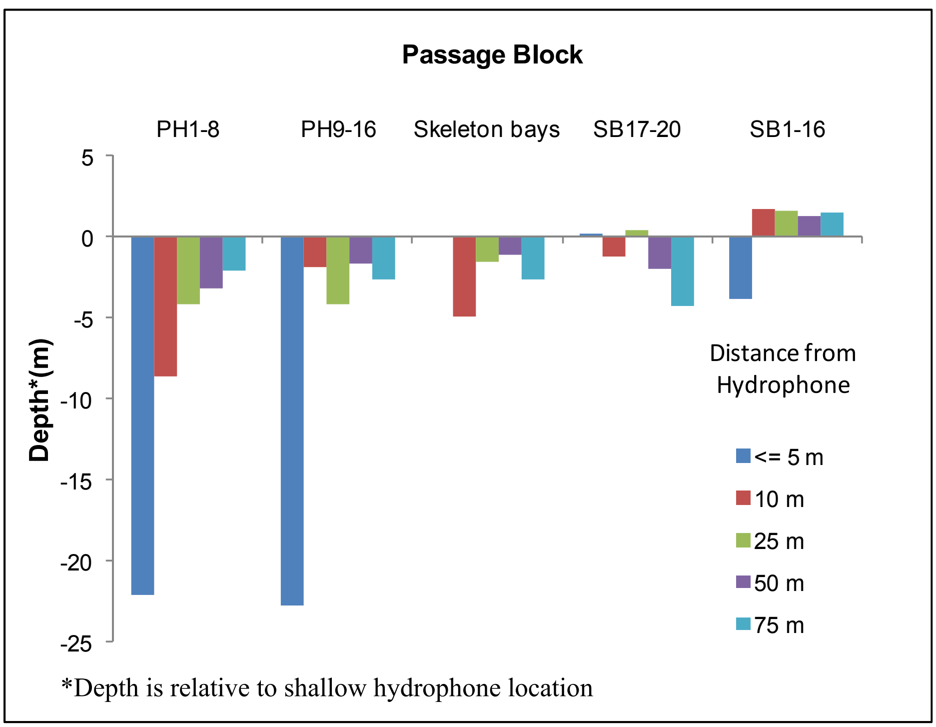

Figure 7.6. Median depth at last detection of tagged juvenile STH at JDA at night (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL.

8.0 Results – Subyearling Chinook Salmon

This section contains estimates of survival rates, travel times, passage metrics, and distributions for CH0 at JDA during summer 2010. Capture-history data are presented in Appendix D, and tagging tables summarizing fish releases are available in Appendix E.

8.1 Survival Estimates

Seasonal, route-specific, and day/night CH0 survival estimates are presented in the following sections.

8.1.1 Point Estimates

Single-release survival estimates ($\hat{S}$ [±S.E.]) were calculated for 2,660 CH0 released at Roosevelt, Washington (CR390) and regrouped at JDA. Dam passage survival from the upstream dam face of JDA (CR349) to the dam face at TDA (CR309) was 0.908 (SE=0.006), which did not meet the 0.93 survival requirement defined in the BiOp (Table 8.1). However, the required precision of SE ≤0.015 was met.

Survival was similar for fish virtually released from the JDA forebay entrance array (0.904 ±0.006) suggesting low forebay loss (Table 8.1). Survival of CH0 that passed at the spillway was <93%, and Non-TSW-passed fish were observed to have a higher rate of survival (0.937 ± 0.007) than TSW-passed fish (0.912 ± 0.010) (Table 8.2). Survival through spill bay 20, with the modified flow deflector, was lower than any other route through the spillway (0.891 ± 0.027). CH0 that passed through the JBS were observed to have the highest survival rate (0.947 ± 0.013) contrasted to the lowest survival rate observed for turbine-passed fish (0.818 ± 0.022).

Table 8.1. CH0 passage survival from the John Day Dam forebay entrance and dam face to the dam face at The Dalles Dam (CR349 to CR309).

Route	Survival Estimate	SE
JDA dam face to TDA (CR349 to CR309)	0.908	0.006
JDA forebay entrance to TDA (CR351 to CR309)	0.904	0.006

Table 8.2. CH0 route-specific survival from the dam-face virtual release at John Day Dam to The Dalles Dam tailrace (CR349 to CR309).

Route	Survival Estimate	SE
Spillway virtual release to TDA	0.927	0.006
TSW virtual release to TDA	0.912	0.010
Non-TSW virtual release to TDA	0.937	0.007
Bay 20 virtual release to TDA	0.891	0.027
JBS virtual release to TDA	0.947	0.013
Turbine virtual release to TDA	0.818	0.022

8.1.2 Day/Night Trends in Survival

Route-specific survival was generally higher during night periods (civil sunset to civil sunrise) compared to day periods (civil sunrise to civil sunset), but the differences were not statistically significant (Table 8.3). Passage efficiency through the TSW, compared with that through the entire spillway, appeared to be significantly greater during the day (42%) than at night (33%) (Table 8.4).

Table 8.3. Comparison of day/night single-release estimates of survival for CH0 (CR349 to CR309).

	Day		Night	
Survival Reach	Estimate	SE	Estimate	SE
Dam face to TDA	0.914	0.007	0.922	0.009
JBS virtual release to TDA	0.931	0.025	0.955	0.015
Spillway virtual release to TDA	0.923	0.007	0.940	0.011
TSW virtual release to TDA	0.908	0.011	0.931	0.020

Table 8.4. TSWE of CH0 relative to the spillway.

	Day		Night	
Metric	Estimate	SE	Estimate	SE
TSWE‖Spillway	0.423[(a)]	0.013	0.329[(a)]	0.021

(a) Significantly different when comparing ½ 95% CIs.

8.2 Spill Treatment Effects

Spill Blocks 8 and 9 were removed from the analysis because there were insufficient numbers of fish within at least one of the treatments. For example, the 40% spill treatment during Block 8 only included 15 fish (Table 8.5), and lower sample sizes occurred in both treatments of Block 9. The 40% spill treatment in Block 1 had spill levels above 35% most of the time and was retained, although it only reached 40% for a few hours over 2 d. There appeared to be no significant difference in survival of CH0 during 30% or 40% spill within specific blocks as indicated by overlapping CIs. A Shapiro-Wilk normality test determined that data from 30% and 40% spill treatments were normally distributed (alpha = 0.05; $P = 0.249$), allowing t-tests to be used for comparisons. There was no significant difference in mean survival of CH0 passing through JDA during 30% and 40% spill treatments ($P = 0.12$; Table 8.6). In addition, no differences in survival were observed between the spill treatments when estimates were pooled over the entire season (Table 8.7). FPE and SPE were significantly higher during the 40% spill treatment than during the 30% treatment. The inverse was true for TSWEs relative to the dam and spillway because survival was higher for 30% spill than 40% spill. Other major passage metrics did not differ significantly between the spill treatments.

Table 8.5. Estimates of JDA dam face to TDA forebay passage survival rates by two-day block and spill treatment for CH0 (CR349 to CR309).

Block	30% Spill	1/2 95% CI	N	40% Spill	1/2 95% CI	N
1	0.955	0.031	176	0.942	0.039	139
2	0.942	0.039	138	0.958	0.027	214
3	0.908	0.042	184	0.933	0.037	178
4	0.950	0.032	179	0.875	0.050	168
5	0.904	0.045	166	0.906	0.045	159
6	0.911	0.045	157	0.888	0.049	161
7	0.884	0.048	172	0.797	0.068	133
8[(a)]	0.787	0.093	75	0.533	0.253	15

(a) Blocks 8 and 9 were removed from the analysis.

Table 8.6. Results of a one-tailed, paired t-test comparing estimates of JDA face to TDA forebay passage survival rates by two-day block and spill treatment for CH0 (CR349 to CR309).

	30% Spill	40% Spill
Mean	0.9218	0.8998
Variance	0.0007	0.0029
Observations	7	7
Pearson Correlation	0.6058	
Hypothesized Mean Difference	0	
df	6	
t Stat	1.3356	
P(T<=t) one-tail	0.1151	
t Critical one-tail	1.9432	
P(T<=t) two-tail	0.2301	
t Critical two-tail	2.4469	

Table 8.7. Estimates of major passage metrics for by spill treatment for CH0.

Metric	30% Spill Estimate	30% Spill SE	40% Spill Estimate	40% Spill SE	Sig diff[(a)]
Survival – Dam face to TDA (CR349 to CR309)	0.919	0.008	0.914	0.008	
Survival – Forebay entrance to TDA (CR351 to CR309)	0.915	0.008	0.907	0.008	
FPE || Dam	0.857	0.010	0.908	0.008	*
SPE || Dam	0.741	0.012	0.810	0.011	*
TSWE || Dam	0.352	0.013	0.272	0.012	*
TSWE || Spillway	0.475	0.016	0.335	0.014	*
FGE (powerhouse screen efficiency)	0.449	0.027	0.514	0.031	
JBSE || Dam	0.116	0.009	0.097	0.008	

(a) Spill treatments were compared using ½ 95% CIs.

8.3 Travel Times

The median residence time of the 2,635 tagged CH0 from the forebay entrance to the dam was 1.83 h (Table 8.8). Median time until passage through JDA (100-m forebay residence time) was approximately 0.29 h. Median travel time from the JDA face to the tailrace egress array was approximately 0.62 h. Median project passage time for CH0 from the JDA entrance (CR351) to the JDA egress array (CR346) was 2.65 h.

Table 8.8. CH0 residence times (h) at John Day Dam.

Route	n	Median	Mean	Max	Min	SE
Forebay (CR351 to CR349)	2,635	1.83	3.83	204.56	0.48	0.17
100-m forebay residence time	1,847	0.29	2.06	143.21	0.03	0.16
JDA egress time (CR349 to CR346)	2,394	0.62	1.94	813.40	0.27	0.36
Project passage time (CR351 to CR346)	2,396	2.65	5.55	814.84	0.87	0.39

8.4 Estimates of Passage Efficiency

During 2010, estimates of major passage metrics for CH0 at JDA show FPE at 88.3% relative to the dam (Table 8.9). Spill passage efficiency was 77.6%, TSWE was 31.1%, and JBSE was 10.7%. Fish-guidance efficiency was 47.7% for the powerhouse.

Table 8.9. Estimates of major passage metrics for CH0 at JDA.

Metric	Estimate	SE
FPE ‖ Dam[(a)]	0.883	0.006
SPE ‖ Dam[(a)]	0.776	0.008
TSW efficiency ‖ Dam[(a)]	0.311	0.009
TSW efficiency ‖ Spillway	0.401	0.011
FGE (powerhouse screen efficiency)	0.477	0.021
JBS efficiency ‖ Dam[(a)]	0.107	0.006

(a) If dam route is included, proportions will not add up to 1.

8.5 Fish Passage Distributions

The following sections present findings for CH0 horizontal distribution, forebay approach distribution, and forebay vertical distribution.

8.5.1 Horizontal Distribution

The greatest proportion of CH0 passed through spill bays 17–20 (Figure 8.1). In particular spill bays 18 and 19, the location of the TSWs, passed about 31% of all CH0 passing JDA. Passage at spill bays 2–16 ranged from about 0.8% at bay 6 to approximately 3.2% at bay 16. The number of CH0 that passed at the powerhouse was much lower than at the spillway, despite greater discharge at the powerhouse (Figure 8.2). In general, passage of CH0 at the powerhouse through turbines, and CH0 guided into the JBS, was proportional to unit discharge. Highest passage relative to discharge, however, was at turbine units 11–16 nearest the spillway.

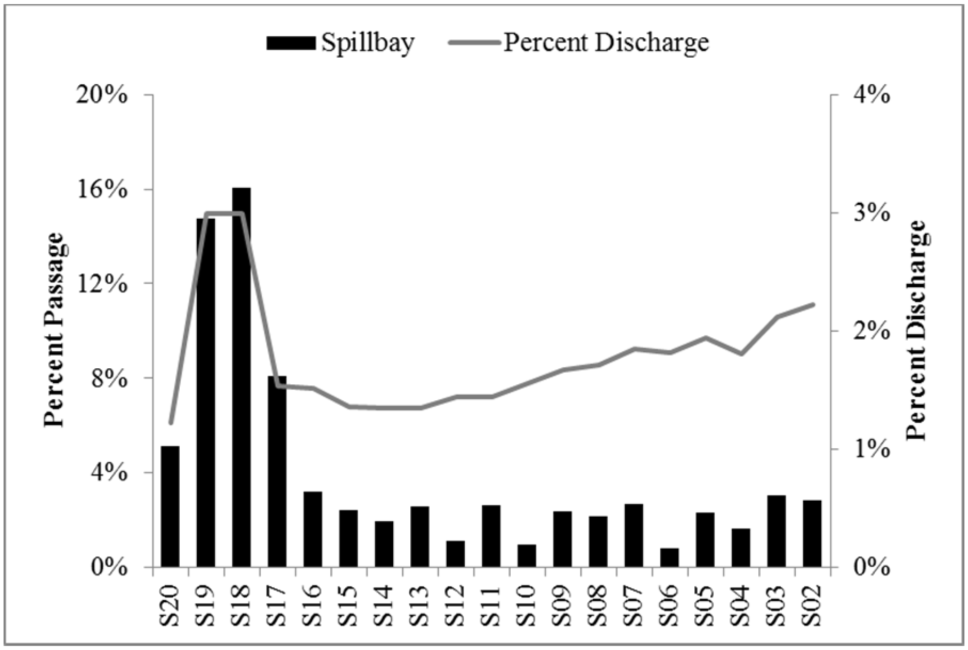

Figure 8.1. Percent passage and discharge of total number of CH0 by spill bay.

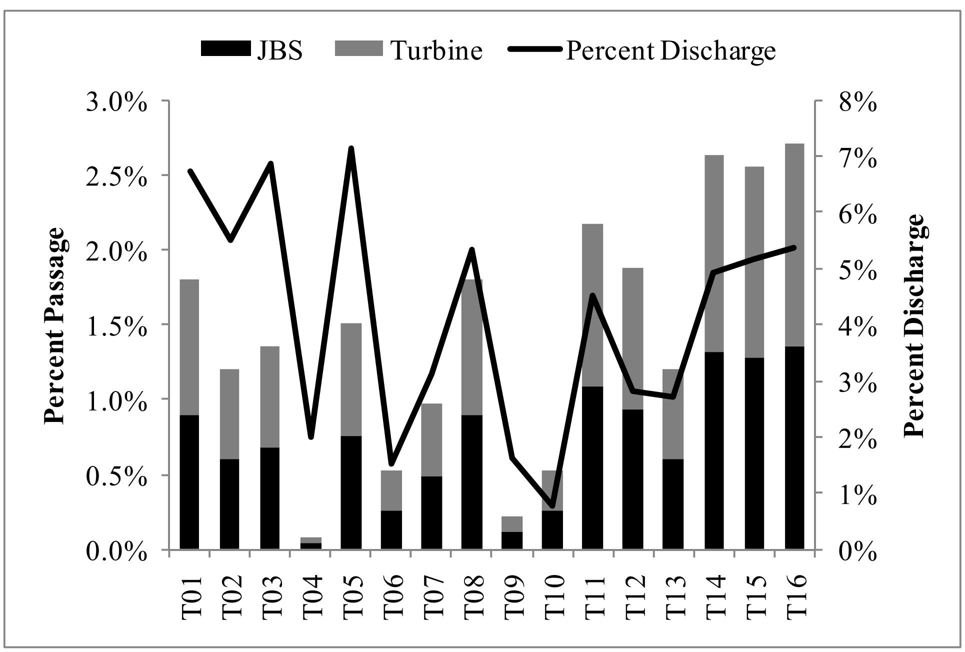

Figure 8.2. Percent passage and discharge of total number of CH0 by turbine (T) unit and juvenile bypass system (JBS) route.

8.5.2 Day/Night Forebay Approach Distribution and Residence Times

Most CH0 passed JDA during the day (≈71%) and the spillway was more effective at attracting CH0 during the day than at night; the spillway attracted 23% of CH0 that approached the powerhouse, and 14% of juvenile salmonids that approached skeleton bays (Figure 8.3). During the day, 50% of CH0 approached the spillway and passed via the spillway as opposed to 43% at night. CH0 that approached the powerhouse at night were much more likely to pass at the powerhouse (31%) than at the spillway (6%). Ten percent of CH0 that approached the skeleton bays at night passed via the powerhouse, while 5% passed via the spillway.

CH0 that either approached the spillway and passed at the powerhouse or approached the powerhouse and passed at the spillway exhibited the longest residence times (Table 8.10). The shortest residence times occurred for fish that approached and passed at the spillway. The longest residence times during day and night periods were observed at night with CH0 that approached the powerhouse and passed at the spillway (5.0 h) and those that approached the spillway and passed at the powerhouse (2.6 h).

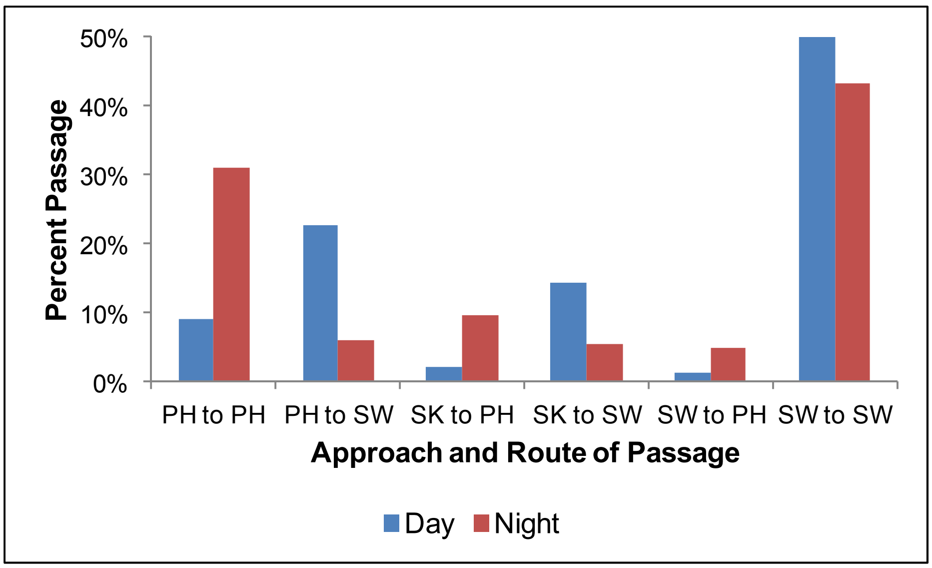

Figure 8.3. CH0 approach and passage distributions during day and night. The first abbreviation is for the approach location, and the second is for the passage location (PH = powerhouse; SK = skeleton bay; SW = spillway).

Table 8.10. CH0 median residence time (h) based on approach and passage structure for day and night periods.

	Median Residence Time (h)		
Approach and Passage	All	Day	Night
Powerhouse to powerhouse	0.30	0.46	0.22
Powerhouse to spillway	1.60	1.48	4.97
Skeleton bays to powerhouse	0.26	0.27	0.25
Skeleton bays to spillway	0.30	0.30	0.32
Spillway to powerhouse	1.95	1.65	2.64
Spillway to spillway	0.15	0.15	0.14

8.5.3 Forebay Vertical Distribution

In general, median CH0 approach depth was less than 5 m below the shallow hydrophone as fish approached spill bays and skeleton bays from a distance of 75 m (Figure 8.4). Median depth decreased during their approach to the skeleton bays and spill bays 17 through 20, and remained constant or slightly increased during the approach to spill bays 1 through 16. CH0 depth increased during the approach to the powerhouse units, reaching a depth of more than 7 m below the hydrophone at a distance of 10 m from the dam and more than 20 m within 5 m of the dam face. Day approach patterns were very similar to the overall patterns (Figure 8.5). During the night, CHO generally approached all structures at slightly greater depths but followed patterns similar to the daytime patterns (Figure 8.6). In particular, median depths of fish that approached the skeleton bays and all turbine units were much deeper (>4 m) at a distance of 10 m from the dam during the night.

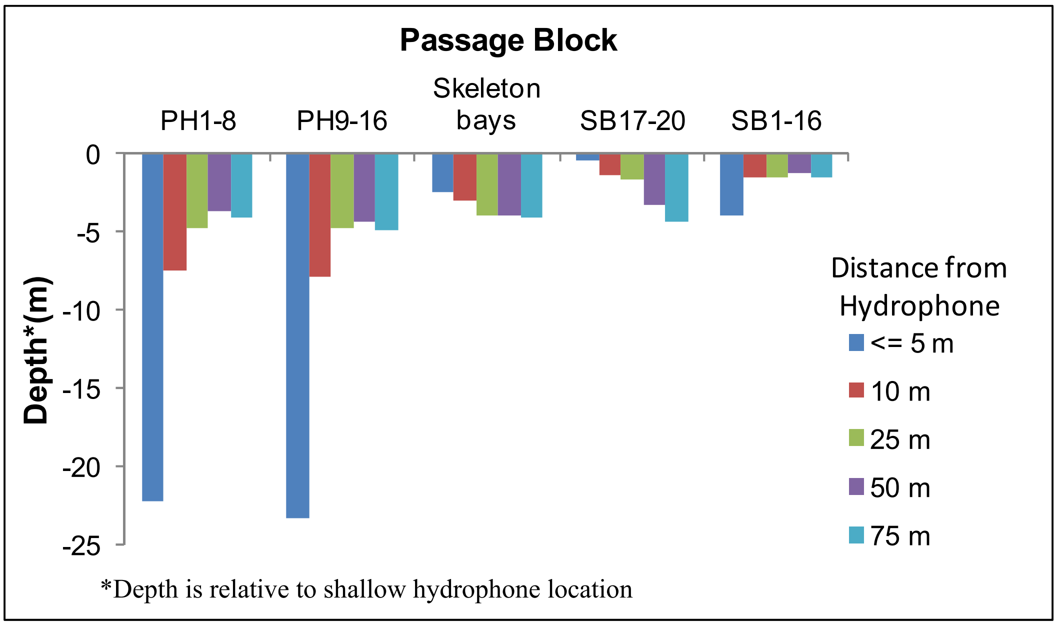

Figure 8.4. Overall median depth at last detection of tagged CH0 at JDA (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL.

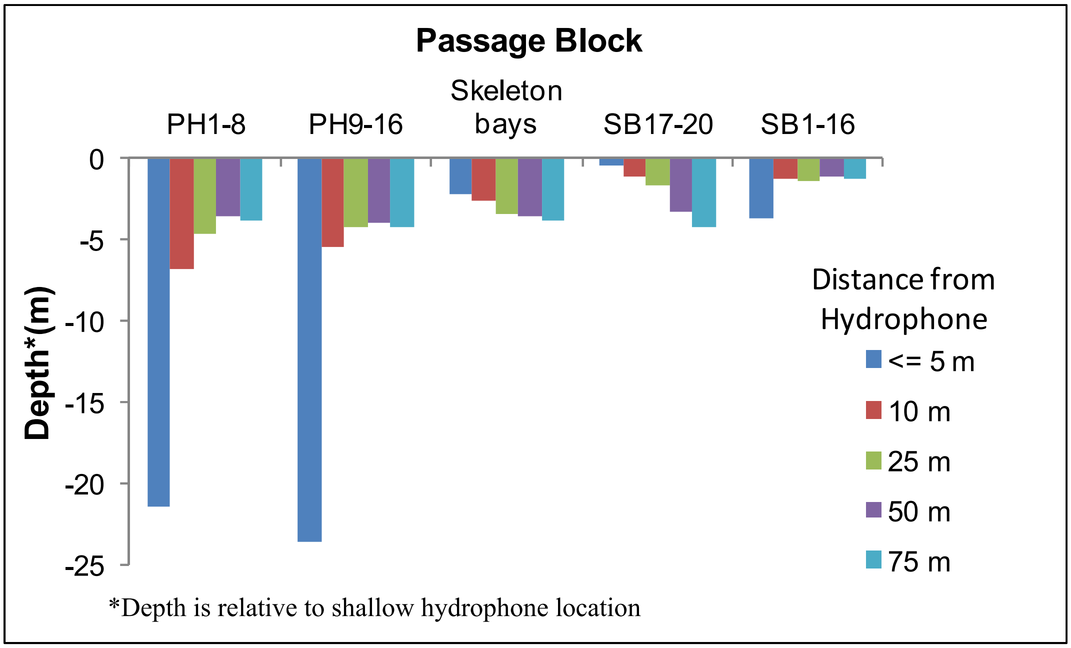

Figure 8.5. Median depth at last detection of tagged CH0 at JDA during daytime (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL.

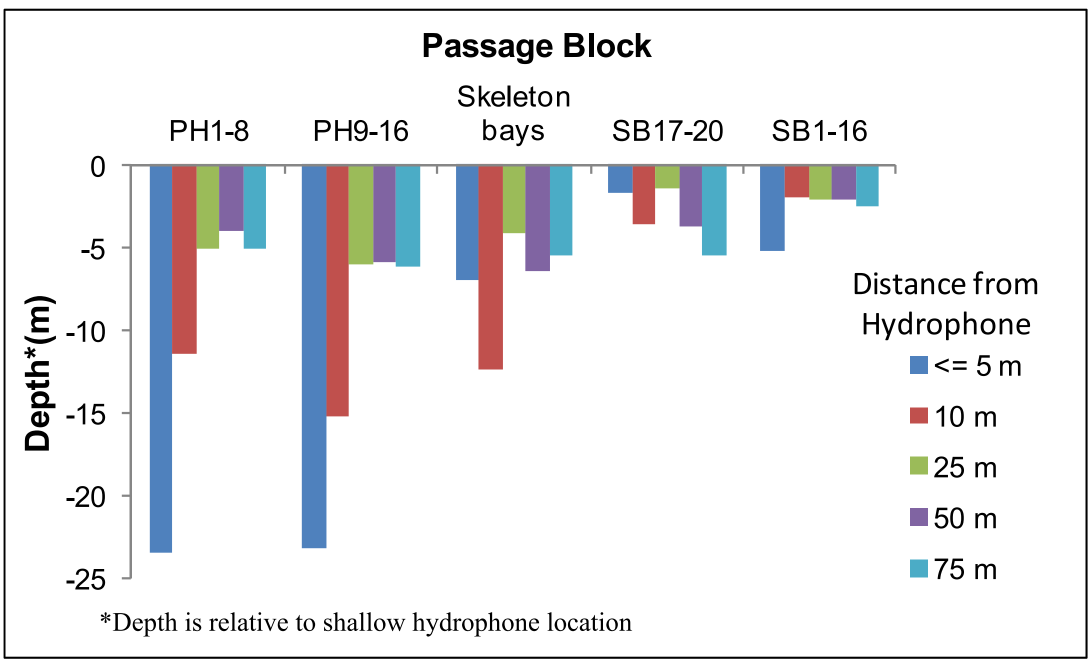

Figure 8.6. Median depth at last detection of tagged CH0 at JDA at night (PH = powerhouse; SB = spill bay). Depth distribution is referenced to hydrophone P00_01S at the south end of the powerhouse at 76.6 m above MSL.

9.0 Discussion

This section includes discussion of statistical performance and survival model assumptions; historical context; comparison of 30% and 40% spill survival and passage results for CH1 and juvenile STH in spring and CH0 in summer; SFO performance; and conclusions and recommendations. The survival study at JDA in 2010 was not an official BiOp test.

9.1 Statistical Performance and Survival Model Assumptions

The 2010 AT study at JDA provided reliable data on fish survival rates, passage rates, and behavior.

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 the run (10th to 90th percentile) for each species was nearly achieved. During the spring, tagging of CH1 and STH occurred during the middle 78% and 73% of the run, respectively. During the summer, tagging of CH0 corresponded with the middle 79% of the run. Comparison of AMT-tagged fish with ROR fish shows that the length frequency distributions were well matched for CH1 and STH. The median length for AMT-tagged CH1 was 152 mm and for tagged STH it was 215 mm. The distribution of fish lengths for CH0 was slightly offset from ROR CH0 sampled at the JDA SMF by the Fish Passage Center. The primary reason for this was the lower limit size restriction of fish <95 mm in length. This size limit has been implemented because the tag/fish-weight ratio (tag burden) is a confounding migratory factor, particularly in smaller fish, which can impede swim performance and increase predation events (Adams et al. 1998).

Detection probabilities for the dam-face cable arrays were excellent. The combined probability of detection for the two independent arrays was 100% (Table 5.1).

Tag-life study results. The majority of AMTs in the tag-life study were active for at least 32 d. In spring, mean tag life was 32.7 d and ranged from 7.8 to 39.6 d. A total of 13.7 d were required for more than 99% of the CH1 to pass the tertiary survival-detection array, and juvenile STH required 15.0 d. Only one of the 49 transmitters tested in the spring had a tag life less than 28 d resulting in minimal tag-life correction to the data. Summer mean tag life, of the 50 transmitters tested, was 35.5 d, ranging from 31 to 40 d. A total of 11.9 d were required for CH0 to pass the tertiary survival-detection array requiring no tag-life correction to survival estimates for CH0.

9.2 Survival Rates

Single-release survival estimates from JDA to TDA were similar whether fish were virtually released from the JDA dam face or JDA forebay entrance (Table 9.1). Survival rates were highest for juvenile STH and lowest for CH0. CH1 and STH did not meet the 96% performance standard set forth in the 2008 BiOp for spring migrants, nor did estimates for CH0 meet the BiOp standard of 93% for summer migrants. However, this study was not designed as a test of BiOp fish passage standards.

AT results from studies conducted in 2008 and 2009 (Weiland et al. 2009, 2011) were comparable to results observed in 2010. Route-specific survival rates for the JDA face virtual release to TDA tailrace are shown in Figure 9.1, Figure 9.2, and Figure 9.3 for CH1, STH, and CH0, respectively. Turbine passage had consistently lower survival rates for all species regardless of study year. CH1 survival in 2010 was highest via the spillways, with or without the presence of a TSW. JBS virtual-release survival rates for CH1 were noticeably lower in 2010 than in previous years; however, the discovery and repair of a loose steel plate in the JBS passage channel did not appear to have influenced survival. Survival rates via the TSWs, located in spill bays 18 and 19 in 2010, were analogous to those observed in 2008 and 2009 for each species.

Table 9.1. Survival from the JDA forebay entrance and dam face to the dam face at TDA (CR349 to CR309), 2010.

Species	Metric	Survival Estimate	Standard Error
CH1	JDA dam face to TDA (CR349 to CR309)	0.937	0.005
	JDA forebay entrance to TDA (CR351 to CR309)	0.934	0.005
STH	JDA dam face to TDA (CR349 to CR309)	0.950	0.005
	JDA forebay entrance to TDA (CR351 to CR309)	0.948	0.005
CH0	JDA dam face to TDA (CR349 to CR309)	0.908	0.006
	JDA forebay entrance to TDA (CR351 to CR309)	0.904	0.006

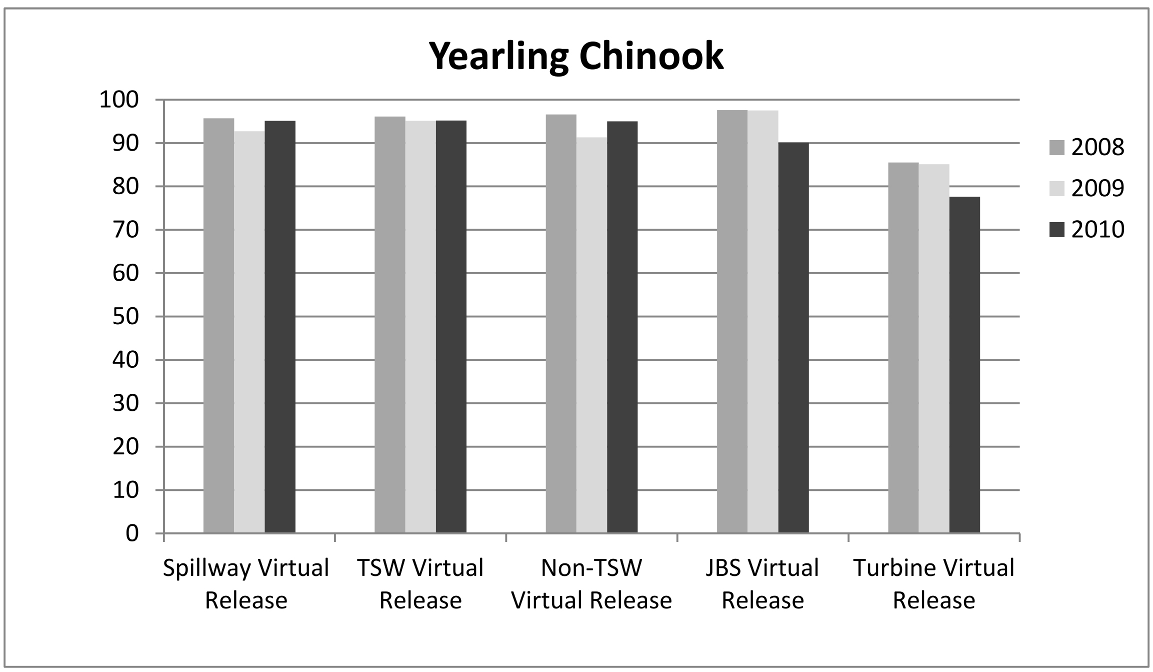

Figure 9.1. CH1 route-specific survival from the dam-face virtual release at John Day Dam to The Dalles Dam tailrace (CR349 to CR309), 2008–2010.

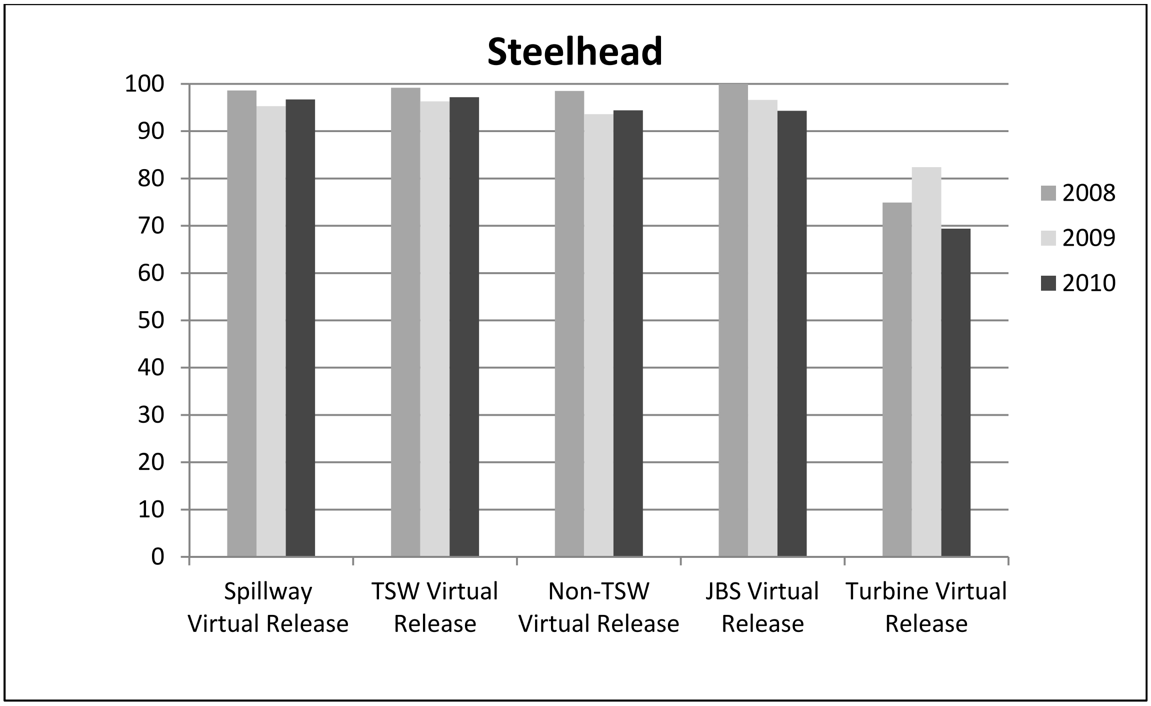

Figure 9.2. STH route-specific survival from the dam-face virtual release at John Day Dam to The Dalles Dam tailrace (CR349 to CR309), 2008–2010.

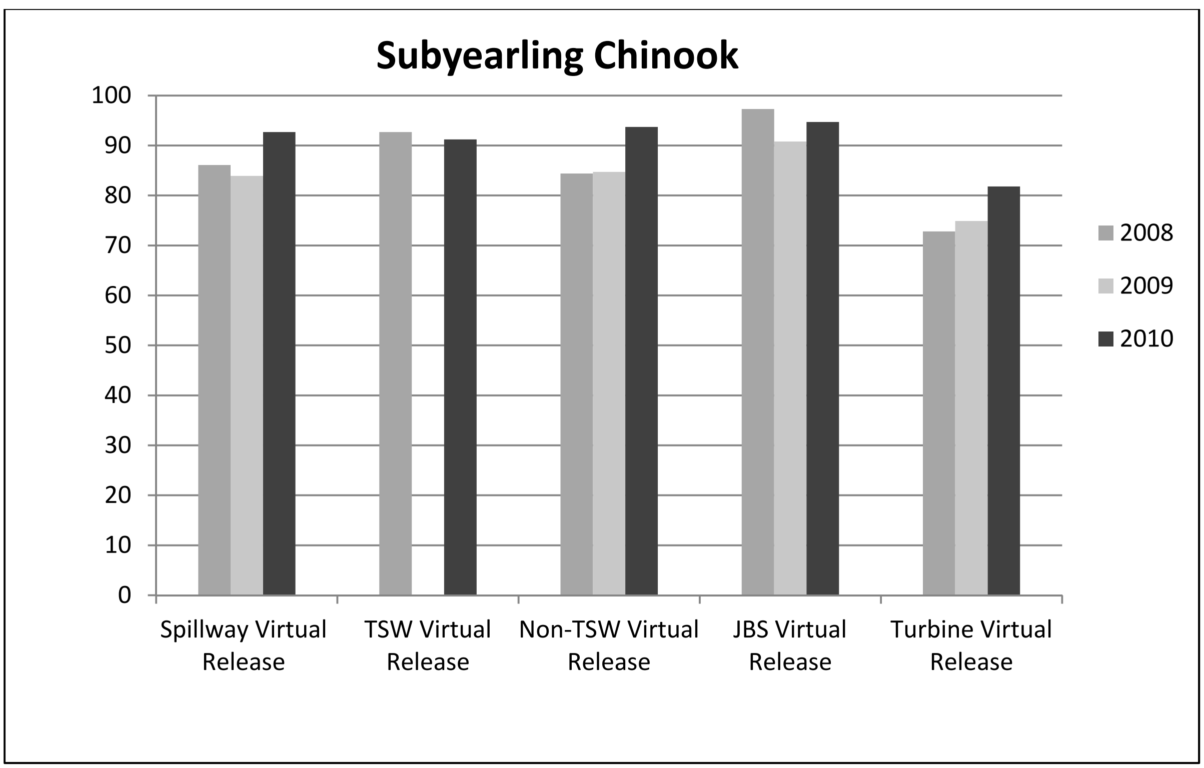

Figure 9.3. CH0 route-specific survival from the dam-face virtual release at John Day Dam to The Dalles Dam tailrace (CR349 to CR309), 2008–2010.

Differences in survival estimates between day and night were generally small and not significantly different for CH1 and CH0 in 2010; however for STH, dam passage survival was significantly higher during the day than at night. Passage efficiency of the TSW, compared with that of the spillway, was significantly lower during the day (61.2%) than at night (72.0%) for CH1, differing from that observed for CH0 and STH, where the TSW was more efficient at passing juvenile salmonids during the day.

9.3 Fish Metrics

During 2010, estimates of major passage metrics at JDA show improved passage efficiencies relative to the dam for FPE, SPE, and TSWE over 2008 and 2009 (Figure 9.4, Figure 9.5, and Figure 9.6; CH1, STH, and CH0, respectively). FPE, FGE, and TSWE were highest for STH, most likely because of their surface orientation, and lowest for CH0. Passage-route metrics showed that SPE, TSWE, and FGE were highest for 2010 passage, although there was a decrease in FGE for STH and CH1 compared to 2008 and 2009. The JBSE was also lower in 2010 than in previous years. Relative to the dam and spillway, TSWE was substantially higher for STH than for CH1 and CH0.

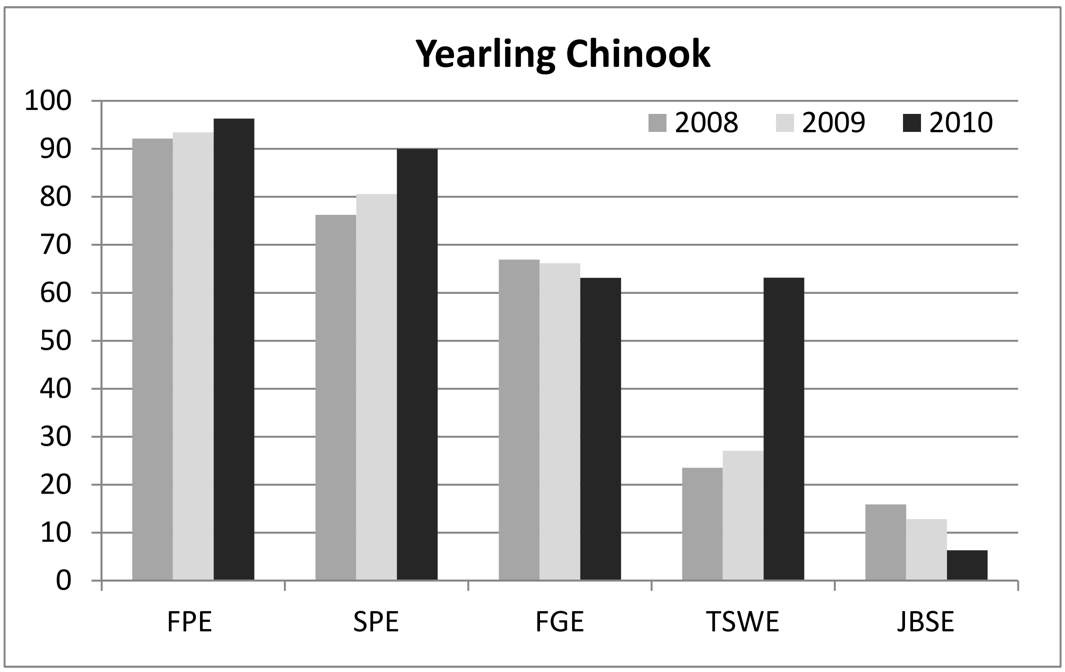

Figure 9.4. Summary of passage efficiency data for CH1, 2008–2010. The TSW was closed during the CH0 migration in summer 2009. (FPE = fish passage efficiency; SPE = spill passage efficiency; FGE = fish guidance efficiency; TSWE = top-spill weir passage efficiency; JBSE = juvenile bypass system passage efficiency).

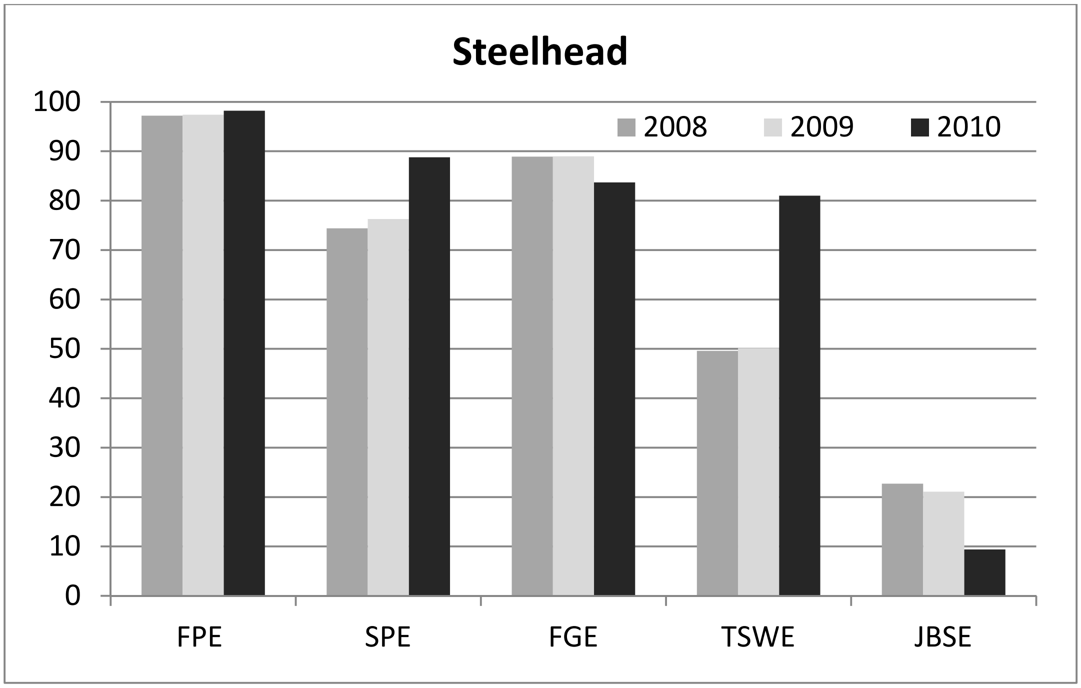

Figure 9.5. Summary of passage efficiency data for STH, 2008–2010. The TSW was closed during the CH0 migration in summer 2009. (FPE = fish passage efficiency; SPE = spill passage efficiency; FGE = fish guidance efficiency; TSWE = top-spill weir passage efficiency; JBSE = juvenile bypass system passage efficiency).

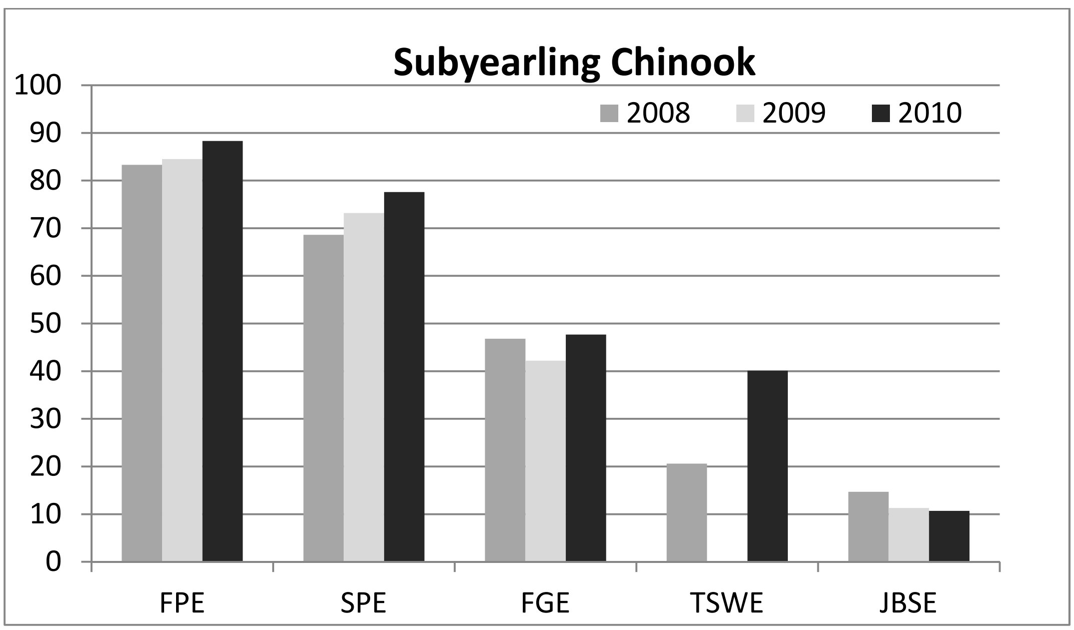

Figure 9.6. Summary of passage efficiency data for CH0, 2008–2010. The TSW was closed during the CH0 migration in summer 2009. (FPE = fish passage efficiency; SPE = spill passage efficiency; FGE = fish guidance efficiency; TSWE = top-spill weir passage efficiency; JBSE = juvenile bypass system passage efficiency).

Most spillway-passed CH1 passed through spill bays 17–20, which included the TSWs (bays 18–19) that had the highest discharge rates. Similar results were observed for STH and CH0, although the percent passage of CH0 was lower, possibly due to CH0 behavior characterized by deeper passage relative to other run types and species. Generally, passage through all spill bays increased proportionately with increase in percent discharge. Similar trends were observed for turbine- and JBS-passed fish; higher rates of discharge resulted in higher passage proportions. However, the proportion of STH that passed through the JBS rather than through the turbines was consistently greater than that observed for CH1 (Figure 7.2 and Figure 7.2).

9.4 Fish Behavior

Fish behavior was characterized by approach patterns and the eventual passage route; residence times and travel times; forebay vertical distribution; and day/night behavior patterns.

9.4.1 Residence Times

For the project as a whole, median residence times in the JDA forebay (CR351 to CR349) were 2.2 h for CH1, 4.4 h for STH, and 1.8 h for CH0 (Table 9.2). Median project passage time ranged from 2.7 h (CH0) to 5.7 h (STH). STH 100-m forebay residence time was greatest, with a median of 1.3 h, and they spent more time milling and possibly searching for a route of passage.

CH1 and CH0 that either approached the spillway and passed at the powerhouse or approached the powerhouse and passed at the spillway exhibited the longest median residence times, and their longest residence times occurred at night (Table 9.3). STH that approached the spillway and passed the powerhouse exhibited the longest residence times, with slightly longer times occurring during the day. Extended residence times were also noted for STH approaching the powerhouse and passing the spillway during the night.

Table 9.2. Residence times (h) at John Day Dam, 2010.

	CH1		STH		CH0	
Route	Mean	Median	Mean	Median	Mean	Median
Forebay (CR351 to CR349)	5.32	2.15	13.70	4.44	3.83	1.83
100 m Forebay residence time	3.26	0.58	8.12	1.37	2.06	0.29
JDA egress time (CR349 to CR346)	2.31	0.74	2.49	0.63	1.94	0.62
Project passage time (CR351 to CR346)	7.44	3.09	16.09	5.71	5.55	2.65

Table 9.3. Median residence time (h) by approach and passage route for day and night.

Approach and Passage	CH1 Median Residence Time (h)			STH Median Residence Time (h)			CH0 Median Residence Time (h)		
	All	Day	Night	All	Day	Night	All	Day	Night
Powerhouse to powerhouse	0.6	0.7	0.3	0.9	1.6	0.8	0.3	0.5	0.2
Powerhouse to spillway	1.8	1.6	3.6	2.9	2.4	7.6	1.6	1.5	5.0
Skeleton bays to powerhouse	0.5	0.7	0.5	1.6	2.9	1.5	0.3	0.3	0.3
Skeleton bays to spillway	0.3	0.3	1.2	0.6	0.5	0.9	0.30	0.3	0.3
Spillway to powerhouse	2	1.5	3.2	11.4	12.7	11.4	2.0	1.7	2.6
Spillway to spillway	0.2	0.2	0.4	0.4	0.5	0.4	0.2	0.2	0.1

9.4.2 Approach and Passage

CH1 forebay approach totaled 39.3% at the powerhouse, 17% at the skeleton bays, and 43.7% at the spillway (Figure 9.7a). Of the tagged CH1 first detected approaching the powerhouse or skeleton bays, 83% eventually moved north and passed at the spillway. Fish approaching at the spillway were more likely to pass through the dam at the spillway (98.4% of total approach) than at the powerhouse (1.6% of total approach). The TSWs and adjacent bays (spill bays 17 through 20) passed the majority of CH1 (76%). Dam passage was highest during the day (78.6%); most CH1 passed through the TSWs. Most of the CH1 passing during the night also passed through the TSWs, although turbine passage was also higher at night.

The forebay approach pattern for STH was 43.8% at the powerhouse, 14.6% at the skeleton bays, and 41.6% at the spillway (Figure 9.7b). Of the tagged STH first detected approaching the powerhouse or skeleton bays, 83% eventually moved north and passed at the spillway. Fish approaching at the spillway were more likely to pass through the dam at the spillway (96.5% of total approach) than at the powerhouse (3.5% of total approach). The TSWs and adjacent bays (spill bays 17 through 20) passed the majority of juvenile STH (82.4%), which is understandable, because STH tend to be more surface oriented. Dam passage was highest during the day (74.3%); most STH passed through the TSWs. The majority of STH passing during the night passed through the TSWs; although turbine passage was also higher at night.

The forebay approach pattern for CH0 was 33.2% at the powerhouse, 16.2% at the skeleton bays, and 50.6% at the spillway (Figure 9.7c). Of the tagged CH0 first detected approaching the powerhouse or skeleton bays, 59.7% eventually moved north and passed at the spillway. Fish approaching at the spillway were more likely to pass through the dam at the spillway (95.1% of total approach) than at the powerhouse (4.9% of total approach). While the majority of CH0 (45%) passed through the TSWs and adjacent bays (spill bays 17 through 20), the overall proportion was less than that observed for CH1 and STH, because CH0 tend to swim deeper in the water column. Dam passage was highest during the day (53.6%); most CH0 passed through the TSWs. Night passage was highest through the turbines.

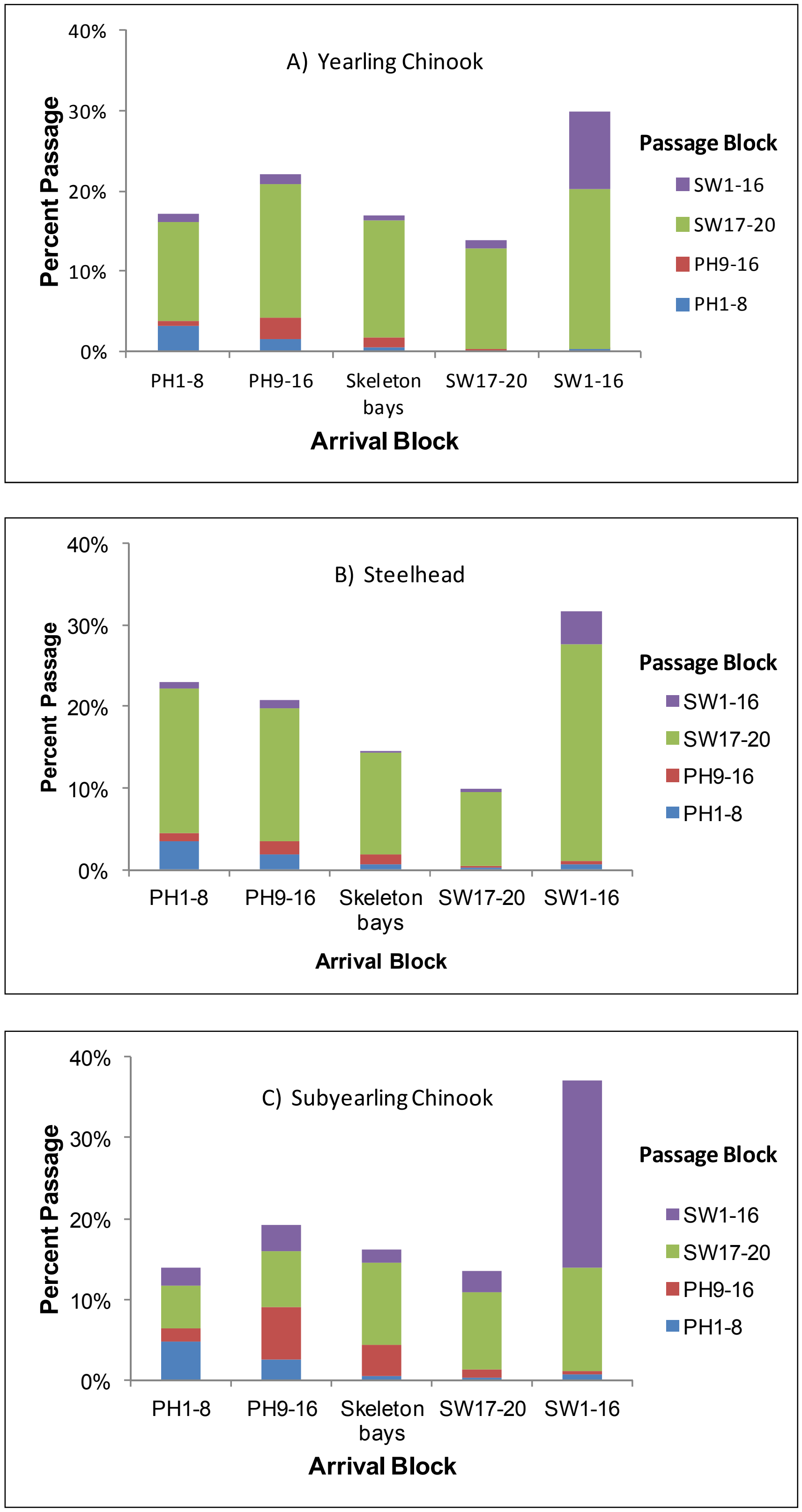

Figure 9.7. Behavior expressed as approach and passage patterns at the forebay of John Day Dam, 2010.

9.4.3 Forebay Vertical Distribution

Migration depth was less than 5 m below the shallow hydrophone (located at a depth of ~3 m) as fish approached the dam from a distance of 75 m. Depth generally decreased for CH1 and STH during the first 70 m of the approach, increasing to more than 20 m within 5 m of the dam face for turbine- or JBS-passed fish. In contrast to CH1 and STH depths, CH0 depth increased during the approach to the powerhouse units, reaching a depth more than 7 m below the hydrophone at a distance of 10 m from the dam, before increasing to more than 20 m when within 5 m, as expected for turbine and JBS passage.

Depth decreased for CH1 and CH0 during the 75-m approach to spill bays 17 through 20, but minimal depth fluctuation was observed for STH, which migrated at a depth similar to that of the shallow hydrophone. During their approach to spill bays 1 through 16, no pattern was observed for CH1 and CH0, because depth remained constant or increased during their approaches. STH approach-depth decreased rapidly within 5 m of spill bays 1 through 16.

When comparing day and night passage depths, day passage showed similar patterns for all tagged juvenile salmonid. During night, CH1 approaching the spillway were generally shallower, whereas night passage depths for STH and CH0 were deeper as they approached the powerhouse and skeleton bays.

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

There was no difference in survival rates between the 30% and 40% spill treatments for CH1 (94%) and CH0 (92%). Juvenile STH survival was significantly higher for the 40% spill treatment (97.5%) than the 30% spill treatment (94.2%). Relative to the dam and the spillway, TSWE was substantially higher during the 30% spill treatment than during the 40% treatment for all three test groups. Relative to the dam, FPE and SPE were both significantly higher during the 40% spill condition for CH0. FGE and JBSE did not differ significantly between the two treatments for any of the species tested (Table 9.4).

Table 9.4. Estimates of major passage metrics at John Day Dam, 2010.

	CH1		STH		CH0	
Metric	30% Spill	40% Spill	30% Spill	40% Spill	30% Spill	40% Spill
Survival - Dam face to TDA (CR349 to CR309)	0.940	0.944	**0.942**	**0.975**	0.919	0.914
Survival - Forebay entrance to TDA (CR351 to CR309)	0.935	0.941	**0.931**	**0.962**	0.915	0.907
FPE ‖ Dam[(a)]	0.969	0.958	0.982	0.982	**0.857**	**0.908**
SPE ‖ Dam[(a)]	0.917	0.884	0.871	0.904	**0.741**	**0.810**
TSWE ‖ Dam[(a)]	**0.662**	**0.478**	**0.752**	**0.692**	**0.352**	**0.272**
TSWE ‖ Spillway	**0.722**	**0.541**	**0.864**	**0.765**	**0.475**	**0.335**
FGE (powerhouse screen efficiency)	0.625	0.641	0.857	0.813	0.449	0.514
JBSE ‖ Dam[(a)]	0.052	0.074	0.111	0.078	0.116	0.097

(a) If dam route is included, proportions will not add up to 1.
Bold font indicates significant difference.

10.0 Conclusions

During the evaluation of juvenile salmonids at JDA in 2010, JSATS provided reliable data for estimating survival rates and fish passage metrics, and characterizing fish behavior. Moving the TSWs to spill bays 18 and 19, from spill bays 15 and 16, increased estimates of FPE, SPE, and most dramatically TSWE. Survival rates for fish passing at the TSWs after moving them to spill bays 18 and 19 did not change substantially but did aid in increasing SPE, thereby drawing fish away from the powerhouse and the turbines. There was no significant difference between survival rates during 30% spill and 40% spill for CH1 and CH0. There was, however, significantly higher survival for STH during 40% spill.

Performance evaluations of two independent cabled arrays deployed on the dam face (powerhouse and spillway) were confirmed to be ready for the 2011 BiOp compliance test.

Recommendations from the 2010 JDA study are as follows:

1. Proceed with an official BiOp and Fish Accords compliance test in 2011. The JSATS acoustics monitoring system appears to be ready, barring unforeseen circumstances.
2. Based on the results of the 2010 study, we recommend that the TSWs remain installed at spill bays 18 and 19.
3. The new deflector at spill bay 20 and the installation of the avian array appear to have helped increase survival and reduce bird predation on juvenile salmonids passing the dam. This was very noticeable at the south end of the spillway.
4. From this study, and 2008 and 2009 studies, there is not a consistent trend in survival, travel times, and passage metrics between 30% and 40% spill treatments.

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Appendix A

Review of Fish Condition Associated with Juvenile Salmon Collected and Tagged for the Lower River Survival Study

Appendix A

Review of Fish Condition Associated with Juvenile Salmon Collected and Tagged for the Lower River Survival Study

Prepared by CM Woodley, KA Wagner, and AL Miracle

In 2010, researchers from Pacific Northwest National Laboratory (PNNL) conducted a study to evaluate the condition of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) tagged with Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic micro-transmitters (AMTs) and passive integrated transponders (PITs). The purpose of this task was to test the assumptions that 1) tagged fish are representative of in-river fish and that 2) tagged fish did not have altered behavior or physiological costs compared to in-river fish. These assumptions are primary to the larger concurrent study – the *Acoustic Telemetry Evaluation of Dam Passage Survival and Associated Metrics at John Day, The Dalles, and Bonneville Dams, 2010* (herein referred to as the Lower Columbia River Survival Study, "LCR") that monitored survival of juvenile salmonids as they migrated downstream through the Federal Columbia River Power System (FCRPS) for the U.S. Army Corps of Engineers (USACE), Portland District, as stipulated by the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp; NOAA Fisheries 2008) and the Columbia Basin Fish Accords (Fish Accords; 3 Treaty Tribes−Action Agencies 2008).

To evaluate fish condition throughout various stages of the tagging process, gross necropsy observations and physiological indicators were investigated in yearling Chinook salmon (CH1) and steelhead (STH) in the spring, and subyearling Chinook salmon (CH0) in the summer. This is a summary of juvenile salmon condition at the time of collection, before tagging, after tagging and transport to the Bonneville Dam (BON) Smolt Monitoring Facility (SMF), and lastly fish recollected at the BON SMF using the sort-by-code (SyBC) system as an assessment of the 2010 LCR survival study.

A.1 Background

Telemetry applications for fish range from monitoring fine spatial movements and habitat preferences to monitoring large-scale migratory patterns (Skalski 1998; Scruton et al. 2007). In the Columbia River, scientists have identified acoustic telemetry as being an essential technology for observing the behavior and estimating the survival of juvenile salmonids passing through the side channels and the main-stem FCRPS (Faber et al. 2001; McComas et al. 2005; Ploskey et al. 2007, 2008; Clemens et al. 2009). Telemetry methodology and survival models used within the FCRPS are based on a number of assumptions that are often poorly or not tested, thus weakening the resultant data and leading to potentially erroneous conclusions about the population of interest.

The first assumption of telemetry models is that the behavior, migration, and physiological state of the fish are not affected by the transmitter presence or tagging process (Skalski et al. 2002; Deriso et al. 2007). In addition, the transmitter presence or tagging process should not affect fish growth or survival (herein referred to as "tag effects"; Jepsen et al. 2002; Zale et al. 2005). Prior to the 2010 LCR survival study, this assumption was examined by testing the effects of taggers, correcting for early tag-life failure, and testing for tag-lot effects. Tag effect and/or the effect of tagging responses have been a staple of the telemetry literature since 1933 (Markus 1933) and have remained a concern as newer approaches and transmitter technologies have been developed (Moore et al. 1990; Jepsen et al. 2002; Welch et al. 2007). Some studies have found little to no tag effects on fish (Brown et al. 1999; Chittenden et al. 2009); while others, in particular studies that use surgical implantation of transmitters, have concluded there were negative effects from transmitter presence and/or the tagging process such as reduced growth or increased mortality (Lacroix et al. 2004; Welch et al. 2007; Brown et al. 2010).

Acoustic transmitters, when used in fish survival studies, are usually surgically implanted into the coelomic cavity of the fish. Surgical implantation is a well-established method for attaching transmitters to study fish behavior and survival, although it does have disadvantages (Mulcahy 2003). Transmitter loss (or shedding) can occur through foreign body rejection processes (referred to as tag expulsion), the transmitter dropping through the incision due to poor apposition, or when external mechanical forces such as pressure are applied (Stephenson et al. 2010). In many cases, the expulsion of surgically implanted transmitters has occurred through a rupture of the incision zone (Lucas 1989; Moore et al. 1990; Petering and Johnson 1991). In other cases, the implants have exited by rupturing the abdominal body wall outside of the incision area (Marty and Summerfelt 1986; Lucas 1989) or have passed into the lumen of the intestine to be expelled by peristalsis (Martinelli et al. 1998; Baras and Westerloppe 1999). Regardless of the mechanisms or reasons for shedding, transmitter loss can affect data by indicating a mortality rate greater than the actual mortality rate. If the rate of transmitter loss and/or expulsion is documented, corrections for transmitter loss can be calculated into survival models. To account for transmitter loss and/or expulsion, the 2010 LCR survival study documented the number of dropped tags in the overnight holding period, and conducted a tag expulsion study, which could then be used in the survival models (Woodley et al. 2011).

Another survival model assumption examined by the 2010 LCR survival study is that fish implanted with AMTs and PITs are representative of the population of inference. This second assumption, in previous years, was often tested by comparing the length distributions of fish collected at JDA Smolt Monitoring Facility (SMF) with those of tagged fish, which were originally collected from the JDA SMF collection system. However, stress, altered behavior, recovery time, and survivability for fish with pre-existing conditions or effects from tagging can critically affect the results and conclusions of research and monitoring programs. In the FCRPS, researchers tasked with standardizing JSATS AMT surgical implantation procedures have noted that the time fish are held in induction anesthesia, ("knockdown" or surgical anesthesia to prepare them for surgery), could influence their survival (CBSPSC 2011). The extended knockdown time may lead to adverse effects on fish survival and an inability to compare results directly within or among survival studies. Lastly, surgery itself can cause immunosuppression. Poor sutures and/or open wounds can result in slow tissue healing, osmotic stress, tissue damage, or possible premature mortality (Fontenot and Neiffer 2004; Harms 2005; Greenburg and Clark 2009). Excessive suture tension on tissue can cause ischemic areas that reduce or slow revascularization; increase stretching, tearing, and necrosis; and ultimately slow healing. Improperly tied knots can become untied, thereby releasing wound margins, slowing healing, and allowing transmitter loss. Large knots can be a point source for tissue irritation due to the concentrated amount of foreign material making up the knot (van Rijssel et al. 1989). Thus, surgeon performance can cause behavioral or physiological differences between tagged fish and run-of-river populations.

In addition to tag and tagging effects, hydroelectric production systems expose migrating salmonids and other fish to physical hazards, such as structures, turbines, and hydraulic forces, which can lead to physical trauma, physiological imbalances, and immediate or delayed mortality. In the past, individual fish trauma and impaired condition induced by these stressors was commonly determined by observed injuries, such as embolisms in the kidney and open wounds (Stephenson et al. 2011; Carlson et al. 2011; Halvorsen et al. 2011). Observations of health and injury are relatively easy to collect from the juvenile fish bypass systems at the hydroelectric dams, but the techniques are lethal and limited in their ability to assess nutrition, immune, and trauma conditions (Carlson et al. 2011; Woodley et al. 2011). Advances to more accurately assess both internal and external fish condition include the use of physiological measures, such as alpha II-spectrin that measure whole body internal injury from a plasma sample or traumatic brain injury from a brain tissue sample (Miracle et al. 2009). Understanding stressor effects on fish encountering hydroelectric systems or other underwater hazards and how the stressors affect individual condition, performance, and behavior will more accurately estimate individual survival and vitality to predict population-level effects on fish in the coastal and estuarine regions.

The objective of this task was to assess the condition of fish that were 1) in-river at the time of tagging, 2) selected for tagging, 3) implanted and then transported to a release site, and 4) implanted with AMTs and PITs that travelled through the hydropower system. This assessment was conducted in a manner that would be sensitive to physiological state changes as a result of handling, the effects of the tags, and the tagging process. The goal of the fish condition research is to further define measures used for population viability analyses that assess the vulnerability of a population to FCRPS and assist with the ranking of management priorities based on the condition of fish moving through the FCRPS. To provide an evaluation of injury we measured the presence of alpha II-spectrin and spectrin breakdown products (SBDPs). Alpha II-spectrin is a cytoskeletal protein, whose breakdown protein fragments in brain tissue have been demonstrated to be a diagnostic marker of head injury in salmonids and have been correlated with mortality/malady metrics (Miracle et al. 2009). Presence of alpha II-spectrin and SBDPs in the blood is hypothesized to be indicative of cellular injury. To provide a broad assessment of immune function, we measured gene expression of several immune markers: interleukin-1 beta (IL1-β), recombinase activating gene (RAG-1), and immunoglobulin M (IgM) from spleen and liver tissue. Immune markers were chosen based on the availability of primer sequences and the function of the marker. IL1-β is a cytokine involved in the innate immune response and is indicative of a generalized inflammation response to injury or pathogens. Up-regulated IL1-β gene expression has been demonstrated in response to physical injury (Ingerslev et al. 2010). Both RAG-1 and IgM are involved in adaptive immune responses against specific antigens (viral, bacterial, etc.).

A.2 Methods and Materials

This study was conducted during two 5-wk sampling periods, one in the spring and one in the summer of 2010; and involved the acquisition of fish, surgical implantation of transmitters, release of fish, physiological assessment of fish, and statistical analysis, as described below.

A.2.1 Fish Acquisition

In the spring 2010, CH1 and STH were collected, tagged, and sampled from late April to late May. In the summer, CH0 were collected, tagged, and sampled from mid-June to mid-July. Only fish with a fork length between 95 and 264 mm were used for this study. All study fish were collected at the John Day Dam (JDA; rkm 349) SMF and sorted into treatments, except SBC. The treatment groups are identified and explained below:

- Run-of-River (ROR): During the fish collection for surgical implantation of AMTs, individuals were randomly subsampled for fish condition. Subsampling occurred before fish were observed for acceptance into the larger LCR survival study pool, but after fish were sorted for species, size, and prior tagging; thus ROR samples included fish that may have been rejected from the LCR survival study due to noticeable external damage such as hemorrhaging, >25% scale loss, etc. Fish with these conditions may not be capable of outmigration or may have high stress levels and potential for delayed mortality; however, they are still representative of in-river migrants.
- Pre-Tagged (PRT): During the daily tagging process, fish were randomly selected for fish condition assessment prior to tag implantation. These fish were held 12 to 24 h after sorting before sampling for fish condition, as were the fish held for tagging. As fish were anesthetized for surgical implantation for the survival study, PRT fish were removed prior to tag assignment.
- Tagged (TGD): Fish were randomly selected to be tagged for fish condition assessment. Fish were held 12 to 24 h after sorting, implanted with a JSATS AMT and a PIT, held in recovery for at least 24 h, and then transported (est. 1.5 h, 78 miles) to the BON SMF for sampling.
- Sort-by-Code (SBC): Fish selected for tag implantation, implanted with a JSATS AMT and PIT, recovered for at least 24 h, transported and released in river near Roosevelt, Washington, and recaptured downriver at BON (travel time 4–10 d) using the SByC system. Fish may have been held up to 24 h before sampling.

The number of fish collected for each treatment by week of collection are listed in Table A.1.

Table A.1. Samples sizes for fish condition assessment by species and week.

Species	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Total
CH1	ROR	18	11	20	20	20	89
	PRT	20	20	20	20	20	100
	TGD	21	21	21	21	18	102
	SBC	5	0	14	0	5	24
STH	ROR	16	20	20	20	20	98
	PRT	20	20	20	20	20	100
	TGD	21	21	21	21	18	102
	SBC	2	0	7	0	8	17
CH0	ROR	20	20	20	20	20	100
	PRT	20	20	20	20	20	100
	TGD	20	20	21	21	21	103
	SBC	4	12	2	0	0	22

A.2.2 Surgical Implantation of Transmitters

For the fish in the TGD and SBC assessments, each were surgically implanted with an AMT and a PIT. The weights of the tags were 0.438 g in air for the JSATS AMT and 0.085 g in air for the PIT (combined weight of 0.523 g for the TGD and SBC treatments). Prior to surgical implantation, fish were anesthetized in buffered (with 80 mg/L $NaHCO_3$) tricaine methanesulfonate (MS-222; 80 mg/L), until loss of equilibrium was observed (Stage 4; Summerfelt and Smith 1990). Anesthetized fish were immediately weighed, measured, and both flanks were photographed. Once properly anesthetized, fish were placed on the surgery table and given a maintenance anesthetic dose (river water containing 40 mg/L MS-222 and 40 mg/L $NaHCO_3$) through silicone rubber tubing from a gravity-fed cooler system. The surgeon controlled the anesthetic dose during the surgery by mixing river water with maintenance anesthetic water. With the fish facing ventral side up, a 6- to 8-mm incision was made along the linea alba, between the pectoral fin and pelvic girdle. An AMT and PIT were inserted into the coelomic cavity through the incision. The incision was closed with two, simple interrupted sutures using a 2×2×2×2 wrap knot with 5-0 Monocryl™ sutures. Post-surgery, fish were placed into 18.9-L perforated recovery buckets (five fish per bucket) with fresh aerated river water and monitored to ensure recovery to equilibrium. The density of fish in each bucket did not exceed 15 kg/m^3. The buckets were placed into a larger holding tank supplied with flow-through river water. Fish were left to recover for 18 to 24 h before being transported. In addition to necropsy notes, daily notes included found transmitters or tags, water temperature at BON and JDA, dissolved oxygen levels, signs of disease, and general health. Water temperatures at the JDA SMF and BON SMF increased (Figure A.1) and dissolved gas percent decreased (Figure A.2) over the study; however, there was little change in the dissolved oxygen content, due to the inline stripping columns.

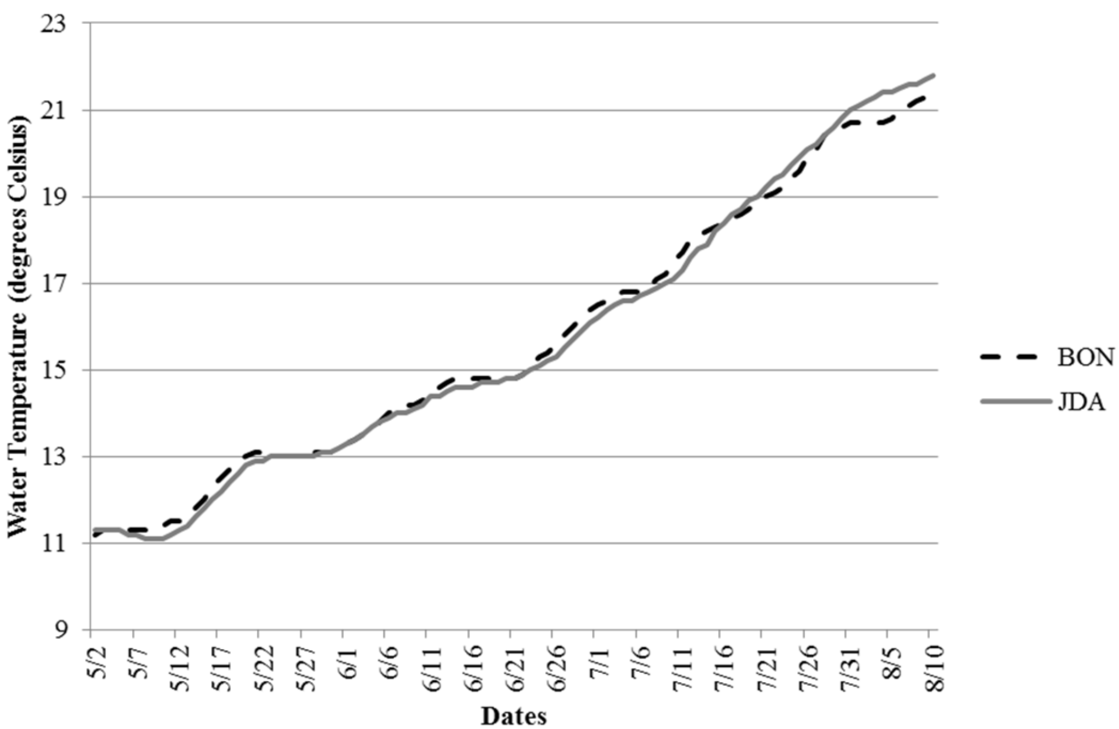

Figure A.1. Water temperature between May 2 and August, 2010, at the JDA SMF and the BON SMF.

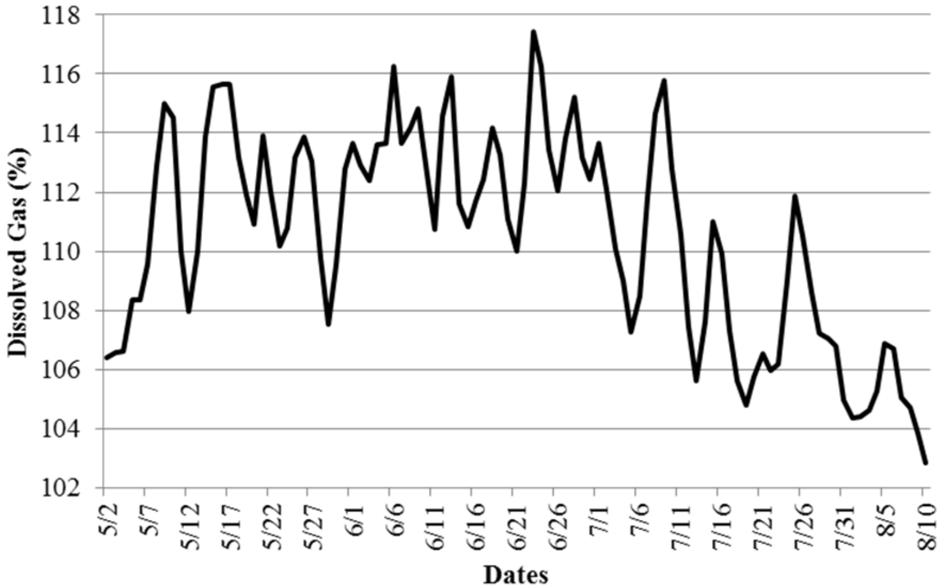

Figure A.2. Total dissolve gas percent between May 2 and August 10, 2010 at the BON SMF.

A.2.3 Fish Transportation and Release

For transportation of TGD and SBC fish, 18.9-L perforated buckets were placed in insulated transportation totes containing 757 L of river water supplied with supplemental oxygen. During transportation, water temperature and dissolved oxygen were monitored to ensure that the tote water did not increase more than 1°C from the reference temperature (holding water at JDA), and remained at or near saturation. SBC fish (the same fish tagged for the survival studies) were transported to Roosevelt and upon arrival, water temperature and dissolved oxygen levels were noted. If needed, the water temperature was adjusted to in-river water temperature with ice and then buckets were loaded into a boat. Upon reaching the release site, fish were transferred (water to water) from buckets to river. PIT codes from the released fish were logged into the PIT Tag Information System (PTAGIS) fish database program. TGD fish were transported to the BON SMF (rkm 234; 78 driving miles, average driving time 1.5 h) for sampling. Upon arrival, water temperature and dissolved oxygen were noted. Perforated buckets were then transferred into 379-L Bonar™ totes supplied with flow-through river water until sampling.

A.2.4 Sampling and Necropsy Techniques

Fish were anesthetized in buffered MS-222 (250 mg/L) until stage 5 anesthesia (slowing of gill rate). Fish were immediately weighed and measured. Blood samples (0.5 mL) were taken from the caudal vein using a 23-gauge needle and 1-mL syringe containing 0.05 mL of sodium heparin. Blood samples were dispensed in a 1.0-mL microcentrifuge tube, centrifuged at 3,000 *g* for 10 min, and plasma was collected in a separate tube. Plasma samples were stored at –80°C for later analyses. Both flanks of the fish were photographed, and fish were then euthanized by spinal transection while under stage 5 anesthesia. External and internal examinations were conducted to provide a thorough description of the fish condition. More than 150 observations of fish condition are noted by the condition presence/absence (Table A.2). Observations were scored on a presence or absence basis. After necropsy, brain tissue, liver, and spleen were harvested from each fish, placed in individual cryovials, and frozen at –80°C for later biochemistry analyses. The biochemistry analyses quantified alpha II-spectrin, IL1-β, RAG-1, and IgM. Fish sampling occurred at JDA (ROR, PRT) and BON SMF (TGD, SBC).

Table A.2. An abbreviated list of observations of fish conditions (including health and trauma).

External	Internal
Dead or Moribund	Damage: Ruptures, Lacerations
Damage: Eye(s)	Embolism: Connective Tissue
Damage: Vent (Prolapse)	Embolism: Pericardium
Deformities	Embolism: Renal
Emesis	Embolism: Swim Bladder
Erosion	Hematoma: Fat
Exophthalmia	Hematoma: GI Tract
Hematoma: Caudal Peduncle	Hematoma: Hepatic
Hematoma: External Body	Hematoma: Internal Body Wall
Hematoma: Fins	Hematoma: Pericardium
Hematoma: Isthmus	Hematoma: Pyloric Caeca
Hematoma: Operculum	Hematoma: Swim Bladder
Hematoma: Vent	Hemorrhage: Capillaries
Hemorrhage: Caudal Peduncle	Hemorrhage: Fat
Hemorrhage: Eye(s)	Hemorrhage: GI Tract
Hemorrhage: Fins	Hemorrhage: Hepatic
Hemorrhage: Gill(s)	Hemorrhage: Pericardium
Lacerations	Hemorrhage: Renal
Scale Loss	Hemorrhage: Spleen
	Hemorrhage: Swim Bladder

A.2.4.1 Alpha II-Spectrin

Plasma and brain tissue samples were disrupted by bead beating using a MiniBeadbeater-8 and 1.0-mm zirconia/silica beads (BioSpec Products, Inc., Bartlesville, OK) in a lysis buffer containing 50 mM Tris (pH 7.4), 5 mM EDTA, 1% (v/v) Triton X-100, 1 mM DTT, and protease inhibitor. The plasma lysates were then centrifuged at 14,000 rpm for to remove any insoluble debris, and snap-frozen and stored at –80°C until used. Protein concentrations of lysates were determined by DC™ Protein assay (BioRad, Hercules, CA) with albumin standards.

Thirty micrograms of total protein from each plasma sample and 20 μg of total protein for each brain tissue sample were used for gel electrophoresis and electrotransfer as described by Miracle et al. (2009). Semi-quantitative evaluation of alpha II-spectrin expression was evaluated via digital image analysis with Image J software (version 1.6; Rasband 2012). To assess the amount of total alpha II-spectrin present, we calculated the pixel density for intact and cleaved protein bands using density histograms with background subtraction. This step allowed quantification by the assignment of numerical values as a correlation of abundance of the protein.

A.2.4.2 QPCR

Differential expression in spleen ribonucleic acid (RNA) was determined using semi-quantitative PCR (qPCR; Freeman et al. 1999). Total RNA was isolated from spleen tissue using TriReagent (Ambion, Austin, TX), and relative RNA concentrations were determined by ultraviolet spectrophotometry (GENE SYS 10). Complementary DNA (cDNA) was prepared using a High Capacity cDNA Reverse Transcription Kit (Applied Biosystems) and a Gene AMP PCR system 9700 (Applied Biosystems). Primers for amplification of were designed using PrimerQuest (IDT, Coralville, IA), and are given in Table A.3. If Chinook salmon (*Oncorhynchus tshawytscha*) sequence information was not available, rainbow trout (*O. mykiss*) sequences were used for primer construction. Briefly, 1 μg of total RNA from spleen samples was reverse transcribed with 50-μM random hexamers, using reagents and protocol recommended by Applied Biosystems (Foster City, CA). One tenth of the cDNA was used for each PCR reaction along with a SYBR green master mix (Applied Biosystems, Foster City, CA) and 2 pmol of primers. Cycling was carried out with 40 cycles of 95°C for 20 s, 60°C for 20 s, and 72°C for 10 s. Target fluorescence was measured at the end of the 72°C step for each cycle. Each gene assay included a standard curve of gel purified, template-specific cDNA, which was amplified from identity-confirmed clones using different primer sets in serial dilutions for setting the cycle threshold. The cDNA expression levels for all samples were normalized to expression levels for 18S, using Ambion's QuantumRNA™ primers (Austin, TX). To authenticate that observed PCR products were specific for IgM, RAG-1, or IL1-β, mRNA respectively, DNA sequencing was performed on isolated amplification products from spleen tissues of hatchery Chinook salmon. Fragments were gel purified and cloned into a TA cloning® vector per vendor protocol (Applied Biosystems, Foster City, CA). Isolated colonies were shipped to Agencourt (Danvers, MA) for sequencing using M13 forward and reverse primers. The resulting DNA sequence information was compared with known sequences for identity using the BLAST algorithm (NCBI, NIH) and all three target sequences were confirmed.

Table A.3. Target gene with forward (F) and reverse (R) primer sequences derived from GenBank accession number (Acc).

Gene and Reference	Primer Sequence
Interleukin 1-β (IL1-β); Acc# FJ890361.1	F 5' AGCAGGGTTCAGCAGTACATCACA 3' R 5' ATCAGGACCCAGCACTTGTTCTCA 3'
Recombinase activating gene I (Rag-1); Acc# U15663.1	F 5' TGCCGGTATAGCTTCAACTCCCAA 3' R 5' TGTACTTGAAGACGGTGGAGAGCA 3'
Immunoglobulin M (IgM), heavy chain constant domain; Acc# DQ778947.1	F 5' GTGACCCTGACTTGCTACGTCAAA 3' R 5' GCTCATCGTTAACAAGCCAAGCCA 3'

A.2.5 Statistical Analysis

Prior to statistical analyses, spleen and liver relative immune gene expression was investigated for outliers. Values were considered outliers and removed from analyses if 18S expression was more than 2 standard deviations greater or less than the plate mean.

To evaluate the effects of tagging and to determine if tagged fish are representative of in-river fish, necropsy observations, total plasma alpha II-spectrin and SBDPs and spleen immune gene expression were compared between ROR, PRT, and TGD treatments. To determine 24-h and in-river effects of tagging, necropsy observations and physiological metrics were compared between PRT, TGD, and SBC treatments. Necropsy observations for these analyses were totaled per fish and analyzed with ANOVAs, followed by Tukey's HSD post-hoc analyses. All assumptions for parametric statistics were met prior to testing. Linear regressions were also used to examine fish size relationships and detect outliers. Lastly, principal component analysis was used to investigate the relationship between fish size and condition. The frequency of alpha II-spectrin and SBDPs was treated as binomial data, because the variable could either be present or absent (not detected) in each fish. The variables total alpha II-spectrin and SBDPs, spleen IL1-β, and spleen IgM were continuous data. For the comparison of frequency of alpha II-spectrin and SBDPs between treatments, a Chi Squared Test (χ^2) was used. To compare continuous variables between groups, a Kruskal-Wallis test was used followed by a Steel-Dwass all pairs comparison post hoc test (where applicable). Between species comparisons were not made. All analyses were performed using JMP (Version 10) and level of significance was tested at $P < 0.05$.

A.3 Results

A.3.1 Data Adjustments

The submersible traveling screens (STSs), which guide the outmigrating juvenile salmonids into the bypass channel and through the SByC system at the BON SMF, were removed on June 3, 2010, because of heavy debris loading resulting from high river flow conditions. Because the STSs were removed, CH0 could not be collected from the SByC system at the BON SMF in summer. Table A.1 indicates actual number of fish sampled for necropsy and thus samples taken for biochemistries.

At the start of the study, 3 to 40 randomly selected brain samples from each sampling week in spring were investigated to determine preliminary trends (Table A.4). Preliminary analyses indicated brain alpha II-spectrin results were invariant between groups for CH1 and STH. Given budget and time constraints encountered during the study period, brain alpha II-spectrin analyses were eliminated from further investigation.

All plasma samples were processed for alpha II-spectrin presence with the following exceptions: clotted samples, insufficient sample volumes, or lack of sufficient protein following extraction (Table A.5).

All spleen samples were processed for relative immune gene expression with the exception of not enough cDNA or low RNA quantity or quality (Table A.6). In addition, samples were considered outliers if relative expression of 18S (used for normalization) was more than 2 SDs greater or less than the plate mean. Preliminary analysis of liver immune gene expression revealed low relative expression for all immune markers, and thus given budget and time constraints analyses were eliminated from further investigation (Table A.7).

Table A.4. Adjusted sample sizes for brain alpha II-spectrin presence for CH1, STH, and CH0.

Species	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	**Total**
CH1	ROR	9	8	6	2	0	**25**
	PRT	8	9	8	0	0	**25**
	TGD	10	8	9	4	3	**34**
	SBC	6	0	14	4	0	**24**
STH	ROR	10	7	6	0	2	**25**
	PRT	9	9	7	2	0	**27**
	TGD	8	9	17	1	3	**38**
	SBC	2	1	10	1	0	**14**
CH0	ROR	0	0	0	0	0	**0**
	PRT	0	0	0	0	0	**0**
	TGD	0	0	0	0	0	**0**
	SBC	0	0	0	0	0	**0**

Table A.5. Adjusted sample sizes for plasma alpha II-spectrin presence for CH1, STH, and CH0.

Species	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	**Total**
CH1	ROR	19	8	16	11	20	**74**
	PRT	18	18	15	14	18	**83**
	TGD	20	16	12	12	12	**72**
	SBC	5	0	13	3	6	**27**
STH	ROR	9	18	17	19	19	**82**
	PRT	19	20	20	18	18	**97**
	TGD	21	16	20	20	20	**97**
	SBC	2	1	11	2	10	**26**
CH0	ROR	15	13	12	16	2	**58**
	PRT	13	8	13	18	2	**54**
	TGD	11	5	3	6	0	**25**
	SBC	2	5	0	0	0	**7**

Table A.6. Adjusted sample sizes for relative expression of spleen immune genes for CH1, STH, and CH0.

Species	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	**Total**
CH1	ROR	17	11	15	0	0	**43**
	PRT	19	18	0	0	5	**42**
	TGD	0	19	21	19	7	**66**
	SBC	7	0	13	0	5	**25**
STH	ROR	15	19	9–12[(a)]	0	0	**43–46**
	PRT	19	21	0	0	0–19[(b]	**40–59**
	TGD	0	19	21	21	18	**79**
	SBC	2	0	7	0	8	**17**
CH0	ROR	18	18	16–20	19–20[(c)]	0	**71–76**
	PRT	20	18–20	18–20[(d)]	7–8[(e)]	0	**63–68**
	TGD	16–20[(f)]	20	21	21	18	**96–100**
	SBC	4	11	4	2	0	**21**

(a) N=9 for IL1-β.
(b) N=0 for IL1-β.
(c) N=19 for IL1-β.
(d) N=18 for IL1-β.
(e) N=7 for IL1-β.
(f) N=16 for IL1-β and RAG-1.

Table A.7. Adjusted sample sizes for relative expression of liver immune genes for CH1, STH, and CH0.

Species	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	**Total**
CH1	ROR	0–5[(a)]	0	0	0	0	**0–5**
	PRT	0	0	0	0	0–8[(b)]	**0–8**
	TGD	0	19	21	0	0	**40**
	SBC	0–5[(a)]	0	0–14[(a)]	0	0–5[(a)]	**0–24**
STH	ROR	0–2[(a)]	0	0	0	0	**0–2**
	PRT	0	0	0	0	0–19[(b)]	**0–19**
	TGD	0	15–19[(c)]	18–21[(d)]	7–8[(e)]	0	**40–48**
	SBC	0–2[(a)]	0	0–7[(a)]	0	0–8[(a)]	**0–17**
CH0	ROR	0–20[(b)]	0–20[(b)]	0	0	0	**0–40**
	PRT	0–19[(b)]	0	0	0	0	**0–19**
	TGD	0	0	0	0	0	**0**
	SBC	0–4[(a)]	0–12[(a)]	0–4[(a)]	0–2[(a)]	0	**0–22**

(a) N=0 for IL1-β and RAG-1.
(b) N=0 for IL1-β.
(c) N=15 for RAG-1.
(d) N=18 for RAG-1.
(e) N=7 for RAG-1.

A.3.2 Size Variability

At the time of sampling for ROR and PRT and at the time of tagging for TGD and SBC, fork lengths (FLs) and wet weights (WWs) ranged from 99 to 216 mm and 11.7 to 101.2 g for CH1; from 120 to 264 mm and 14.3 to 164.3 g for STH; and from 95 to 152 mm and 7.4 to 37.9 g for CH0 (Table A.8). Fish size (FL and WW) did not significantly vary by treatment for CH0 (F (3, 318) = 0.32, P = 0.81) and STH (F (3, 327) = 1.47, P = 0.22); fish size significantly varied between treatments for CH1 (F (3, 325) = 2.89, P = 0.035). Wet weight for CH1, STH, and CH0 significantly predicted FL (all $P < 0.001$; Table A.9). Using Tukey-Kramer honestly significant difference (HSD) criterion, weekly FL and WW significantly varied over the study period for CH1 ($P < 0.001$), but was similar across all weeks for STH and CH0 (all $P > 0.25$; Table A.10, Table A.11). For CH1, the FL and WW were significantly greater in the first sampling week when compared to all other sampling weeks, and the FL and WW from the second week of sampling were significantly greater than the fourth and fifth sampling weeks, but were similar to the third sampling week (all $P < 0.001$).

Table A.8. Average fork length and wet weight of CH1, STH CH0 by treatment and sampling week.

Species	Treatment	Week 1	Week 2	Week 3	Week 4	Week 5
CH1	ROR	167 (15.2) mm 43.4 (10.1) g	150 (20.6) mm 32.4 (13.8) g	136 (20.0) mm 25.5 (13.6) g	146 (20.7) mm 30.8 (16.3) g	147 (16.8) mm 31.1 (11.3) g
	PRT	164 (21.7) mm 43.7 (15.0) g	157 (18.6) mm 37.2 (15.2) g	140 (18.0) mm 27.2 (9.6) g	143 (13.0) mm 27.8 (6.6) g	147 (8.5) mm 27.8 (4.9) g
	TGD	170 (18.8) mm 50.0 (15.2) g	154 (20.3) mm 37.0 (16.2) g	143 (19.1) mm 30.0 (11.9) g	138 (17.7) mm 25.0 (6.8) g	145 (19.5) mm 31.0 (15.4) g
	SBC	142 (10.7) mm 24.5 (5.2) g	170 (11.3) mm 43.7 (10.2) g	145 (16.7) mm 27.9 (12.7) g	144 (16.5) mm 30.7 (9.4) g	144 (11.9) mm 27.9 (7.0) g
STH	ROR	207 (25.7) mm 78.4 (28.4) g	217 (18.0) mm 85.9 (22.0) g	205 (26.0) mm 76.1 (28.6) g	210 (25.2) mm 81.2 (23.5) g	219 (20.7) mm 83.2 (20.8) g
	PRT	210 (28.8) mm 84.8 (32.3) g	213 (15.8) mm 78.7 (16.7) g	211 (23.3) mm 77.1 (27.0) g	217 (29.6) mm 87.1 (29.3) g	222 (29.6) mm 92.0 (31.1) g
	TGD	214 (21.5) mm 90.0 (27.0) g	204 (22.5) mm 71.0 (24.0) g	201 (25.5) mm 71.0 (26.3) g	211 (18.3) mm 79 (23.9) g	195 (34.2) mm 66 (33.5) g
	SBC	230 (17.7) mm 97.4 (29.1) g	218 (33.9) mm 89.5 (40.8) g	201 (18.2) mm 64.8(17.9) g	232 (27.6) mm 100.8 (34.9) g	209 (34.0) mm 77.2 (30.9) g
CH0	ROR	108 (5.6) mm 12.9 (2.2) g	109 (5.8) mm 13.2 (2.3) g	104 (5.7) mm 11.4 (2.2) g	107 (8.0) mm 12.9 (3.1) g	109 (11.1) mm 14.3 (5.6) g
	PRT	111 (7.0) mm 13.8 (2.7) g	107 (4.4) mm 12.4 (1.6) g	105 (4.8) mm 11.5 (1.5) g	108 (7.9) mm 12.6 (3.3) g	109 (6.3) mm 12.0 (2.3) g
	TGD	109 (8.5) mm 14.4 (3.9) g	105 (5.5) mm 12.4 (1.5) g	108 (6.2) mm 13.1 (2.3) g	104 (7.6) mm 13.1 (2.7) g	103 (5.7) mm 12.9 (2.1) g
	SBC	108 (9.2)mm	119.5 (6.2) mm	107.3 (2.9) mm	105.3 (6.5) mm	NA

Table A.9. Regression data for wet weight to fork length relationship by CH1, STH, and CH0.

Species	Intercept	Slope	r^2	N	F	p
CH1	104.9	1.50	0.90	322	3016.9	<0.001
STH	139.4	0.97	0.92	328	3760.0	<0.001
CH0	78.8	2.21	0.80	325	1261.63	<0.001

Table A.10. Results of Tukey-Kramer HSD analyses for fork length by week and by CH1, STH, and CH0. Treatment is not included in these relationships.

Species	Week	Mean	SD	N	Significance
CH1	04/28/2010	165 mm	19.3 mm	66	A
	05/05/2010	155 mm	19.4 mm	52	B
	05/12/2010	141 mm	18.9 mm	78	B, C
	05/19/2010	142 mm	17.3 mm	63	C
	05/26/2010	146 mm	14.5 mm	63	C
STH	04/28/2010	211 mm	25.0 mm	58	NS
	05/05/2010	211 mm	20.0 mm	62	
	05/12/2010	205 mm	23.9 mm	71	
	05/19/2010	214 mm	24.6 mm	64	
	05/26/2010	211 mm	30.9 mm	70	
CH0	06/16/2010	109 mm	7.1 mm	60	NS
	06/23/2010	107 mm	5.4 mm	60	
	06/30/2010	106 mm	5.8 mm	61	
	07/07/2010	106 mm	7.8 mm	61	
	07/14/2010	107 mm	8.5 mm	61	

Table A.11. Tukey-Kramer HSD analyses for wet weight by week and CH1, STH and CH0. Treatment is not included in these relationships.

Species	Week	Mean	SD	N	Significance
CH1	04/28/2010	44.2 g	14.5 g	66	A
	05/05/2010	36.2 g	15.0 g	52	B
	05/12/2010	27.6 g	12.2 g	78	B, C
	05/19/2010	27.8 g	10.7 g	63	C
	05/26/2010	29.7 g	10.4 g	63	C
STH	04/28/2010	85.4 g	29.0 g	58	NS
	05/05/2010	78.7 g	22.2 g	62	
	05/12/2010	73.1 g	25.9 g	71	
	05/19/2010	83.1 g	25.6 g	64	
	05/26/2010	79.9 g	30.4 g	70	
CH0	06/16/2010	13.7 g	3.0 g	60	NS
	06/23/2010	12.7 g	1.8 g	60	
	06/30/2010	12.0 g	2.2 g	61	
	07/07/2010	12.9 g	3.0 g	61	
	07/14/2010	13.1 g	3.7 g	61	

A.3.3 Necropsy Observations

The external observations were not significantly different between the treatment groups ROR, PRT and TGD, regardless of species (all $P > 0.0611$; Table A.12). This result was not the same for the internal observations where the TGD group had significantly more internal observations (e.g., trauma, tag damage, infection) noted than the ROR and PRT groups across the season for each species (Tukey-Kramer HSD, all $P \leq 0.0196$; Table A.13). In the TGD groups, regardless of species, organs like the spleen, swim bladder, and fat were frequently observed to have tag-related irritation. Tag-related irritations included hematomas, hemorrhaging, organ deflation, or impressions left on tissues. The above analyses did not include surgery quality.

Table A.12. Analysis of variance (ANOVA) results for ROR, PRT and TGD comparisons of external and internal observations reported for each species.

Species	Observation Group	Means			ANOVA		
		ROR	PRT	TDG	Df	*F*	*P*
CH1	External	0.50 ± 0.08	0.30 ± 0.08	0.55 ± 0.08	2,284	2.8235	0.0611
	Internal	0.78 ± 0.17	0.88 ± 0.16	1.83 ± 0.16	2,284	12.3931	<0.0001
STH	External	0.79 ± 0.11	0.62 ± 0.11	0.68 ± 0.11	2,301	0.672	0.5113
	Internal	2.05 ± 0.23	1.59 ± 0.22	2.90 ± 0.22	2,301	9.224	<0.0001
CH0	External	1.00 ± 0.12	0.75 ± 0.12	0.72 ± 0.11	2,300	1.799	0.1673
	Internal	2.58 ± 0.53	1.76 ± 0.53	18.27 ± 0.52	2,300	311.987	<0.0001

Table A.13. Tukey-Kramer HSD results for ROR, PRT and TGD comparisons of internal observations reported for each species.

Species	Treatment Group	HSD *P*
CH1	ROR:PRT	0.9067
	PRT:TGD	0.0001*
	TGD:ROR	<0.0001*
STH	ROR:PRT	0.3121
	PRT:TGD	<0.0001*
	TGD:ROR	0.0196*
CH0	ROR:PRT	<0.0001*
	PRT:TGD	<0.0001*
	TGD:ROR	0.5211

* = Significant differences.

For CH1 and STH, the SBC external observations were significantly greater than the PRT and TGD treatment groups (Tukey-Kramer HSD, all $P \leq 0.0005$; Table A.14, Table A.15). This was not the case for CH0, where the external observations were not significant among PRT, TGD, and SBC treatment groups ($P = 0.7281$, Table A.14). The mean internal observations for CH1 and STH were greatest for SBC followed by TGD and then PRT. In CH0, the TGD group was greater than the SBC followed by PRT. CH1 were the only species to have 2 of the 3 pairwise comparisons significant, TGD:SBC and SBC:PRT (Tukey-Kramer HSD, both $P \leq 0.0001$, Table A.15); whereas STH and CH0 were significant for each comparison (Tukey-Kramer HSD, all $P \leq 0.0026$, Table A.15).

Table A.14. ANOVA results for PRT, TGD, and SBC comparisons of external and internal observations reported for each species.

Species	Observation Group	Means			ANOVA		
		PRT	TDG	SBC	Df	*F*	*P*
CH1	External	0.30 ± 0.08	0.55 ± 0.08	1.19 ± 0.14	2, 231	14.175	<0.0001*
	Internal	0.88 ± 0.16	1.83 ± 0.16	5.46 ± 0.58	2, 231	22.5468	<0.0001*
STH	External	0.62 ± 0.11	0.68 ± 0.11	1.88 ± 0.19	2, 238	17.9417	<0.0001*
	Internal	1.59 ± 0.22	2.90 ± 0.22	5.53 ± 0.48	2, 238	25.4259	<0.0001*
CH0	External	0.75 ± 0.12	0.72 ± 0.11	0.90 ± 0.20	2, 231	0.3178	0.7281
	Internal	1.76 ± 0.53	18.27 ± 0.52	9.34 ± 1.20	2, 231	154.0077	<0.0001*

* = Significant differences.

Table A.15. Tukey-Kramer HSD results for PRT, TDG, and SBC comparisons of external and internal observations reported for each species.

Species	Treatment Group	External HSD *P*	Internal HSD *P*
CH1	PRT: TGD	0.1111	0.1474
	TGD: SBC	0.0005*	<0.0001*
	SBC: PRT	<0.0001*	<0.0001*
STH	PRT: TGD	0.9246	0.0026*
	TGD: SBC	<0.0001*	<0.0001*
	SBC: PRT	<0.0001*	<0.0001*
CH0	PRT: TGD	NA	<0.0001*
	TGD: SBC	NA	<0.0001*
	SBC: PRT	NA	<0.0001*

* = Significant differences.

To further elucidate factors that may have influenced the frequency of observed responses for each treatment within and among species, ANOVA tests were conducted to examine observed responses over time. External and internal observations were pooled and assigned a week of collection (1 through 5) based on the 5 wk per tagging season (Table A.16). Weeks 2, 4, and 5 for CH1 had significantly more observations noted than in week 1 (Table A.17). Week 3 was not significantly different from week 4, but it had significantly more observations noted than week 1.

Table A.16. ANOVA results for week comparisons of external and internal observations reported for each species.

	Means					ANOVA		
Species	WK1	WK2	WK3	WK4	WK5	Df	*F*	*P*
CH1	0.56 ± 0.23	2.30 ± 0.25	1.47 ± 0.23	1.77 ± 0.23	2.18 ± 0.24	4,282	8.6552	<0.001
STH	1.68 ± 0.35	2.94 ± 0.33	2.08 ± 0.33	3.89 ± 0.33	3.74 ± 0.33	4,299	8.3875	<0.0001
CH0	3.45 ± 1.18	9.63 ± 1.18	7.84 ± 1.17	10.44 ± 1.17	10.90 ± 1.17	4,298	6.6053	<0.0001

Table A.17. Tukey-Kramer HSD results for week comparisons of external and internal observations reported for each species.

Species	WK1	WK2	WK3	WK4	WK5
CH1	C	A	B	AB	A
STH	D	BC	CD	A	AB
CH0	B	AB	A	A	A

Fork lengths of fish were examined to determine if the necropsy observations were influenced by fish size. After pooling all species, runs, and treatments, smaller fish (as measured by fork length) had more trauma-and disease-related external and internal observations than larger fish. The analysis yielded a two factor solution, which accounted for 62.6% of the variance ($P < 0.0001$; Figure A.3). The first factor naturally focused on the length and weight relationship explaining 49.5% of the variation. The second factor focused on the relationship between wet weight and necropsy observations, shown below as internal and external combined, explaining 13.1% of the data variation.

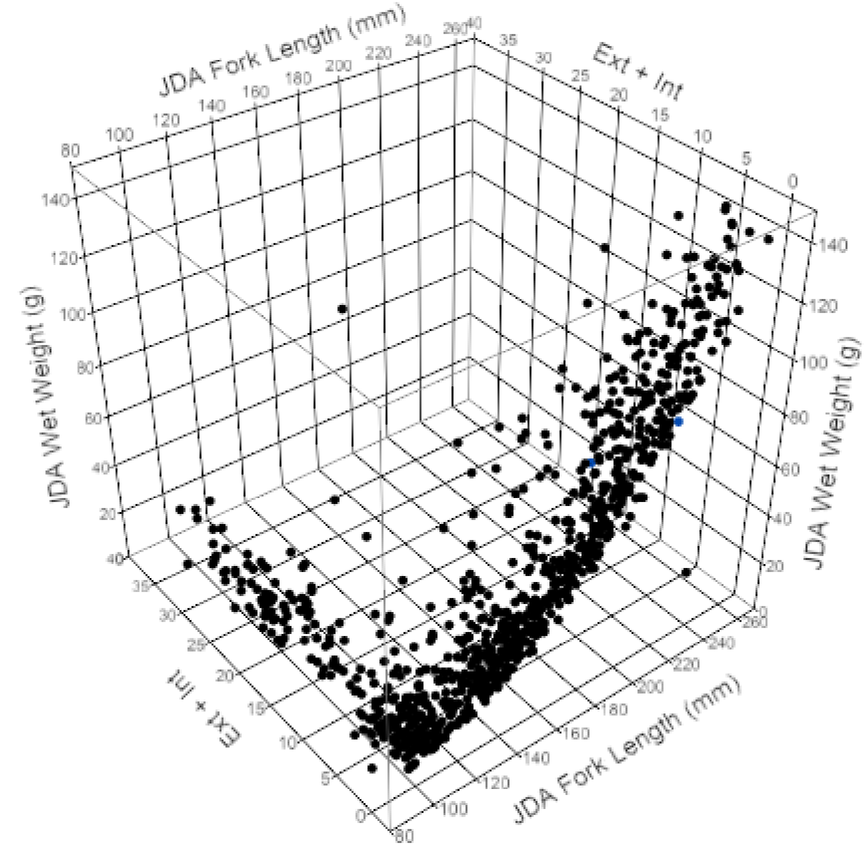

Figure A.3. The frequency of external and internal observations made per fish compared to the fork length and wet weight of all species and treatments combined.

A.3.4 Alpha II-Spectrin

For CH1 and STH, relative expression of brain alpha II-spectrin was not significantly different between ROR, PRT, and TGD treatments (all $P > 0.05$; Table A.18; Figure A.4). For CH1, relative expression of plasma alpha II-spectrin significantly varied with treatment ($P < 0.01$; Table A.18; Figure A.5). The PRT had significantly lower plasma alpha II-spectrin expression than both the ROR and TGD treatments (all $P < 0.05$). Expression was not different between the ROR and TGD treatments. For STH, plasma alpha II -spectrin expression was not significantly different between ROR, PRT, and TGD treatments ($P > 0.05$; Table A.18; Figure A.6). For CH0, plasma alpha II-spectrin expression was significantly different between ROR, PRT, and TGD treatments ($P < 0.001$; Table A.18; Figure A.5). Both the ROR and PRT treatments had significantly greater plasma alpha II-spectrin expression compared to the TGD treatment.

Table A.18. Results for Kruskal-Wallis analyses comparing alpha II-spectrin between ROR, PRT, and TGD treatments for CH1, STH, and CH0.

Species	Tissue	Df	χ^2	*P*
CH1	Brain	2	0.18	0.9142
	Plasma	2	11.21	0.0037
STH	Brain	2	1.70	0.4279
	Plasma	2	5.80	0.0551
CH0	Brain	-	-	-
	Plasma	2	17.52	<0.001

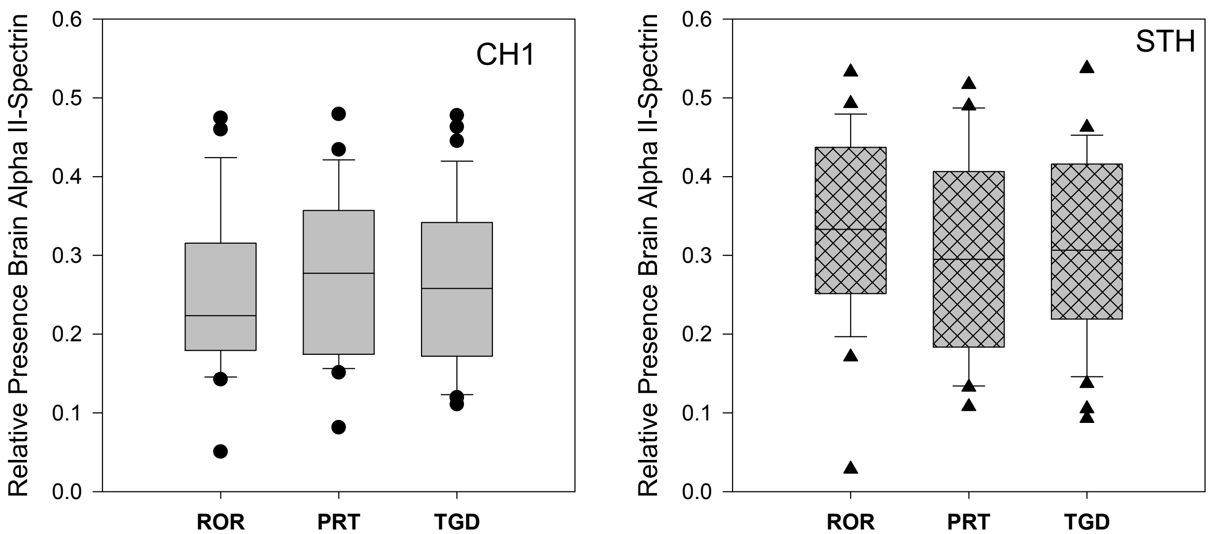

Figure A.4. Relative presence of brain alpha II-spectrin breakdown products for CH1 and STH during the tagging process. Each box plot represents the median and upper and lower quartiles for brain alpha II-spectrin expression.

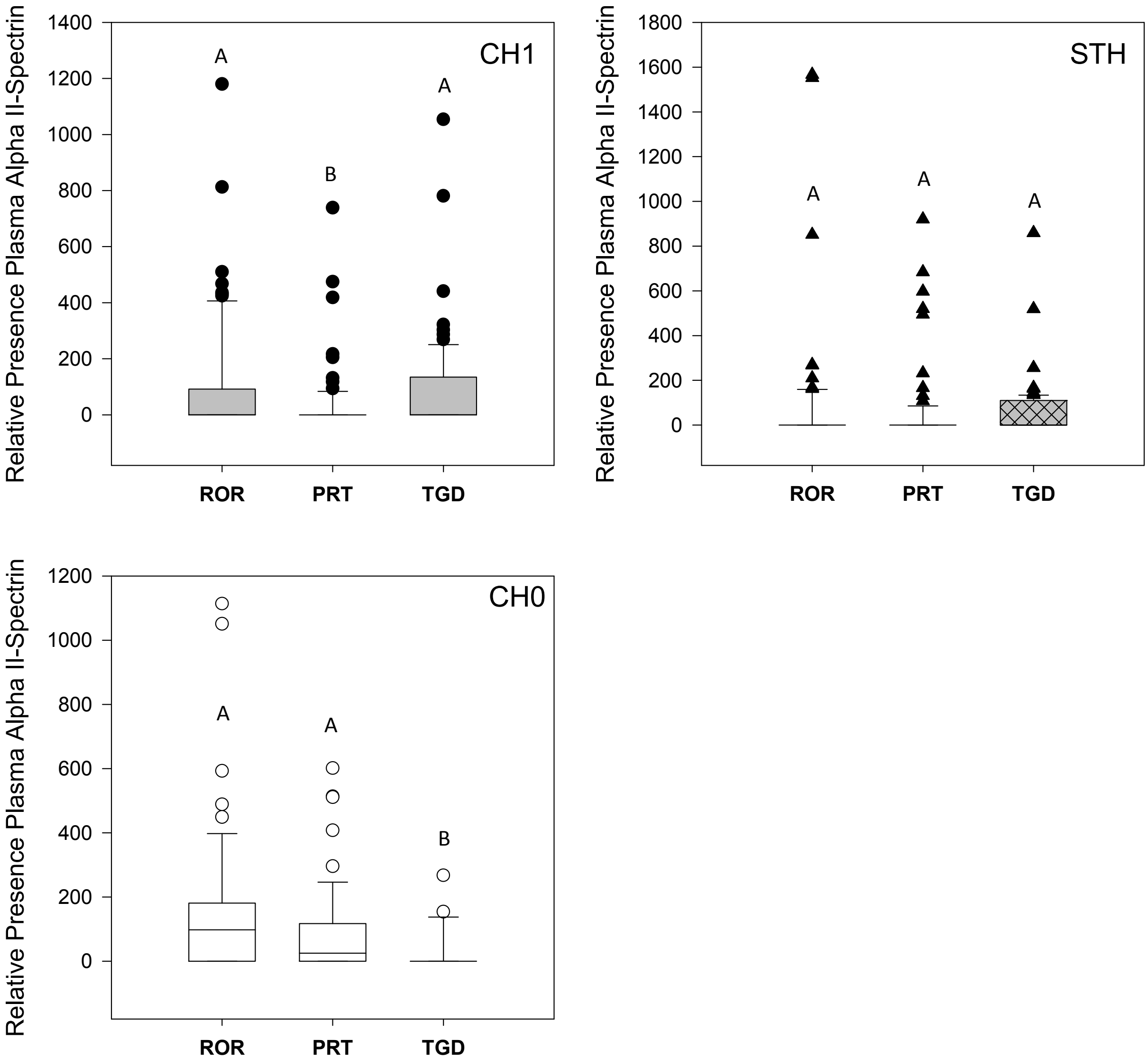

Figure A.5. Box plots of relative presence of plasma alpha II-spectrin for CH1 (●), STH (▲), and CH0 (○) during the tagging process. Each box plot represents the median and upper and lower quartiles for plasma alpha II-spectrin expression. Different uppercase letters indicate significant differences ($P < 0.05$).

For CH1 and STH, relative expression of brain alpha II-spectrin was not significantly different between TGD and SBC treatments (all $P > 0.05$; Table A.19; Figure A.6). For CH1, STH, and CH0, relative expression of plasma alpha II-spectrin was not significantly different between TGD and SBC treatments (all $P > 0.05$; Table A.19; Figure A.7).

Table A.19. Results for Kruskal-Wallis analysis comparing alpha II-spectrin between TGD and SBC treatments for CH1, STH, and CH0.

Species	Tissue	Df	N	χ^2	*P*
CH1	Brain	1	58	0.001	0.9748
	Plasma	1	99	0.35	0.5520
STH	Brain	1	52	1.20	0.2742
	Plasma	1	123	0.46	0.4984
CH0	Brain	-	0	-	-
	Plasma	1	32	1.23	0.2668

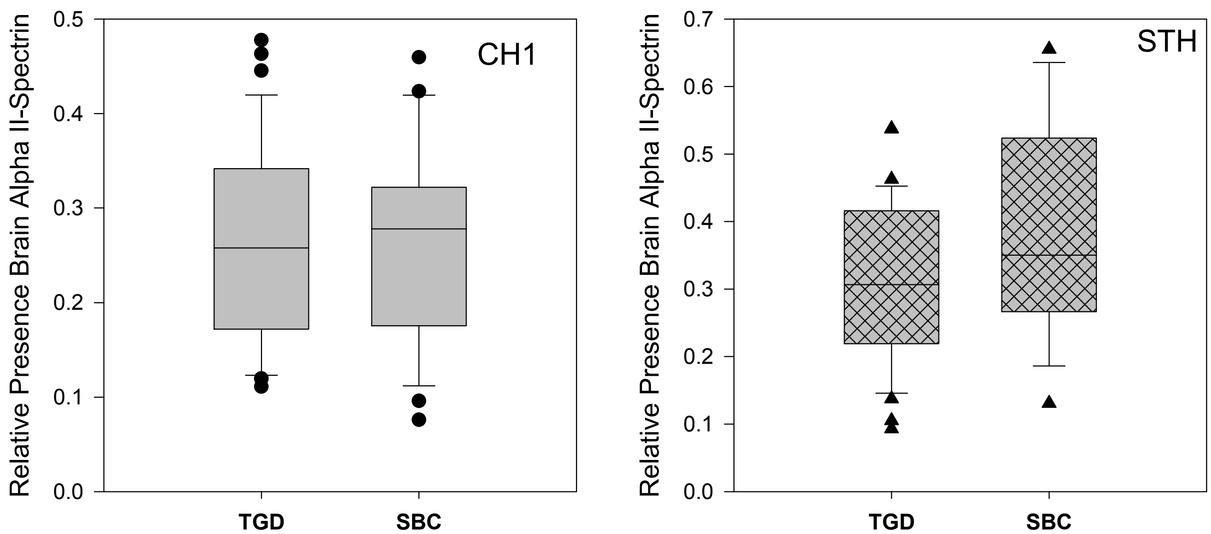

Figure A.6. Box plots of brain alpha II-spectrin breakdown products for CH1; ● and STH; ▲ after tagging. Each box plot represents the median and upper and lower quartiles for brain alpha II-spectrin expression.

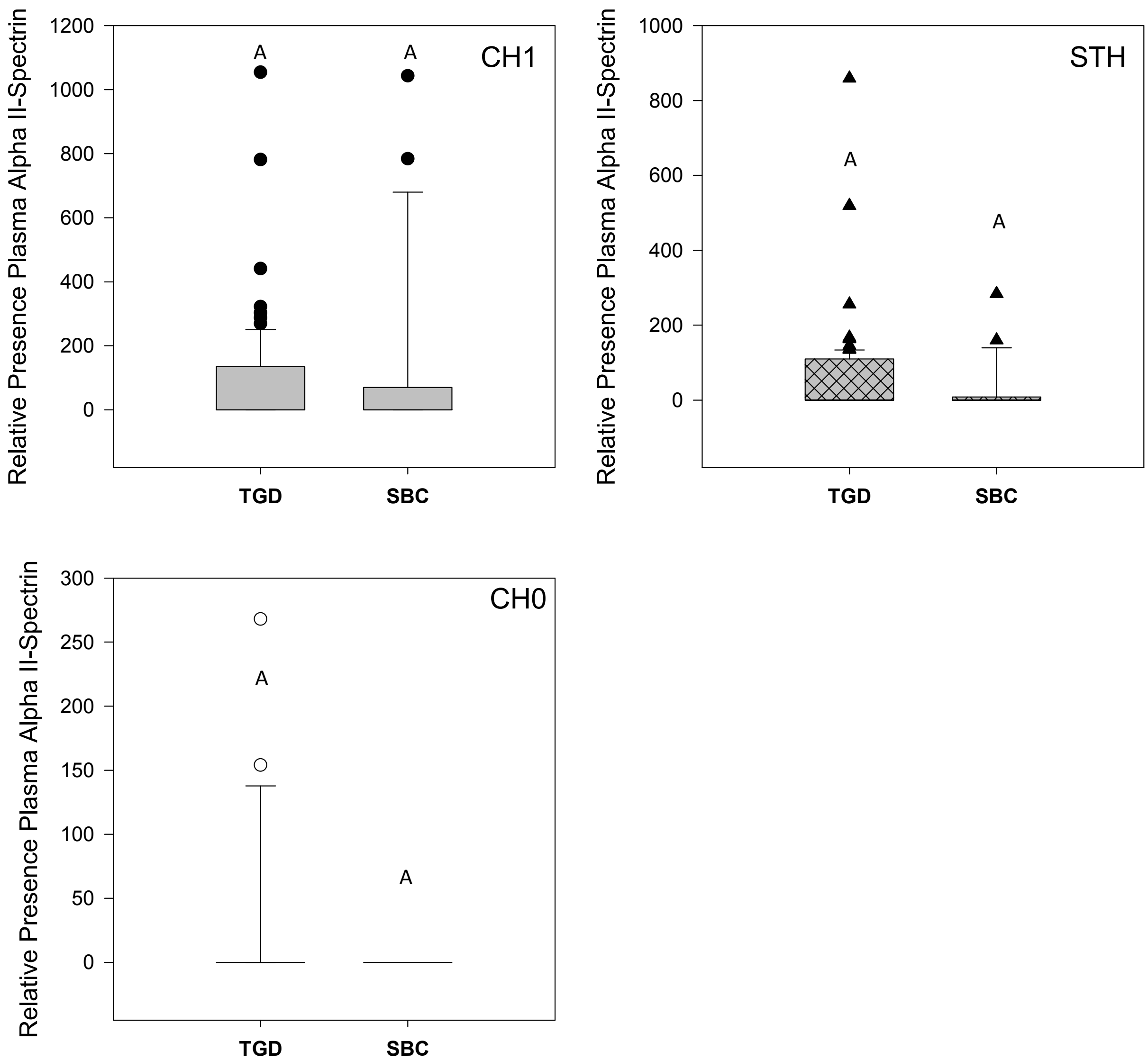

Figure A.7. Box plots of relative presence of plasma alpha II-spectrin for CH1 (●), STH (▲), and CH0 (○) after tagging. Each box plot represents the median and upper and lower quartiles for plasma alpha II-spectrin expression. Different uppercase letters indicate significant differences ($P < 0.05$).

A.3.5 Spleen Immune Gene Expression

For CH1, IL1-β gene expression significantly varied with treatment ($P < 0.0001$; Table A.20; Figure A.8). TGD CH1 had significantly higher IL1-β gene expression compared to ROR and PRT (all $P < 0.0001$). There was no difference in IL1-β expression for ROR and PRT CH1 ($P > 0.05$). For STH and CH0, IL1-β expression significantly varied with treatment ($P < 0.0001$; Table A.20; Figure A.8). TGD STH and CH0 had significantly higher IL1-β gene expression compared to the ROR and PRT (all $P < 0.0001$). ROR STH had significantly higher IL1-β gene expression compared to the PRT ($P < 0.0001$), but IL1-β expression was not different for CH0 ROR and PRT ($P > 0.05$).

Table A.20. Kruskal-Wallis results for untagged versus tagged fish by immune gene for CH1, STH, and CH0.

Species	Gene	Df	N	χ^2	*P*
CH1	IL1-β	2	151	86.92	<0.0001
	RAG-1	2	151	30.48	<0.0001
	IgM	2	151	45.11	<0.0001
STH	IL1-β	2	181	107.70	<0.0001
	RAG-1	2	185	47.11	<0.0001
	IgM	2	185	32.04	<0.0001
CH0	IL1-β	2	230	95.41	<0.0001
	RAG-1	2	238	70.61	<0.0001
	IgM	2	244	12.07	<0.005

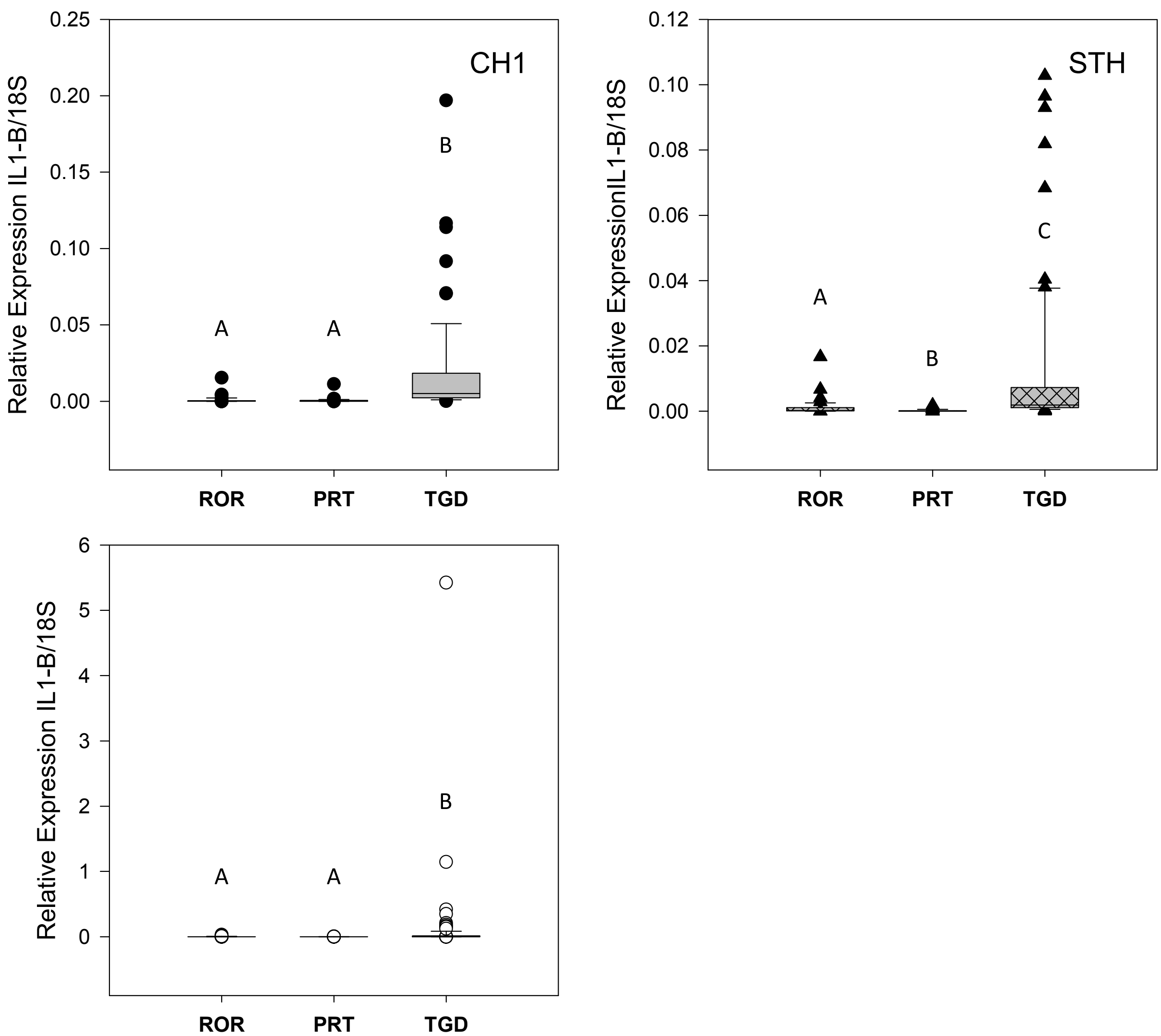

Figure A.8. Box plots of relative spleen IL1-β gene expression for CH1 (●), STH (▲), and CH0 (○) during the tagging process. Each box plot represents the median and upper and lower quartiles for IL1-β expression. Different uppercase letters indicate significant differences ($P < 0.05$).

For CH1, STH, and CH0, RAG-1 gene expression significantly varied with treatment (all $P < 0.0001$; Table A.20; Figure A.9). TGD fish had significantly higher RAG-1 gene expression compared to ROR and PRT (all $P < 0.0005$). There was no difference in RAG-1 gene expression between ROR and PRT (all $P > 0.05$).

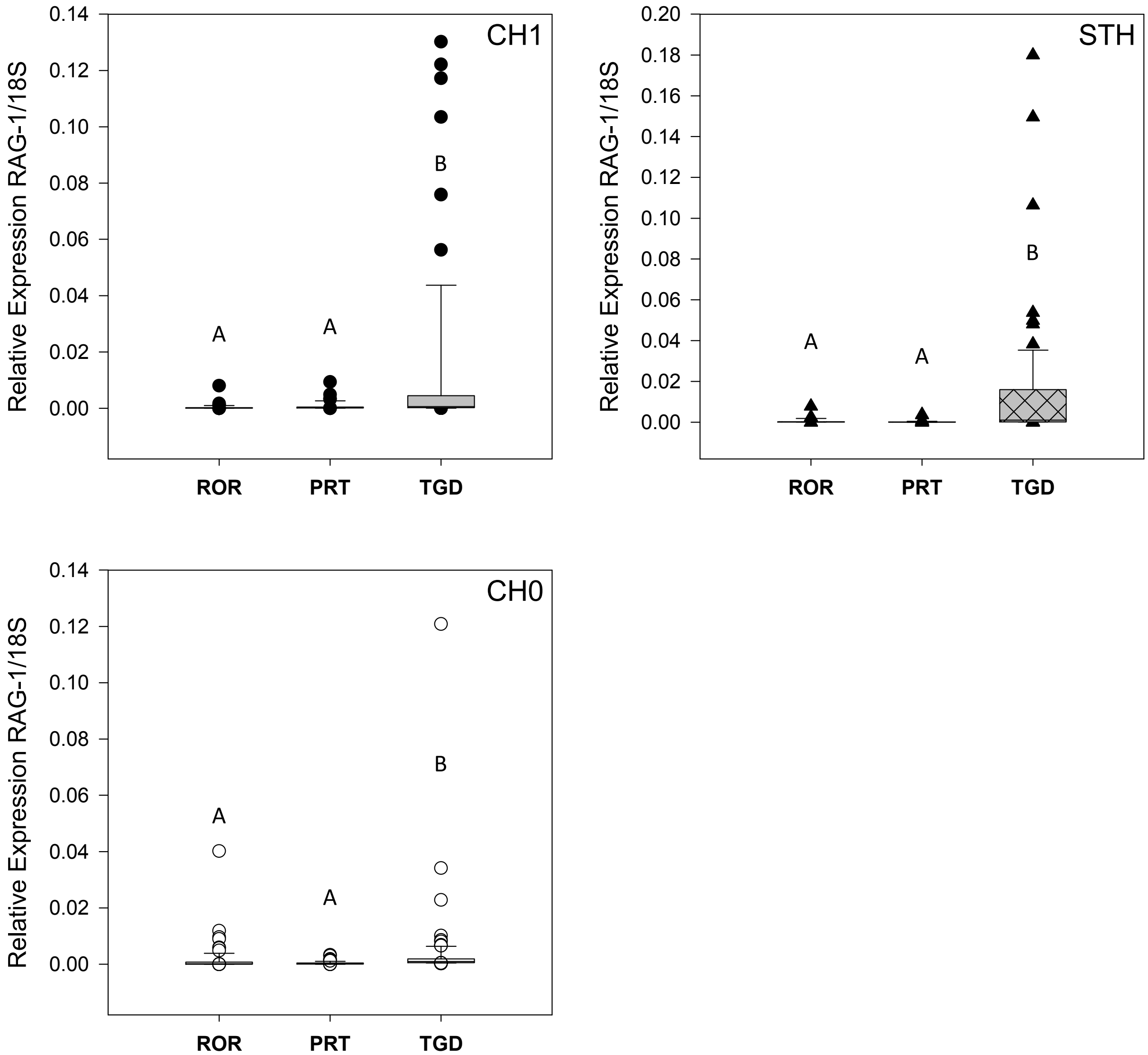

Figure A.9. Box plots of relative spleen RAG-1 gene expression for CH1 (●), STH (▲), and CH0 (○) during the tagging process. Each box plot represents the median and upper and lower quartiles for RAG-1 expression. Different uppercase letters indicate significant differences ($P < 0.05$).

For CH1, IgM gene expression significantly varied with treatment ($P < 0.0001$; Table A.20; Figure A.10). TGD CH1 had significantly higher IgM gene expression compared to ROR and PRT (all $P < 0.0005$). PRT CH1 had a significantly higher IgM expression compared to the ROR treatment ($P < 0.05$). For STH, IgM expression significantly varied with treatment ($P < 0.0001$; Table A.20; Figure A.10). TGD STH had significantly higher IgM expression when compared to ROR and PRT (all

$P < 0.0001$). There was no difference in IgM expression between ROR and PRT ($P > 0.05$). For CH0, IgM gene expression significantly varied with treatment ($P < 0.005$; Table A.21; Figure A.10). PRT CH0 had significantly higher IgM gene expression compared to ROR and TGD (all $P < 0.05$) treatments. There was no difference in IgM expression for ROR and TGD ($P > 0.05$).

For CH1, STH, and CH0, IL1-β and RAG-1 gene expression were significantly higher for TGD compared to SBC (all $P < 0.0001$; Table A.21; Figure A.11; Figure A.12). There is no difference in IgM gene expression for TGD and SBC CH1 ($P > 0.05$; Table A.21; Figure A.13). For STH and CH0, IGM was significantly lower for the SBC compared to the TGD (all $P < 0.0001$; Table A.21; Figure A.13).

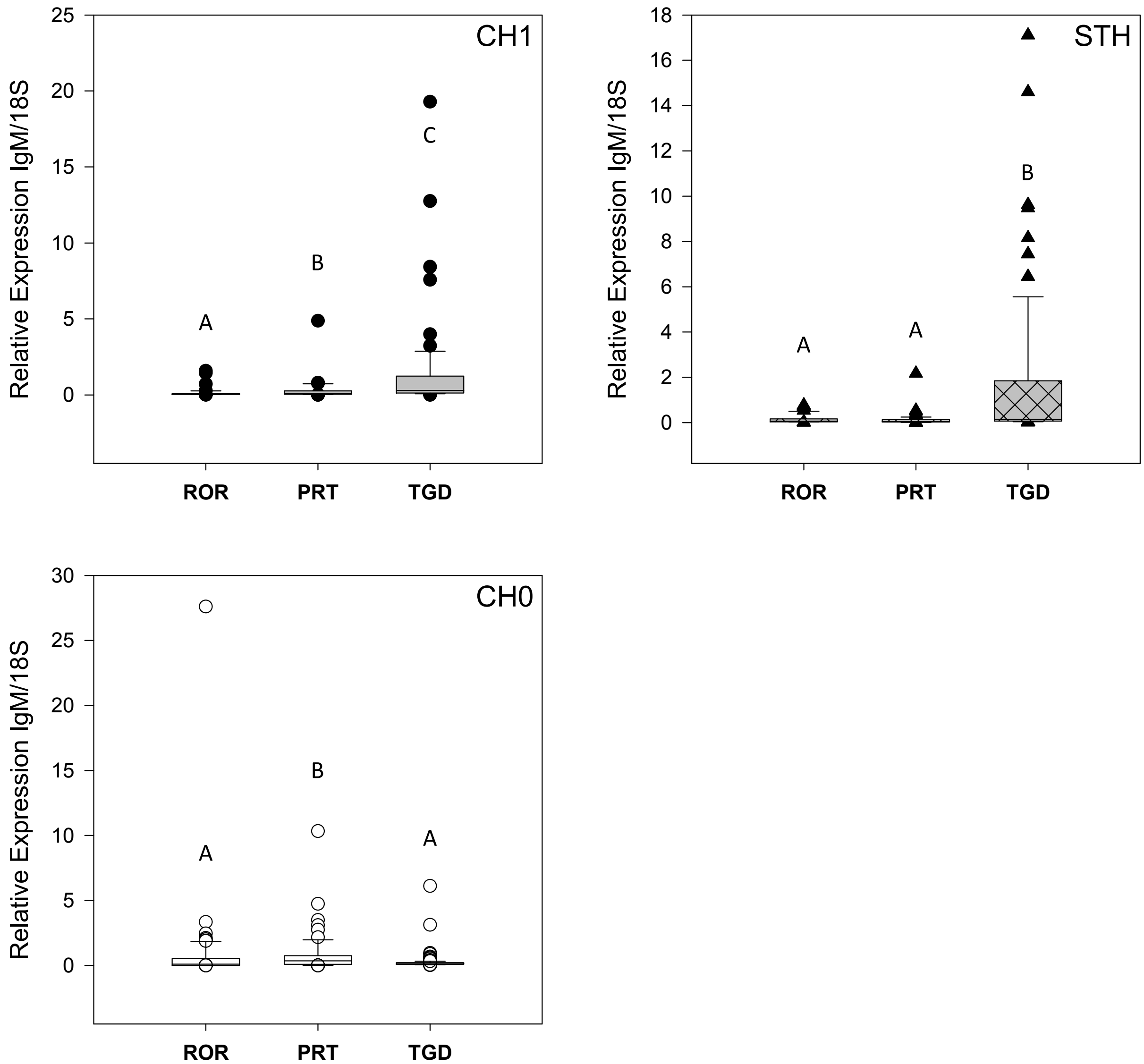

Figure A.10. Box plots of relative spleen IgM gene expression for CH1 (●), STH (▲), and CH0 (○) during the tagging process. Each box plot represents the median and upper and lower quartiles for IgM expression. Different uppercase letters indicate significant differences ($P < 0.05$).

Table A.21. Kruskal-Wallis results for tagged versus tagged and released in river by immune gene and species.

Species	Gene	Df	N	χ^2	*P*
CH1	IL1-β	1	91	22.29	<0.0001
	RAG-1	1	91	42.36	<0.0001
	IgM	1	91	1.52	>0.05
STH	IL1-β	1	96	29.88	<0.0001
	RAG-1	1	96	39.34	<0.0001
	IgM	1	96	15.00	<0.0001
CH0	IL1-β	1	117	44.43	<0.0001
	RAG-1	1	121	51.26	<0.0001
	IgM	1	117	27.16	<0.0001

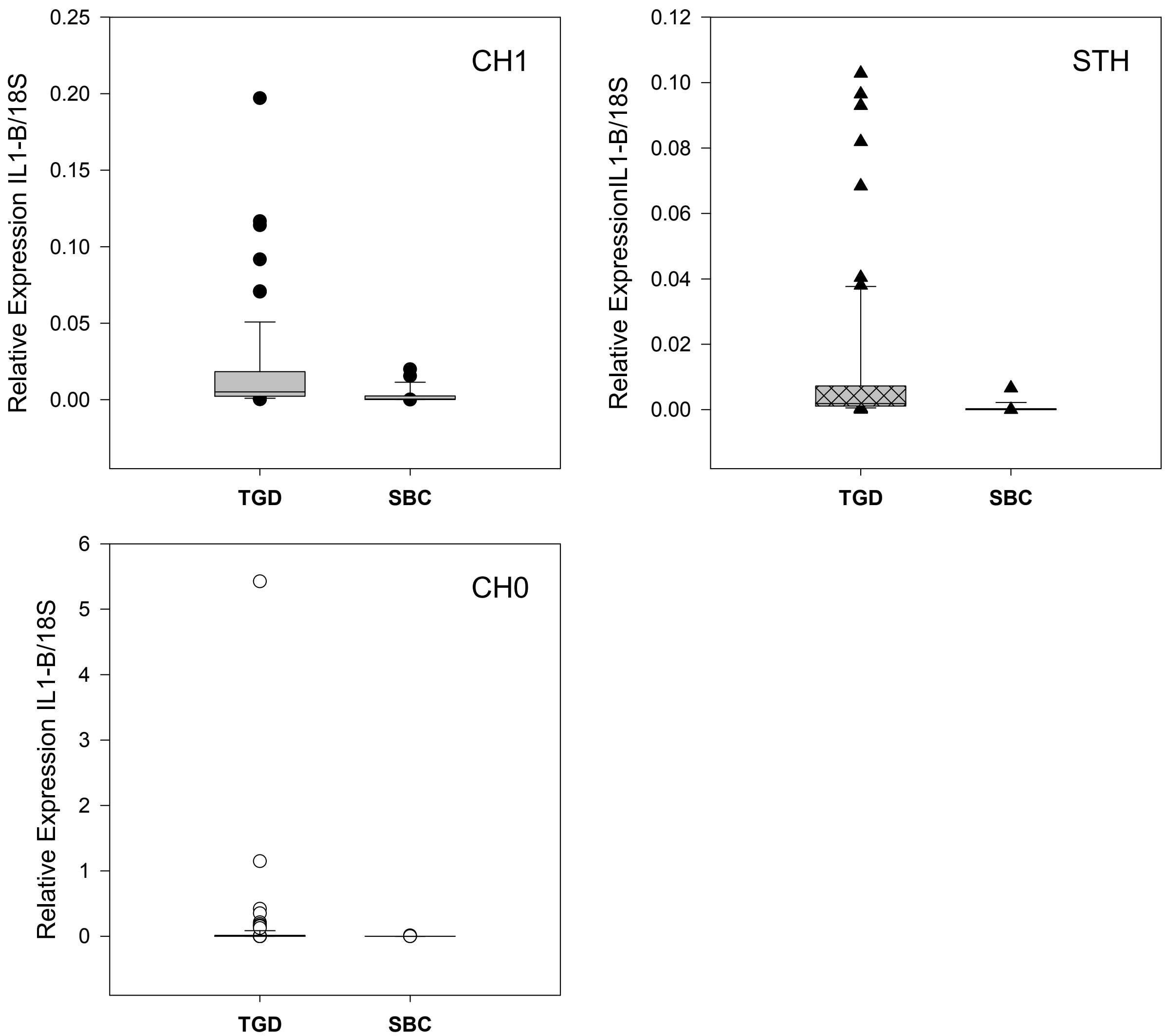

Figure A.11. Box plots of relative spleen IL1-β gene expression for CH1 (●), STH (▲), and CH0 (○) after tagging. Each box plot represents the median and upper and lower quartiles for IL1-β expression.

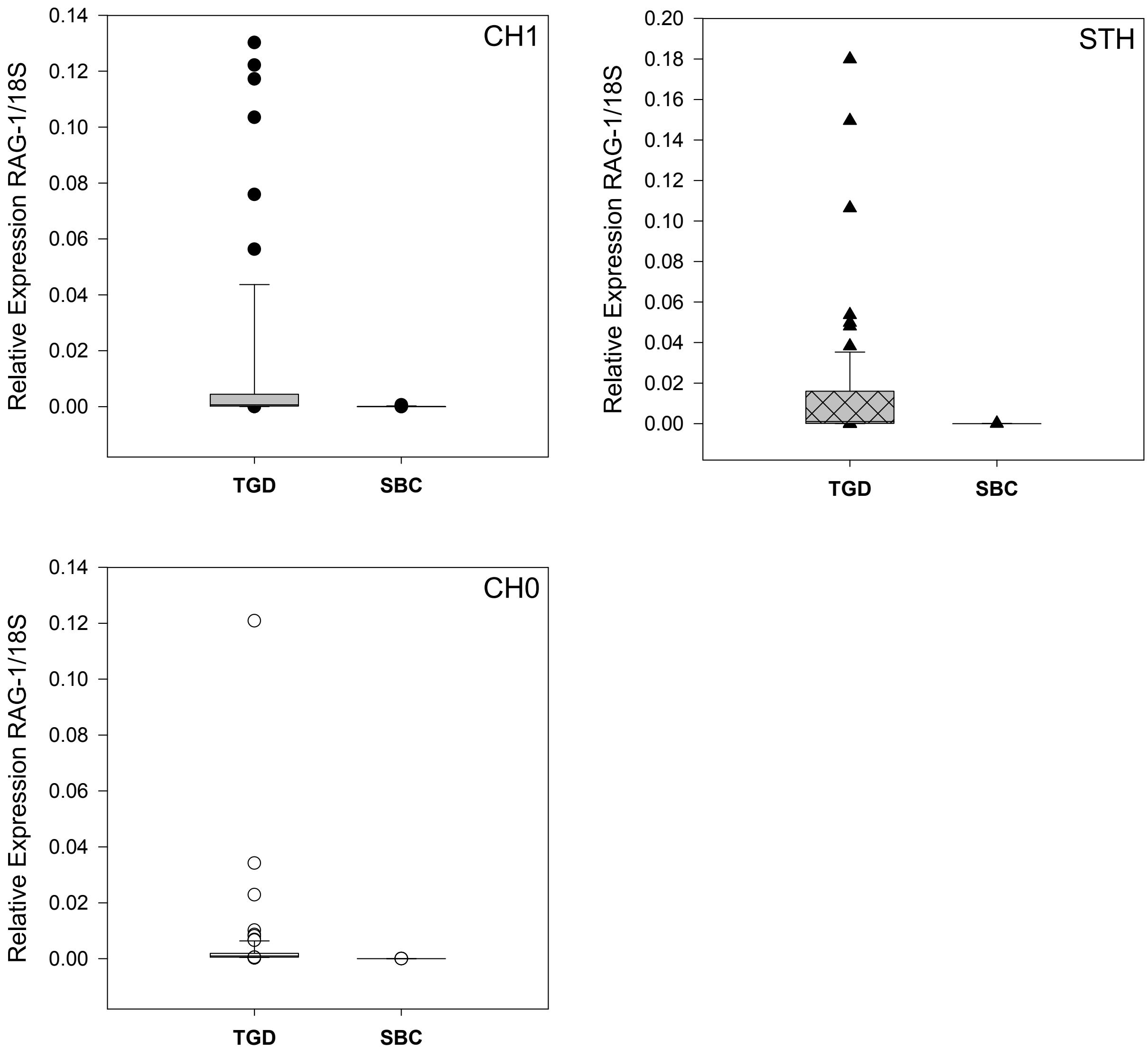

Figure A.12. Box plots of relative spleen RAG-1 gene expression for CH1 (●), STH (▲), and CH0 (○) after tagging. Each box plot represents the median and upper and lower quartiles for RAG-1 expression.

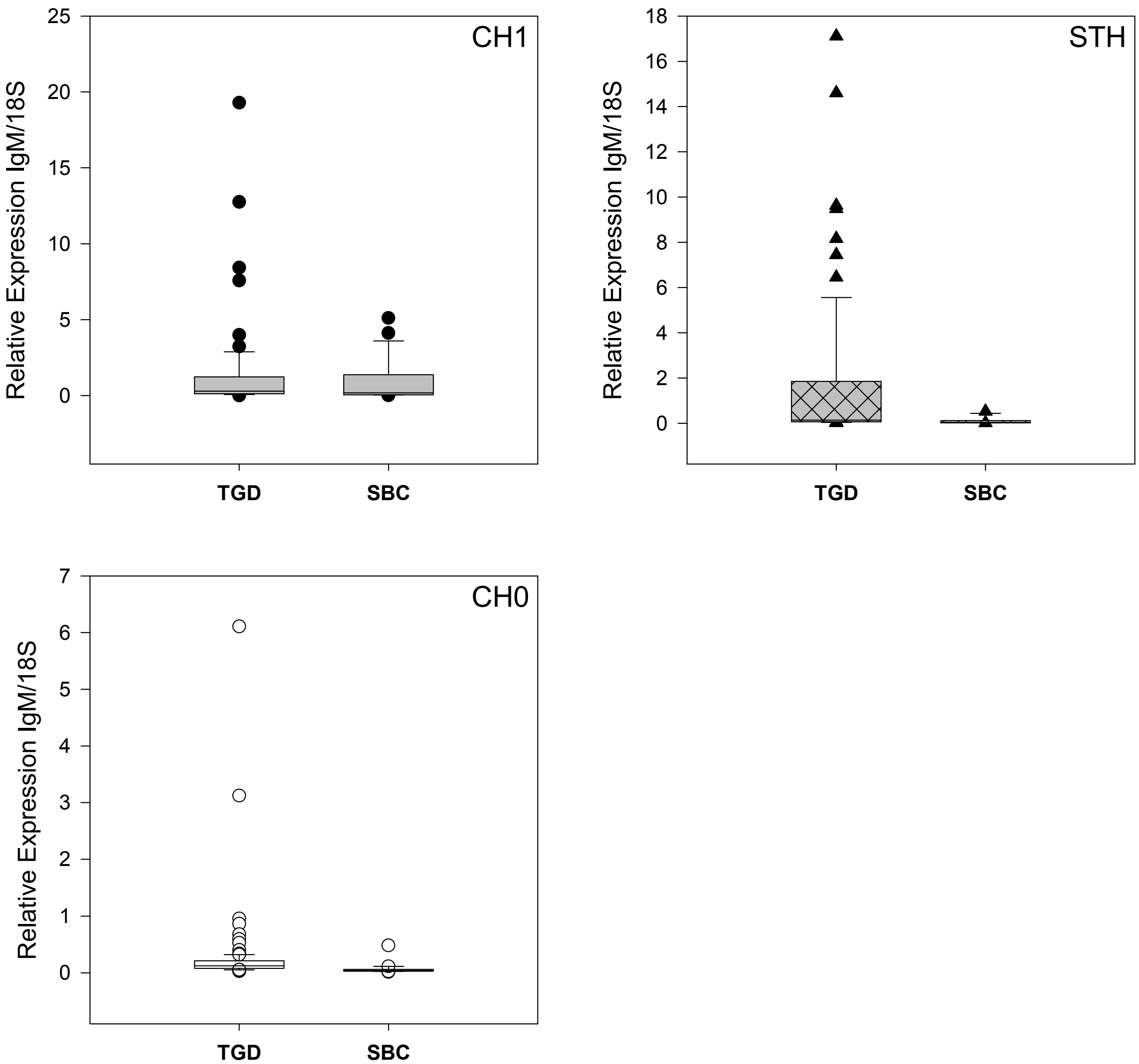

Figure A.13. Box plots of relative spleen IgM gene expression for CH1 (●), STH (▲), and CH0 (○) after tagging. Each box plot represents the median and upper and lower quartiles for IgM expression.

A.3.6 Liver Immune Gene Expression

TGD CH1 liver IL1-β gene expression ranged from 8.94×10^{-7} to 1.67×10^{-5} (mean = 8.83×10^{-6}; Figure A.14) and TGD STH IL1-β expression ranged from 8.38×10^{-7} to 1.23×10^{-5} (mean = 2.47×10^{-6}). Descriptive statistics for RAG-1 and IgM are summarized in Table A.22 (Figure A.15) and Table A.23 (Figure A.16). Statistical analyses of liver immune gene expression were not performed.

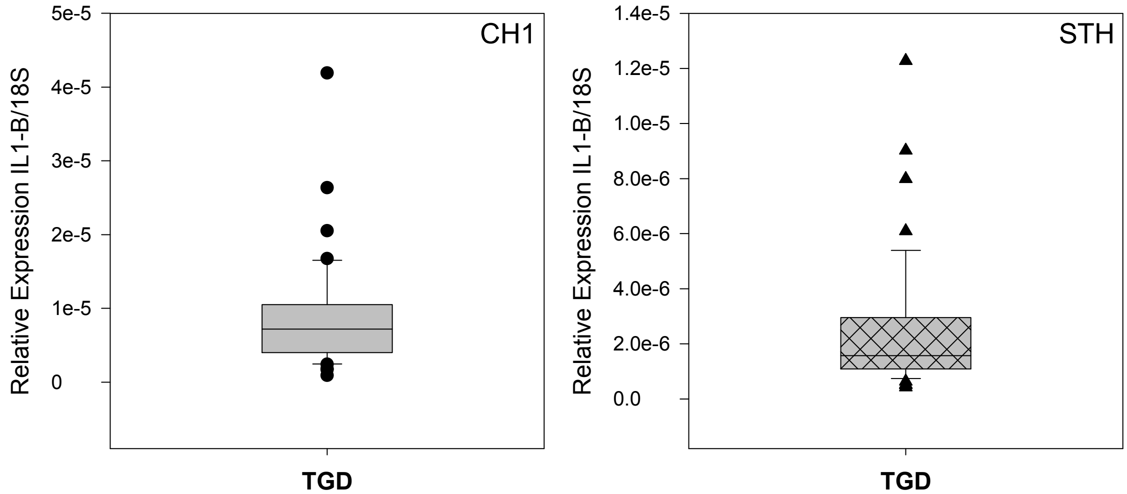

Figure A.14. Box plots of relative expression of TGD liver IL1-β for CH1 (●) and STH (▲) during the tagging process. Each box plot represents the median and upper and lower quartiles for liver IL1-β expression.

Table A.22. Liver RAG-1 descriptive statistics for CH1, STH, and CH0.

Species	Treatment	N	min	max	mean
CH1	ROR	-	-	-	-
	PRT	8	1.3×10^{-6}	1.4×10^{-4}	2.3×10^{-5}
	TGD	40	4.7×10^{-7}	9.9×10^{-5}	4.3×10^{-6}
	SBC	-	-	-	-
STH	ROR	-	-	-	-
	PRT	19	1.7×10^{-7}	2.8×10^{-6}	1.0×10^{-6}
	TGD	40	1.3×10^{-7}	2.0×10^{-4}	5.9×10^{-6}
	SBC	-	-	-	-
CH0	ROR	40	4.4×10^{-7}	5.3×10^{-5}	8.9×10^{-6}
	PRT	19	1.3×10^{-6}	2.8×10^{-5}	8.8×10^{-6}
	TGD	-	-	-	-
	SBC	-	-	-	-

Table A.23. Liver IgM descriptive statistics for CH1, STH, and CH0.

Species	Treatment	*N*	min	max	mean
CH1	ROR	5	2.2×10^{-5}	7.11×10^{-5}	4.5×10^{-5}
	PRT	8	6.5×10^{-5}	4.5×10^{-3}	1.1×10^{-3}
	TGD	40	1.8×10^{-5}	1.2×10^{-3}	1.2×10^{-3}
	SBC	24	6.5×10^{-6}	1.8×10^{-4}	5.8×10^{-5}
STH	ROR	2	1.7×10^{-5}	2.4×10^{-5}	2.1×10^{-5}
	PRT	19	7.0×10^{-6}	4.7×10^{-4}	9.8×10^{-5}
	TGD	48	4.0×10^{-6}	4.8×10^{-4}	6.7×10^{-5}
	SBC	17	7.0×10^{-6}	3.6×10^{-5}	1.4×10^{-5}
CH0	ROR	40	1.2×10^{-5}	1.2×10^{-3}	1.6×10^{-4}
	PRT	19	1.6×10^{-5}	3.2×10^{-4}	7.6×10^{-5}
	TGD	-	-	-	-
	SBC	22	1.0×10^{-5}	3.3×10^{-4}	5.2×10^{-5}

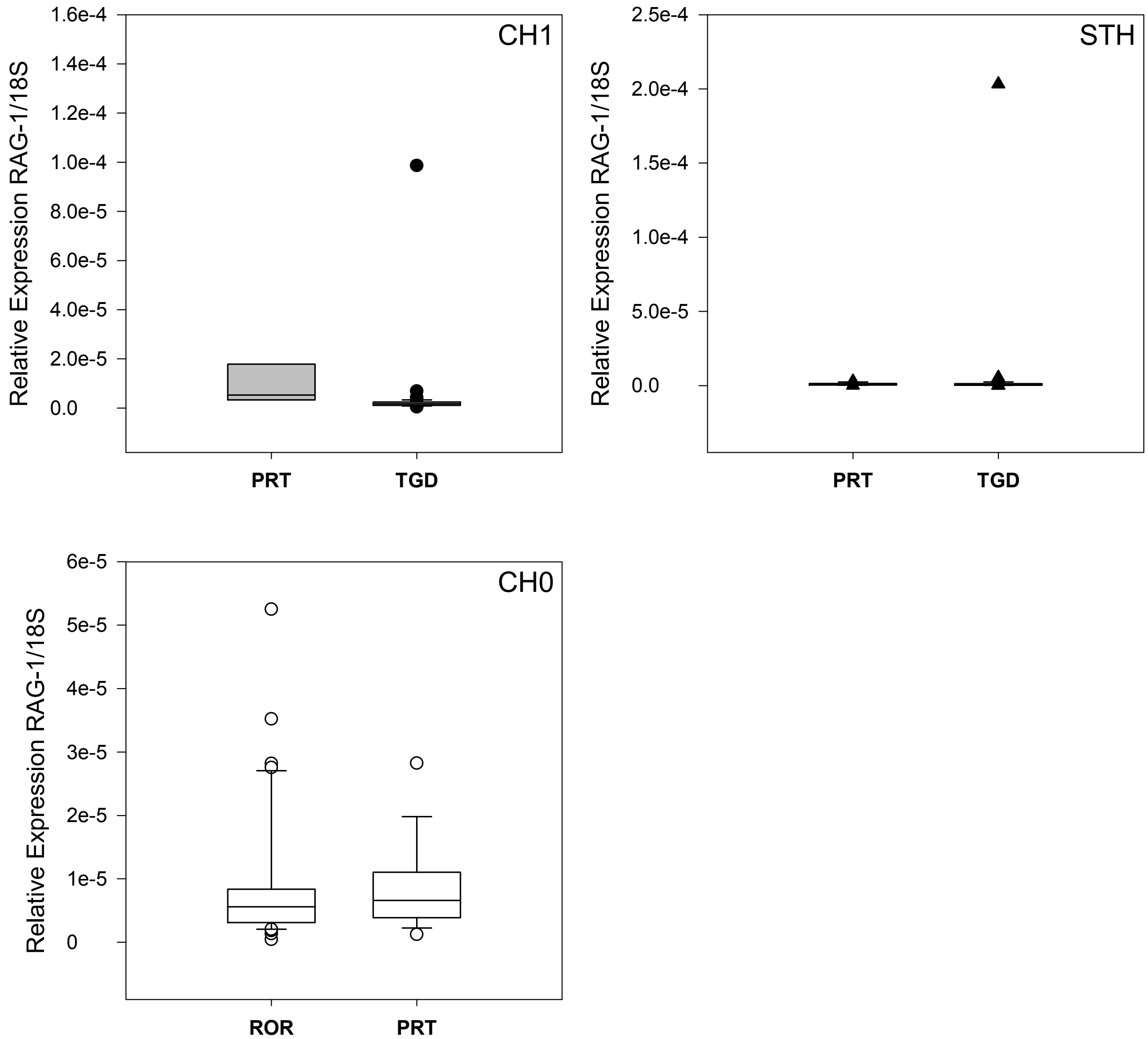

Figure A.15. Box plots of relative expression of liver RAG-1 for CH1 (●), STH (▲), and CH0 (○) during the tagging process. Each box plot represents the median and upper and lower quartiles for liver RAG-1 expression.

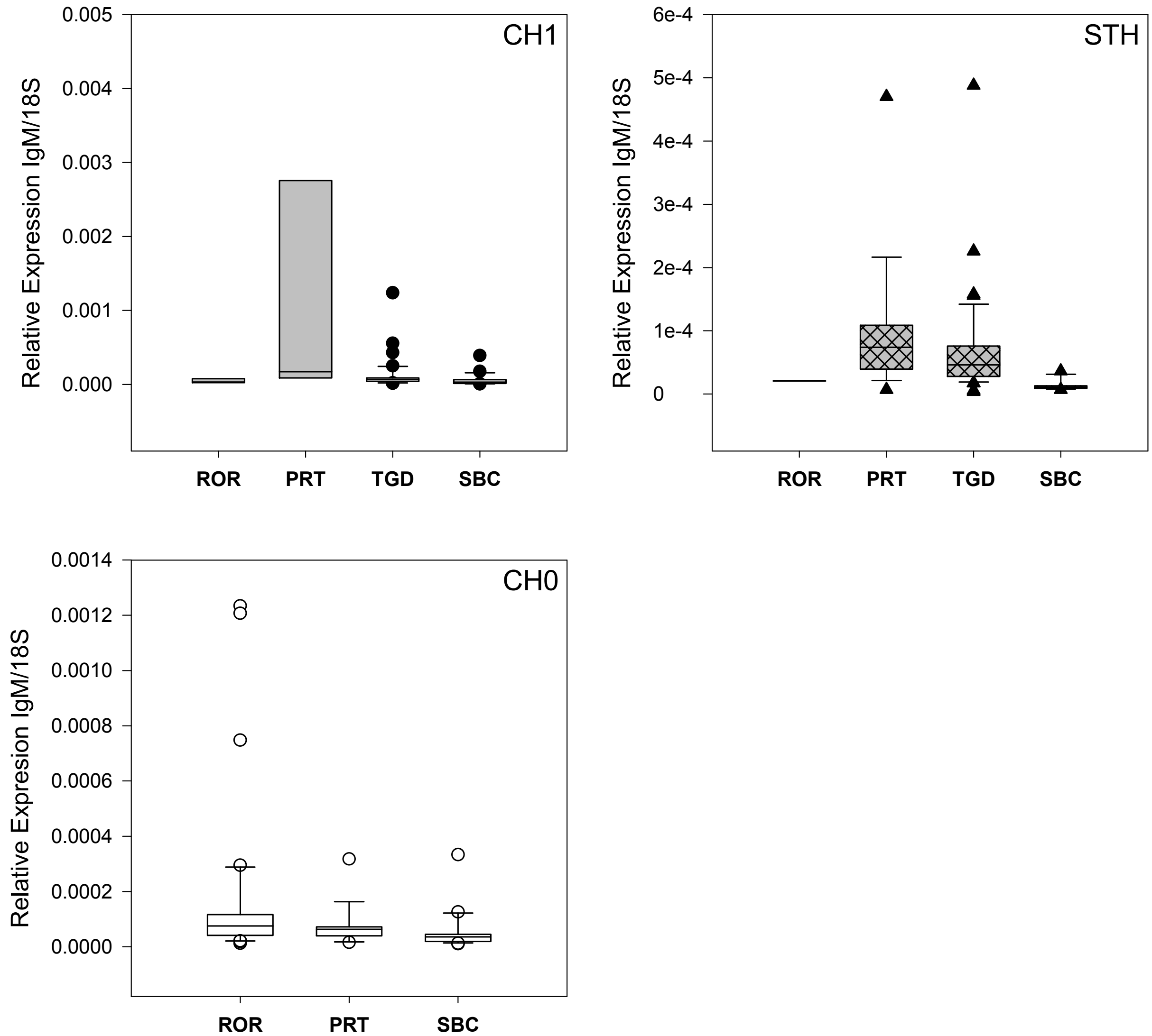

Figure A.16. Box plots of relative expression of IgM for CH1 (●), STH (▲), and CH0 (○) during the tagging process. Each box plot represents the median and upper and lower quartiles for liver IgM expression.

A.4 Discussion

A.4.1 Necropsy

The necropsy observations proved to be useful in determining juvenile salmon condition variation over time, size, and treatments. Species and/or run comparisons were not conducted. Because juvenile salmonids were collected and tagged at JDA for the concurrent survival study, the fish condition experimental design was developed to examine fish that were taken directly yet randomly from the sort table during the survival study collection periods, then during the survival study tagging events, and random tagged fish were transported to BON for condition examination. External observations, when summed for total observations made per fish, for ROR, PRT, and TGD fish were not significantly different, regardless of species. Conversely, internal observations, again when summed for total observations made per fish, indicated that the TGD group had significantly more internal trauma- and disease-related issues compared to the ROR and PRT groups, regardless of species. Trauma associated with damage from the tagger, incised tissue or tag, and infection was noted most frequently as the cause of damage. For example, the TGD fish internal examinations noted that the spleen, swim bladder, and fat were most often damaged or irritated by tag presence. Damage or irritation caused by tags included hematomas, hemorrhaging, deflation of organs, or impressions left on tissues. The effects of tags and tagging within the first 24 h were quite pronounced in the TGD fish, although not examined, are likely indicative of altered performance after release and perhaps even survival.

The study design allotted for the comparison of the PRT, TGD, and SBC fish released in-river that were later retrieved using the SByC at BON. Fish collected at BON were from the uppermost release point, taking 3 to 4 d to travel to BON. Acoustic-tagged CH1 and STH recollected at BON had significantly more observations of external health and trauma than those noted for the PRT and TGD treatment groups. Conversely, CH0 recollected at BON did not have more external indications of health and trauma issues than PRT and TGD fish. Internally, CH1 and STH had more observations of internal trauma and infection noted in the SBC treatment group than the TGD and PRT treatment groups. CH0, though, had greater internal trauma and infection observations noted in the TGD treatment group than in the PRT and SBC groups. This could be a result of fish size and tag size and burden. CH0 tend to be smaller, both in length and weight, than the other species. It is possible that at the time of tagging and insertion of the tags, CH0 simply lack the internal cavity space needed for the transmitters. As the mean observations indicate, in CH0 TGD treatment group, the tag and tagging damage is almost three-fold that of the CH1 and STH TGD treatment groups. By the time the CH0 are recollected, the fish were in the river longer than CH1 and STH, elevated temperature influenced metabolic rate, and subsequently, the tag-related damage was in a progressed state of healing.

The fish condition necropsy indicated that the overall condition of each species changed over time. During the second week of the spring session, facility malfunction at JDA caused damage to fish that entered the bypass. The necropsy approach was able to detect the increase in both external and internal damage caused by the facility malfunction. Therefore, if week 2 is excluded from the spring session, the general trend of the condition for the CH1 and STH indicated that the beginning of each tagging session (week 1), the juvenile salmon, regardless of species, were in better condition than those fish towards the end of the tagging session (weeks 4 and 5). This could be related to several factors such as water temperature and/or flow, river debris, salmon origination, and/or state of smoltification. Efforts to predict fish condition over time as a factor of survival may prove to be useful for both monitoring survival across dams as well as facility operations to improve fish passage.

Lastly, the combination of external and internal necropsy observations indicated that smaller fish tend to have a poor condition. Over the spring and summer session, there were no significant size variations for STH and CH0. However, in the spring, CH1 tended to be larger the first week of the season, and smaller in the fourth and fifth week. Therefore, fish condition and size are covariates that long-term data should be able to better address.

A.4.2 Alpha II-Spectrin

Alpha II-spectrin is a cytoskeletal protein that is broken down by enzymatic activity. These SBDPs in brain tissue have been measured in rats and juvenile Chinook salmon to quantify head trauma (Kobeissy et al. 2006; Miracle et al. 2009). Unlike mammals, teleosts have the ability to regenerate neural tissue throughout life; therefore, there is always a basal level of SBDPs from neural tissue (Zupanc 2008). However, a comparative examination of SBDP levels can be used to assess possible head trauma differences between treatment groups. It is predicted that alpha II spectrin could be measured as an internal injury marker, based on the assumption that damaged cells would release this intact and broken structural protein into biological fluids (i.e., blood, cerebral spinal fluid), which could be detected in plasma. Therefore, presence of alpha II -spectrin in a plasma sample may be indicative of some level of internal trauma or injury.

In this study, there were no significant differences in brain SBDPs between treatments for CH1, STH, or CH0, suggesting that the tagging process does not result in increased head trauma. For STH, there were no differences in the presence of plasma alpha II-spectrin and SBDPs between treatment groups, which could possibly be a result of pre-existing damage (e.g., descaling, open wounds, skeletal deformities) masking any effects of surgery. STH often had more external signs of damage prior to the tagging process than CH1 (Table A.14). For CH1, the PRT had significantly lower plasma alpha II-spectrin and SBDPs compared to both the ROR and TGD treatments. Higher levels of plasma alpha II-spectrin and SBDPs in the ROR treatment may be a result of pre-existing conditions, as described for STH. Prior to tagging, fish are sorted and fish that exhibit certain maladies (e.g., open wounds, skeletal deformities, >20% descaling) are not accepted for tagging. The ROR treatment group contains some fish that would not be accepted when following these criteria, and may have contributed to the higher levels of plasma alpha II-spectrin and SBDPs. The higher presence of plasma alpha II-spectrin and SBDPs in the TGD treatment group may be a result of the tagging itself, because intracoelomic implantation involves the cutting of tissue. However, in CH0, plasma alpha II-spectrin expression was lowest in the TGD treatment group when compared to the ROR and PRT treatment groups. Although species comparisons were not conducted, plasma alpha II-spectrin patterns suggest that there is are species difference and that presence of alpha II -spectrin and SBDPs are likely dependent upon pre-existing conditions.

For all measured immune markers in all species, gene expression appeared to have subsided or have been absent in the SBC treatment compared to TGD treatment. Again, the BON SBC fish were sampled from one release group, Roosevelt at rkm 390, where fish were in the river from 4–10 d before sampling.

A.4.3 Spleen Immune Gene Expression

Teleosts have both innate and adaptive immune responses. Tagging is expected to elicit an innate immune response. Adaptive responses, such as up-regulated RAG-1 and IgM gene expression, may occur in response to antigen exposure that may be introduced during the tagging process or in support of the innate immune response. In this study, we measured IL1-β gene expression in the spleen to infer innate immune responses and RAG-1 and IgM to infer adaptive immune responses.

IL1-β is a cytokine indicative of a generalized inflammation response to injury or pathogens. Spleen IL1-β was elevated in the TGD treatment compared to the ROR and PRT treatments for CH1, STH, and CH0. Similarly, Ingerslev et al. (2010) demonstrated that rainbow trout have elevated muscle tissue IL1-β expression in response to physical injury.

RAG-1 is expressed in B and T cells where it is responsible for the rearrangement of antigen receptors in order to fight specific antigens (viral, bacterial, etc.). In CH1, STH, and CH0 there was a significant up-regulation of spleen RAG-1 gene expression in response to tagging. Such an up-regulation in RAG-1 expression would be expected to precede B cell and T cell receptor expression.

IgM is a B cell surface receptor. For both CH1 and STH, there is a higher expression of IgM in TGD fish compared to ROR and PRT fish, which may be indicative of an active adaptive immune response. CH0 had a higher IgM gene expression in the PRT treatment compared to the ROR and TGD treatments. CH0 migrate downstream during higher water temperatures and have a higher tag burden than both CH1 and STH, both of which can increase stress. Stress (i.e., cortisol) has been shown to have an inhibitory effect on secreted IgM (Saha et al. 2004), and thus it may be possible that IgM expression in TGD CH0 was inhibited. In addition, IgM gene expression may be delayed in the younger and smaller CH0 compared to the STH and CH1 treatments. It is important to recognize that, because IgM is a marker of adaptive immunity, prior exposure to vaccines and pathogens, during hatchery operations or downriver migration, can alter the response to an antigen (Olsen et al. 2011).

A.4.4 Liver Immune Gene Expression

Liver immune gene expression was analyzed because teleost liver tissue is involved in secondary innate immune responses. Although liver immune gene expression followed similar patterns as spleen immune gene expression, expression levels overall were much lower in the liver. This is likely because the spleen is one of the major lymphoid organs in teleosts (Uribe et al. 2011), and the liver is not a primary lymphopoetic organ.

A.5 Implications for Management

In the Columbia River Basin, many programs assess fish condition by documenting external observations as an indicator of physiological state and internal damage. The approach used in this study, though, indicated that external observations were not necessarily good indicators of internal and physiological state. Thus, programs based simply on external observation of fish condition are likely to underestimate or under describe the actual condition of the fish. These programs and even this study would benefit by developing indices for external and internal condition that would predict juvenile salmon condition. In addition telemetry-based studies, such as the concurrent survival study, can benefit from the approach by increasing their ability to quantify the effects of surgery and transmitter implantation and separating the effects from anesthetic exposure (Woodley et al. 2012). Selected biochemistries further elaborate on fish condition for each treatment and warrant additional investigations into non-lethal fish condition assessments that do not underestimate condition. Internal physical damage that was more extensive in the TGD and SBC treatment groups, could cause delayed mortality, decreased performance, altered behavior, and increased physiological costs (Jepsen et al. 2002, Lacroix et al. 2004; Welch et al. 2007).

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Appendix B

Autonomous Node and Hydrophone Deployment Tables

Appendix B

Autonomous Node and Hydrophone Deployment Tables

Table B.1. List of waypoint coordinates of autonomous node deployment locations for the 2010 study. The waypoint name is a concatenation of CR for Columbia River with river kilometer, followed by a sequenced numbering system from the Washington to the Oregon shore for an individual array.

Array_Node	Array Function	Latitude in decimal deg. (neg. is south)	Longitude in decimal deg. (neg. is west)
CR351.0_01	JDA Forebay Entrance; Regroup fish for virtual releases	45.7313189	-120.6771875
CR351.0_02		45.7302789	-120.6758453
CR351.0_03		45.7291670	-120.6747872
CR351.0_04		45.7281806	-120.6737032
CR351.0_05		45.7271943	-120.6725159
CR351.0_06		45.7261362	-120.6713286
CR351.0_07		45.7251139	-120.6700381
CR351.0_08		45.7240737	-120.6688766
CR346.0_01	JDA Tailwater Egress; Detect tagged fish to estimate egress rates	45.7084635	-120.7257697
CR346.0_02		45.7074946	-120.7250730
CR346.0_03		45.7064361	-120.7241957
CR346.0_04		45.7057722	-120.7236796
CR275.0_01	Hood River; JDA Secondary	45.7081350	-121.4693915
CR275.0_02		45.7076650	-121.4701141
CR275.0_03		45.7071950	-121.4708366
CR275.0_04		45.7067612	-121.4715076
CR275.0_05		45.7063635	-121.4722301
CR275.0_06		45.7059659	-121.4729525

Table B.2. 2010 John Day Dam cabled hydrophone deployment table.

Hydrophone Name	Northing[a]	Easting[a]	Hydrophone Elevation[b]
JDA_P00_01D	745866.43	1951987.41	165.02
JDA_P00_01S	745864.43	1951976.57	251.39
JDA_P00N	745811.76	1952009.89	255.93
JDA_P00S	745763.97	1952044.58	256.30
JDA_P01_02D	745937.90	1951935.82	165.26
JDA_P01_02S	745936.08	1951924.95	251.63
JDA_P02_03D	746011.70	1951882.98	165.09
JDA_P02_03S	746009.20	1951872.25	251.46
JDA_P03_04D	746093.80	1951824.59	165.4
JDA_P03_04S	746085.00	1951817.95	251.77
JDA_P04_05D	746167.33	1951770.34	165.09
JDA_P04_05S	746157.86	1951764.71	251.46
JDA_P05_06D	746239.41	1951719.35	165.25
JDA_P05_06S	746230.74	1951712.55	251.62
JDA_P06_07D	746312.20	1951666.59	165.13
JDA_P06_07S	746303.51	1951659.81	251.5
JDA_P07_08D	746386.43	1951612.53	165.25
JDA_P07_08S	746377.04	1951606.76	251.62
JDA_P08_09D	746457.75	1951561.78	165.08
JDA_P08_09S	746449.36	1951554.64	251.45
JDA_P09_10D	746528.16	1951511.40	165.19
JDA_P09_10S	746521.56	1951502.58	251.56
JDA_P10_11D	746600.71	1951458.93	165.26
JDA_P10_11S	746594.45	1951449.86	251.63
JDA_P11_12D	746672.45	1951407.04	165.04
JDA_P11_12S	746667.06	1951397.43	251.41
JDA_P12_13D	746744.72	1951354.75	165.08
JDA_P12_13S	746739.79	1951344.90	251.45
JDA_P13_14D	746819.97	1951300.53	164.85
JDA_P13_14S	746813.34	1951291.73	251.22
JDA_P14_15D	746890.78	1951249.32	164.78
JDA_P14_15S	746885.62	1951239.59	251.15
JDA_P15_16D	746966.68	1951194.33	164.79
JDA_P15_16S	746959.38	1951186.08	251.16
JDA_P16_17D	747038.29	1951142.89	165.06
JDA_P16_17S	747032.00	1951133.84	251.43
JDA_P17_18D	747110.14	1951090.86	164.98
JDA_P17_18S	747104.60	1951081.33	251.35
JDA_P18_19D	747184.31	1951037.39	164.92
JDA_P18_19S	747177.86	1951028.46	251.29
JDA_P19_20D	747257.49	1950984.56	164.88
JDA_P19_20S	747250.97	1950975.68	251.25
JDA_P20D	747324.96	1950923.98	193.2
JDA_P20S	747322.40	1950919.40	250.94

Table B.2. (contd)

Hydrophone Name	Northing[a]	Easting[a]	Hydrophone Elevation[b]
JDA_S01_02D	748301.06	1950202.77	228.81
JDA_S01_02S	748301.06	1950202.77	256.31
JDA_S01N	748429.22	1950129.13	255.77
JDA_S01S	748356.19	1950162.40	255.91
JDA_S02_03D	748250.72	1950239.13	228.82
JDA_S02_03S	748250.72	1950239.13	256.32
JDA_S03_04D	748200.49	1950275.35	228.72
JDA_S03_04S	748200.49	1950275.35	256.22
JDA_S04_05D	748150.40	1950311.58	228.69
JDA_S04_05S	748150.40	1950311.58	256.19
JDA_S05_06D	748100.32	1950347.79	228.57
JDA_S05_06S	748100.32	1950347.79	256.07
JDA_S06_07D	748050.30	1950383.92	228.67
JDA_S06_07S	748050.30	1950383.92	256.17
JDA_S07_08D	747999.57	1950420.48	228.66
JDA_S07_08S	747999.57	1950420.48	256.16
JDA_S08_09D	747949.24	1950456.77	228.62
JDA_S08_09S	747949.24	1950456.77	256.12
JDA_S09_10D	747898.91	1950493.15	228.54
JDA_S09_10S	747898.91	1950493.15	256.04
JDA_S10_11D	747848.76	1950529.38	228.79
JDA_S10_11S	747848.76	1950529.38	256.29
JDA_S11_12D	747798.49	1950565.72	228.60
JDA_S11_12S	747798.49	1950565.72	256.10
JDA_S12_13D	747748.42	1950601.88	228.61
JDA_S12_13S	747748.42	1950601.88	256.11
JDA_S13_14D	747698.10	1950638.22	228.69
JDA_S13_14S	747698.10	1950638.22	256.19
JDA_S14_15D	747647.66	1950674.55	228.60
JDA_S14_15S	747647.66	1950674.55	256.10
JDA_S15_16D	747597.49	1950710.82	228.49
JDA_S15_16S	747597.49	1950710.82	255.99
JDA_S16_17D	747547.16	1950747.13	228.51
JDA_S16_17S	747547.16	1950747.13	256.01
JDA_S17_18D	747496.75	1950783.50	228.74
JDA_S17_18S	747496.75	1950783.50	256.24
JDA_S18_19D	747446.47	1950819.80	228.61
JDA_S18_19S	747446.47	1950819.80	256.11
JDA_S19_20D	747396.17	1950856.13	228.64
JDA_S19_20S	747396.17	1950856.13	256.14
JDA_S20D	747346.54	1950892.61	228.1
JDA_S20S	747346.54	1950892.61	255.6

(a) NAD27, Oregon North State Plane, ft.
(b) NGVD29, ft.

Table B.3. 2010 The Dalles Dam cabled hydrophone deployment table.

Hydrophone Name	Northing[(a)]	Easting[(a)]	Hydrophone Elevation[(b)]
TDA_F00_01D	711287.87	1839768.39	106.11
TDA_F00_01S	711282.05	1839773.77	146.93
TDA_F01_02D	711316.84	1839798.87	106.07
TDA_F01_02S	711310.33	1839803.40	146.89
TDAF02_P01D	711344.18	1839827.18	105.84
TDAF02_P01S	711338.52	1839832.73	146.66
TDA_N01	711133.33	1837427.36	143.38
TDA_N02	711104.12	1837466.83	143.36
TDA_N03	711014.22	1837569.77	143.00
TDA_N04	710972.83	1837625.21	142.87
TDA_P01_02D	711406.48	1839892.18	106.91
TDA_P01_02S	711400.66	1839897.57	147.73
TDA_P02_03D	711466.38	1839954.78	106.98
TDA_P02_03S	711460.06	1839959.56	147.8
TDA_P03_04D	711525.43	1840016.17	107.13
TDA_P03_04S	711519.44	1840021.37	147.95
TDA_P04_05D	711583.57	1840076.83	107
TDA_P04_05S	711578.43	1840082.88	147.82
TDA_P05_06D	711642.58	1840138.46	106.96
TDA_P05_06S	711636.91	1840144.01	147.78
TDA_P06_07D	711701.75	1840199.82	107.06
TDA_P06_07S	711696.40	1840205.67	147.88
TDA_P07_08D	711762.13	1840262.74	106.98
TDA_P07_08S	711756.32	1840268.13	147.8
TDA_P08_SS	711814.7	1840330.74	151.59
TDA_PSS_09	711874.68	1840393.06	151.61
TDA_P09_10D	711941.42	1840449.48	106.75
TDA_P09_10S	711935.35	1840454.59	147.57
TDA_P10_11D	712000.15	1840510.80	107.4
TDA_P10_11S	711994.44	1840516.30	148.22
TDA_P11_12D	712059.14	1840572.13	107.51
TDA_P11_12S	712053.60	1840577.81	148.33
TDA_P12_13D	712119.47	1840634.65	106.94
TDA_P12_13S	712113.75	1840640.15	147.76
TDA_P13_14D	712179.14	1840696.67	107.29
TDA_P13_14S	712173.43	1840702.16	148.11
TDA_P14_15D	712237.49	1840757.96	107.3
TDA_P14_15S	712232.31	1840763.98	148.12
TDA_P15_16D	712296.43	1840819.49	107.19
TDA_P15_16S	712291.65	1840825.81	148.01
TDA_P16_17D	712355.41	1840881.02	107.29
TDA_P16_17S	712351.04	1840887.63	148.11
TDA_P17_18D	712416.92	1840944.60	107.48
TDA_P17_18S	712411.42	1840950.32	148.3

Table B.3. (contd)

Hydrophone Name	Northing[(a)]	Easting[(a)]	Hydrophone Elevation[(b)]
TDA_P18_19D	712477.49	1841007.72	107.22
TDA_P18_19S	712471.44	1841012.84	148.04
TDA_P19_20D	712533.97	1841067.00	107.16
TDA_P19_20S	712529.52	1841073.56	147.98
TDA_P20_21D	712596.19	1841131.41	107.02
TDA_P20_21S	712590.32	1841136.74	147.84
TDA_P21_22D	712655.72	1841193.18	107.08
TDA_P21_22S	712649.87	1841198.53	147.9
TDA_P22_00D	712713.68	1841253.79	107.06
TDA_P22_00S	712707.93	1841259.25	147.88
TDA_S00_01D	710930.85	1837683.34	123.55
TDA_S00_01S	710930.85	1837683.34	151.22
TDA_S01_02D	710896.25	1837730.54	123.25
TDA_S01_02S	710896.25	1837730.54	151.00
TDA_S02_03D	710861.01	1837778.26	123.24
TDA_S02_03S	710861.01	1837778.26	150.82
TDA_S03_04D	710824.74	1837827.23	123.31
TDA_S03_04S	710824.74	1837827.23	150.98
TDA_S04_05D	710789.35	1837875.08	123.48
TDA_S04_05S	710789.35	1837875.08	151.07
TDA_S05_06D	710753.58	1837923.32	123.37
TDA_S05_06S	710753.58	1837923.32	150.95
TDA_S06_07D	710717.86	1837971.65	123.39
TDA_S06_07S	710717.86	1837971.65	151.06
TDA_S07_08D	710682.31	1838019.8	123.45
TDA_S07_08S	710682.31	1838019.8	151.20
TDA_S08_09D	710646.35	1838068.22	123.35
TDA_S08_09S	710646.35	1838068.22	151.10
TDA_S09_10D	710610.84	1838116.17	123.40
TDA_S09_10S	710610.84	1838116.17	150.99
TDA_S10_11D	710574.88	1838164.67	123.41
TDA_S10_11S	710574.88	1838164.67	151.08
TDA_S11_12D	710539.38	1838212.74	123.33
TDA_S11_12S	710539.38	1838212.74	151.00
TDA_S12_13D	710503.87	1838260.75	123.47
TDA_S12_13S	710503.87	1838260.75	151.06

(a) NAD27, Oregon North State Plane, ft.
(b) NGVD29, ft.

Table B.4. 2010 Bonneville Dam cabled hydrophone deployment table.

Hydrophone Name	Northing[a]	Easting[a]	Hydrophone Elevation[b]
B01_02D	722558.45	1630298.62	12.75
B01_02S	722562.11	1630289.55	63.11
B01_F1D	722481.87	1630265.50	12.76
B01_F1S	722486.46	1630256.86	63.12
B02_03D	722634.73	1630331.49	12.81
B02_03S	722637.76	1630322.19	63.17
B03_04D	722711.83	1630364.47	12.64
B03_04S	722713.91	1630354.92	63
B04_05D	722782.24	1630395.26	12.66
B04_05S	722787.36	1630386.93	63.02
B05_06D	722859.90	1630428.82	12.55
B05_06S	722863.33	1630419.66	62.91
B06_7ND	722937.06	1630462.92	20.24
B06_7NS	722937.06	1630462.92	63.12
B06_7SD	722931.04	1630459.18	14.71
B06_7SS	722931.04	1630459.18	57.64
B07_08D	723009.42	1630493.22	12.43
B07_08S	723013.66	1630484.41	62.79
B08_09D	723085.98	1630526.45	12.38
B08_09S	723089.34	1630517.27	62.74
B09_10D	723161.35	1630558.98	12.51
B09_10S	723164.60	1630549.75	62.87
B11_12D	725462.2	1632543.49	12.68
B11_12S	725467.54	1632537.75	66.48
B12_13S	725536.37	1632601.81	66.25
B13_14D	725601.78	1632673.14	14.62
B13_14S	725607.11	1632667.4	66.62
B14_15D	725670.51	1632737.13	14.36
B14_15S	725675.84	1632731.39	66.36
B15_16D	725737.88	1632799.16	14.56
B15_16S	725743.22	1632793.41	66.56
B15A_T1	725658.03	1632755.02	69.64
B15C_T2	725699.92	1632795.2	69.66
B16_17D	725806.63	1632862.77	14.23
B16_17S	725811.96	1632857.02	66.23
B17_18D	725875.32	1632927.17	14.43
B17_18S	725880.66	1632921.43	66.43
B17A_T3	725795.26	1632883.48	69.51
B18_19D	725944.25	1632991.2	14.48
B18_19S	725949.58	1632985.46	66.48
B18B_T4	725885.5	1632967.25	70.04
B19_NOS	726018.04	1633048.61	68.24
B1N_10D	723230.932	1630587.467	12.5
B1N_10S	723230.932	1630587.467	62.86

Table B.4. (contd)

Hydrophone Name	Northing[a]	Easting[a]	Hydrophone Elevation[b]
B1S_SW1	723233.274	1630717.667	70.76
BCC_11D	725395.67	1632476.45	55.61
BCC_11S	725398.58	1632473.32	68.19
BGS_C01	725239.775	1632481.978	72.41
BGS_C02	725166.305	1632557.509	72.09
BGS_C03	725119.786	1632609.959	72.37
BGS_C04	725074.877	1632705.249	72.28
BGS_C05	725041.928	1632816.999	72.41
BGS_C06	725021.809	1632892.119	72.35
BGS_C07	725006.111	1632990.469	72.39
BGS_W01	725790.226	1633288.618	72.4
BGS_W02	725726.167	1633379.309	72.26
BGS_W03	725657.968	1633465.29	72.39
BGS_W04	725594.56	1633626.35	72.24
BGS_W06	725538.641	1633732.83	72.23
BGS_W07	725484.842	1633828.51	72.3
BGS_W08	725438.274	1633965.081	72.25
BNORWAL	722291.68	1630421.58	63.57
BPH1NWW	722904.36	1630537.37	68.81
BPH1SWW	722898.47	1630534.77	64.2
BS_00_D	724868.761	1631885.104	39.92
BS_00_S	724868.761	1631885.104	66.75
BS_01_D	724816.451	1631885.425	39.93
BS_01_S	724816.451	1631885.425	66.76
BS_02_D	724756.651	1631883.185	39.05
BS_02_S	724756.651	1631883.185	66.92
BS_03_D	724696.911	1631880.946	39.39
BS_03_S	724696.911	1631880.946	67.31
BS_04_D	724636.65	1631878.477	39.55
BS_04_S	724636.65	1631878.477	67.26
BS_05_D	724576.45	1631876.128	39.22
BS_05_S	724576.45	1631876.128	67.34
BS_06_D	724517.05	1631874.009	39.09
BS_06_S	724517.05	1631874.009	67.01
BS_07_D	724456.97	1631871.6	39.14
BS_07_S	724456.97	1631871.6	67.06
BS_08_D	724396.86	1631869.221	40.4
BS_08_S	724396.86	1631869.221	67.94
BS_09_D	724336.94	1631866.901	40.39
BS_09_S	724336.94	1631866.901	68.05
BS_10_D	724277.36	1631864.692	39.98
BS_10_S	724277.36	1631864.692	67.27
BS_11_D	724217.11	1631862.243	39.86
BS_11_S	724217.11	1631862.243	67.53

Table B.4. (contd)

Hydrophone Name	Northing[(a)]	Easting[(a)]	Hydrophone Elevation[(b)]
BS_12_D	724157.13	1631860.004	39.3
BS_12_S	724157.13	1631860.004	67.05
BS_13_D	724097.83	1631857.675	39.89
BS_13_S	724097.83	1631857.675	67.6
BS_14_D	724037.38	1631855.286	39.79
BS_14_S	724037.38	1631855.286	67.45
BS_15_D	723977.67	1631852.806	39.93
BS_15_S	723977.67	1631852.806	67.47
BS_16_D	723917.56	1631850.707	39.04
BS_16_S	723917.56	1631850.707	66.46
BS_17_D	723857.15	1631848.238	38.12
BS_17_S	723857.15	1631848.238	65.87
BS_18_D	723806.34	1631846.289	39.65
BS_18_S	723806.34	1631846.289	67.52
BS_17_D	723857.15	1631848.238	38.12
BS_17_S	723857.15	1631848.238	65.87
BS_18_D	723806.34	1631846.289	39.65
BS_18_S	723806.34	1631846.289	67.52

(a) NAD27, Oregon North State Plane, ft.
(b) NGVD29, ft.

Appendix C

Assessment of Survival Model Assumptions

Appendix C

Assessment of Survival Model Assumptions

The assessment of assumptions covers fish size distribution, handling mortality and tag shedding, tag-life corrections, arrival distributions, and tagger effects

C.1 Fish Size Distribution

Comparison of fish tagged with acoustic micro-transmitters (AMTs) and run-of-river fish sampled at John Day Dam through the Smolt Monitoring Program shows that the length frequency distributions were generally well matched for yearling Chinook salmon (CH1; Figure C.1), steelhead (STH) (Figure C.2), and subyearling Chinook salmon (CH0; Figure C.3). The median length for AMT-tagged CH1 was 152 mm. The median lengths of tagged STH and CH0 were 215 mm and 110 mm, respectively.

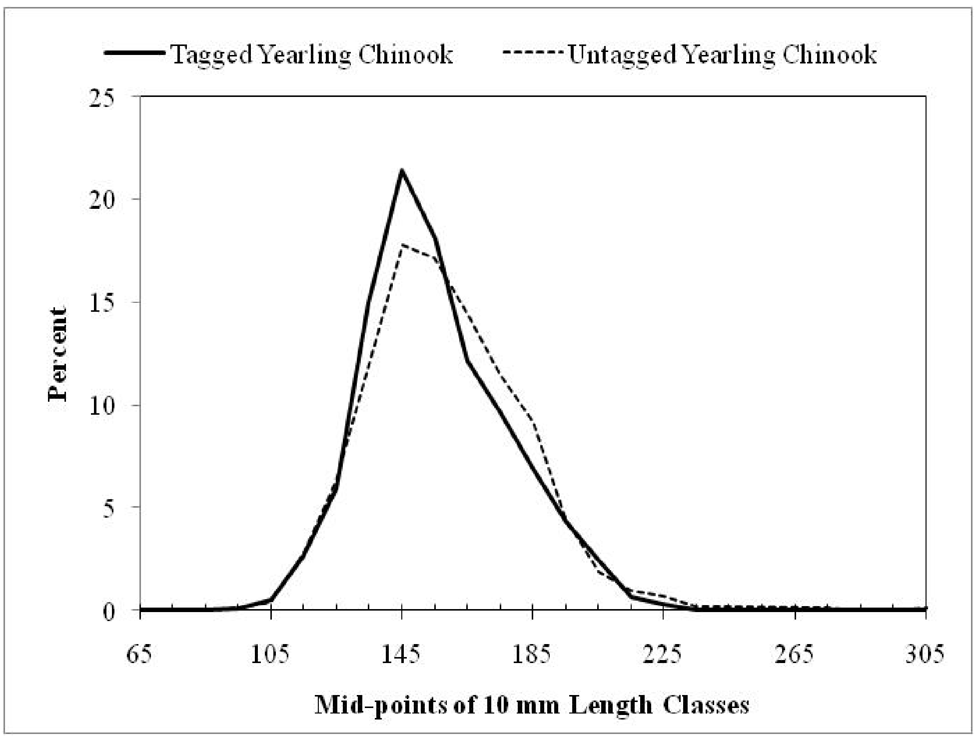

Figure C.1. Length frequency of tagged CH1 and run-of-river CH1 sampled at the John Day Dam smolt monitoring facility in spring 2010.

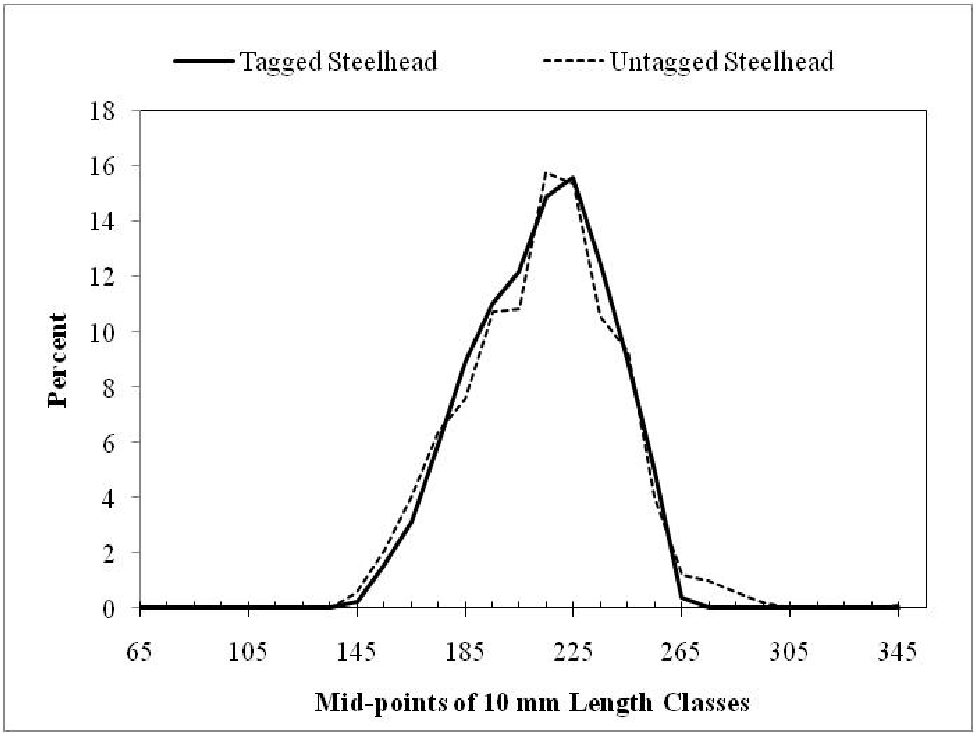

Figure C.2. Length frequency of tagged STH and run-of-river STH sampled at the JDA smolt monitoring facility in spring 2010.

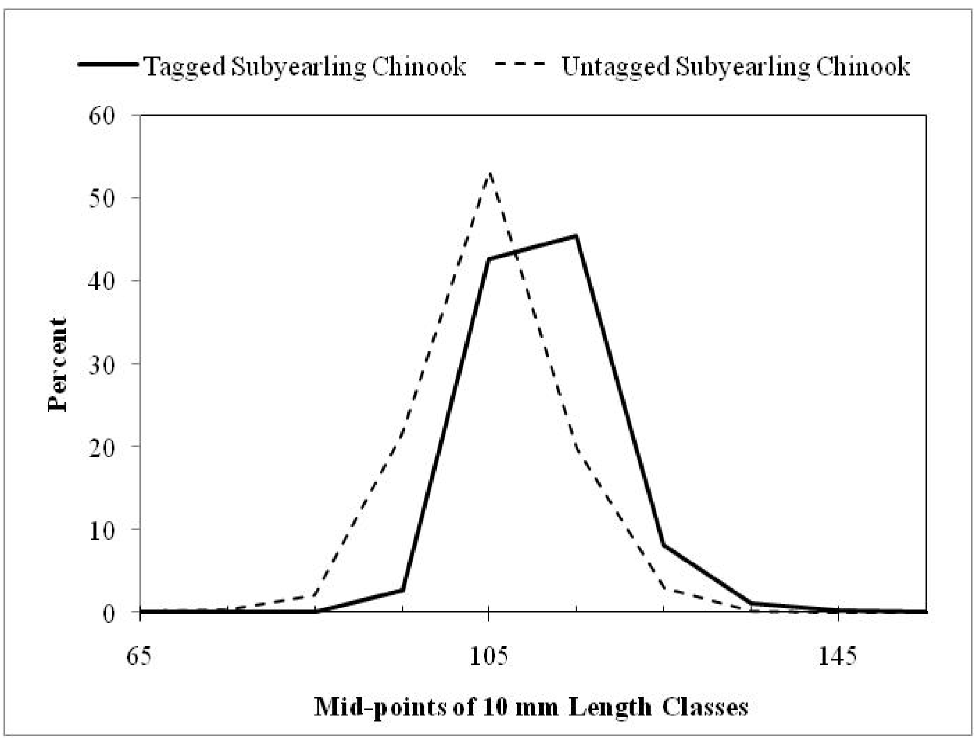

Figure C.3. Length frequency of tagged CH0 and run-of-river CH0 sampled at the JDA smolt monitoring facility in summer 2010.

C.2 Run Timing

The run timings of downstream migrating STH, CH1, and CH0, as indicated by the smolt passage index from the JDA Smolt Monitoring Program (SMP), were compared with study fish-release periods for spring and summer (April 28 to June 1 and June 13 to July 17, 2010, respectively).

Our goal was to tag the middle 80% of the run (10th to 90th percentile) for each species. During the spring, tagging of CH1 and STH occurred during the middle 78% and 73% of the run, respectively. During the summer, tagging of CH0 corresponded with the middle 79% of the run (Figure C.4). The cumulative percentage of fish passage during tagging operations was 6% to 84% for CH1, 6% to 79% for STH, and 9% to 88% for CH0. We relied on the 10-yr smolt index average as an indicator of run timing to determine the start date for tagging fish (Table C.1, Table C.2, and Table C.3).

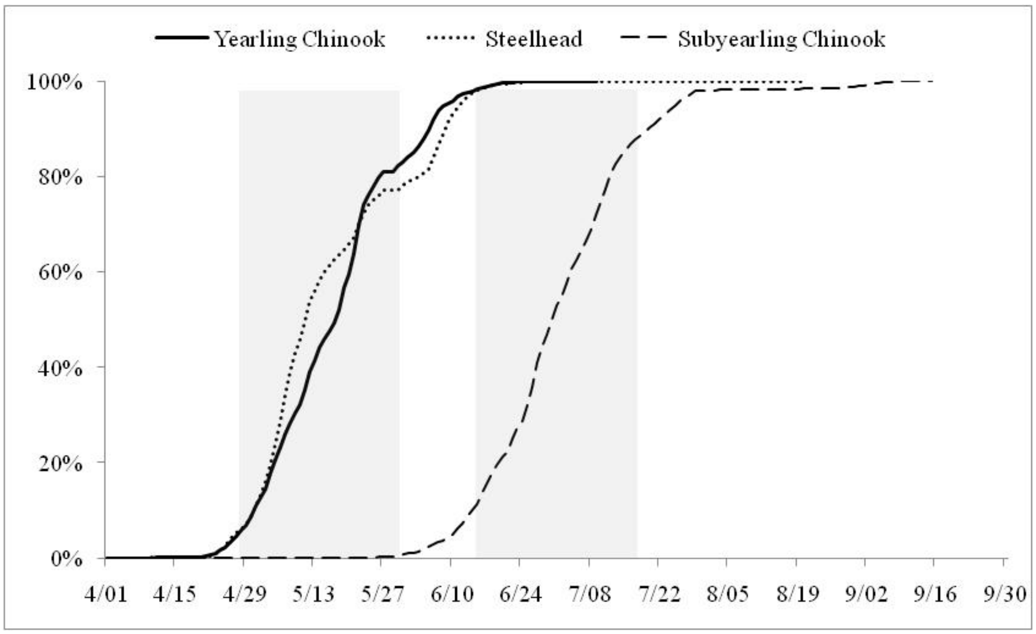

Figure C.4. Juvenile salmonid passage cumulative percentages at JDA by species in 2010. Gray bars represent fish-release periods during spring (4/28–6/1) and summer (6/13–7/17).

Table C.1. Ten-year average CH1 run-timing showing the percent passage at the JDA smolt monitoring facility.

Year	Passage Dates								Middle 80% Days
	First	1%	5%	10%	50%	90%	95%	Last	
2000	04/04	04/10	04/16	04/21	05/09	05/28	06/05	09/18	38
2001	03/30	04/21	05/01	05/06	05/27	06/20	06/27	09/17	46
2002	03/19	04/18	04/25	05/01	05/17	06/01	06/05	08/30	32
2003	04/01	04/14	04/27	05/03	05/19	06/02	06/04	09/15	31
2004	04/02	04/09	04/20	04/28	05/16	05/30	06/06	09/15	33
2005	04/02	04/05	04/18	04/25	05/12	05/22	05/30	09/15	28
2006	04/04	04/14	04/22	04/25	05/11	05/24	05/27	09/14	30
2007	04/03	04/16	04/26	05/02	05/13	05/25	05/30	09/13	24
2008	04/02	04/12	04/26	05/04	05/22	06/01	06/06	09/15	29
2009	04/01	04/16	04/24	04/27	05/17	06/01	06/07	09/15	36
10-yr average	03/31	04/13	04/23	04/29	05/16	05/30	06/05	09/13	33
2010	04/01	04/24	04/28	05/01	05/18	06/06	06/09	07/09	37

Table C.2. Ten-year average STH run-timing showing the percent passage at the JDA smolt monitoring facility.

Year	Passage Dates								Middle 80% Days
	First	1%	5%	10%	50%	90%	95%	Last	
2000	04/04	04/12	04/15	04/16	05/04	05/26	06/02	09/18	41
2001	03/30	04/16	04/25	04/30	05/12	06/02	06/20	09/17	34
2002	03/20	04/14	04/19	04/22	05/16	06/07	06/12	09/16	47
2003	04/01	04/11	04/26	05/02	05/29	06/04	06/06	09/15	34
2004	04/02	04/12	04/25	05/03	05/21	05/31	06/05	09/15	29
2005	04/02	04/17	04/30	05/02	05/18	05/25	05/28	09/15	24
2006	04/04	04/17	04/24	04/27	05/11	05/29	06/01	09/12	33
2007	04/03	04/17	05/01	05/04	05/12	05/26	06/02	09/13	23
2008	04/02	04/25	05/04	05/07	05/18	05/31	06/04	09/15	25
2009	04/01	04/22	04/27	04/28	05/10	05/28	06/07	09/15	31
10-yr average	03/31	04/16	04/25	04/29	05/15	05/30	06/05	09/15	32
2010	04/01	04/24	04/27	05/01	05/12	06/09	06/12	08/20	40

Table C.3. Ten-year average CH0 run-timing showing the percent passage at JDA smolt monitoring facility.

Year	Passage Dates								Middle 80%
	First	1%	5%	10%	50%	90%	95%	Last	Days
2000	04/07	06/01	06/05	06/06	06/29	08/03	08/09	09/18	59
2001	04/22	06/10	06/22	06/27	07/30	08/22	08/29	09/17	57
2002	03/22	06/03	06/11	06/20	06/30	07/21	08/04	09/16	32
2003	04/02	05/30	06/03	06/06	06/27	07/30	08/07	09/15	55
2004	04/07	05/30	06/08	06/14	06/28	07/23	07/30	09/15	40
2005	04/04	05/25	06/09	06/19	07/05	07/27	08/01	09/15	39
2006	04/11	05/25	06/05	06/12	07/02	07/17	07/22	09/14	36
2007	04/06	05/28	06/13	06/25	07/08	07/17	07/27	09/13	23
2008	05/03	05/28	06/01	06/14	07/07	07/30	08/05	09/15	47
2009	04/02	06/05	06/11	06/17	07/01	07/17	07/19	09/15	31
10-yr average	04/08	05/30	06/08	06/16	07/04	07/26	08/02	09/15	42
2010	04/16	06/02	06/11	06/15	07/01	07/20	07/26	09/15	36

C.3 Tag-Life Corrections (Tag-Life Plots)

For the spring 2010 study, mean tag life (n = 49) was 32.73 d. The earliest tag failure was at 7.8 d and the latest at 39.6 d. Failure-time data for the AMTs was fit to a four-parameter vitality model (Li and Anderson 2009). Maximum likelihood estimates for the four model parameters were $\hat{r} = 0.02963$, $\hat{s} = -5.59145\times10^{-9}$, $\hat{k} = 0.00173$, and $\hat{u} = 0.05730$ (Figure C.5). This tag-life survivorship model was subsequently used to estimate the probabilities of tag failure and provide tag-life-adjusted estimates of juvenile salmonid survival.

For the summer study, mean tag life (n = 50) was 35.54 d. The earliest tag failure was at 31.27 d and the latest at 40.13 d. The failure-time data for the AMTs was fit to a four-parameter vitality model of Li and Anderson (2009). The maximum likelihood estimates for the four model parameters were $\hat{r} = 0.028261$, $\hat{s} = -2.91111\times10^{-9}$, $\hat{k} = 0$, and $\hat{u} = 0.058789$ (Figure C.6). This tag-life survivorship model was subsequently used to estimate the probabilities of tag failure and provide tag-life-adjusted estimates of juvenile salmonid survival.

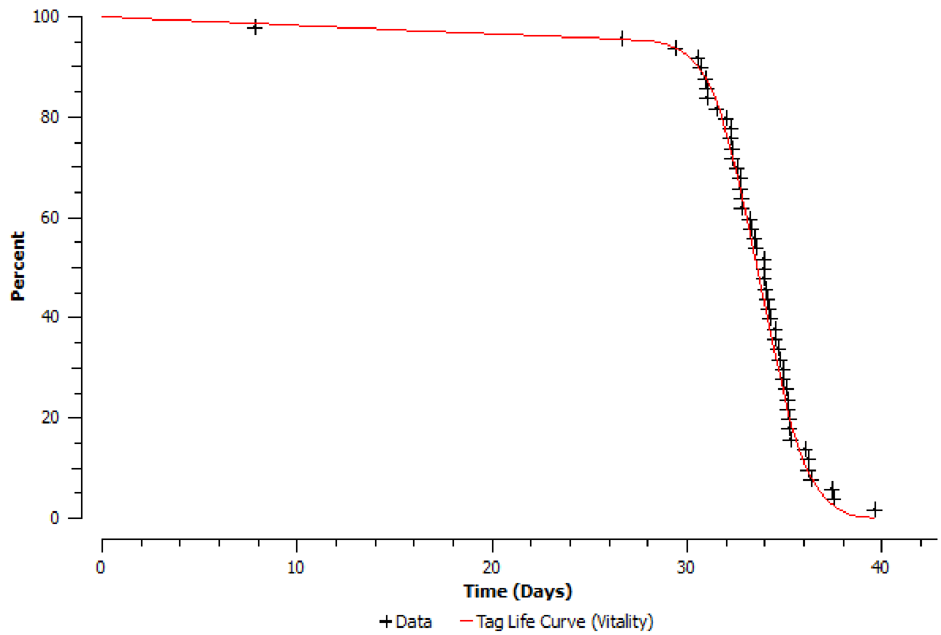

Figure C.5. Individual failure times for acoustic micro-transmitters used in the tag-life study (n = 49) fitted to the four-parameter vitality model (Li and Anderson 2009), spring 2010.

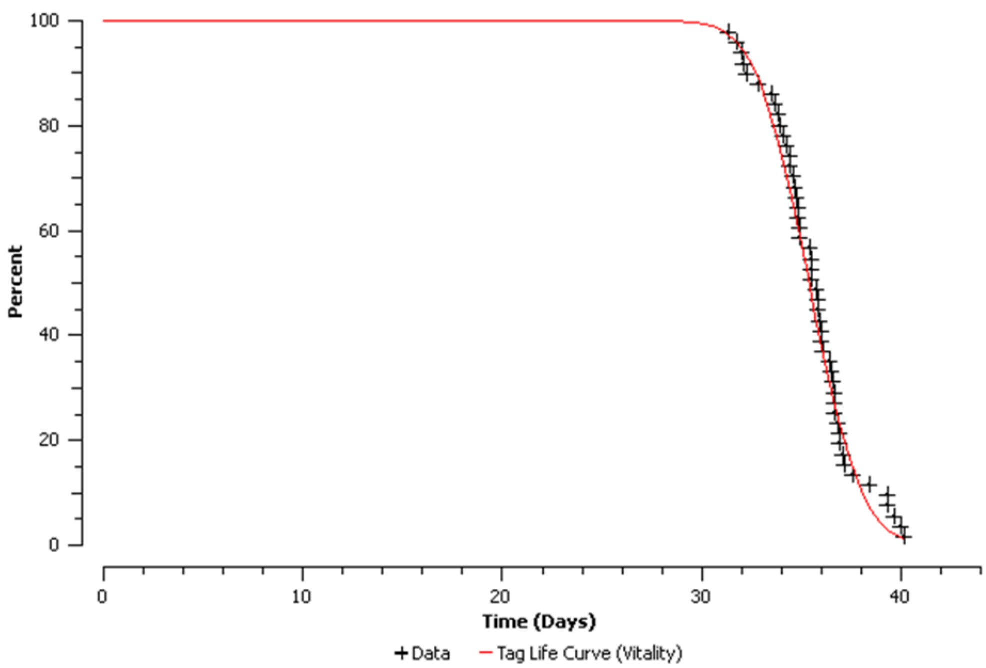

Figure C.6. Individual failure times for acoustic micro-transmitters used in the tag-life study (n = 50) fitted to the four-parameter vitality model (Li and Anderson 2009), summer 2010.

C.4 Arrival Distributions at Downstream Arrays

The estimated probability an AMT was active when fish arrived at a downstream detection array depends on the tag-life curve and the distribution of observed travel times. These probabilities were calculated by integrating the tag survivorship curves (Figure C.5 and Figure C.6) over the observed distribution of fish arrival times (i.e., time from tag activation to arrival) for each of the three tagged fish stocks.

The last detection array used in the survival analysis was at rkm 234 (CR234). Plots of the arrival distributions of each release group to that array indicate both the CH1 (Figure C.7), juvenile STH (Figure C.8), and CH0 (Figure C.9) should have arrived well before tag failure became problematic. Tag-life adjustments to survival estimates would be incomplete if fish have arrival times beyond the range of observed tag lives.

A total of 13.7 d was required for over 99% of the CH1 to pass the tertiary survival-detection array; juvenile STH required 15 d, and CH0 required 11.9 d.

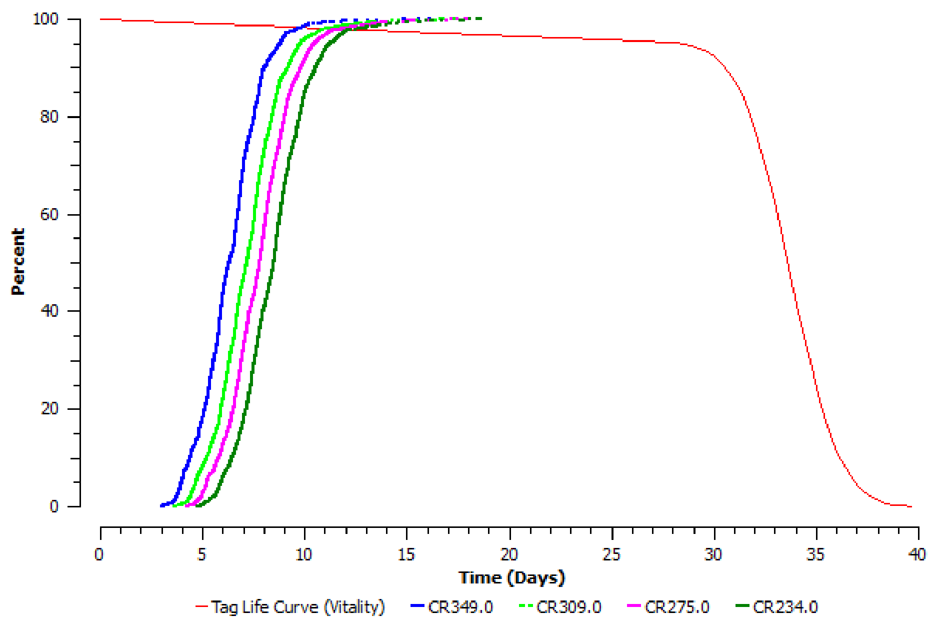

Figure C.7. Cumulative time of arrival of tagged CH1 regrouped at the JDA face to form a virtual dam passage release at all downstream detection sites versus tag-life curve.

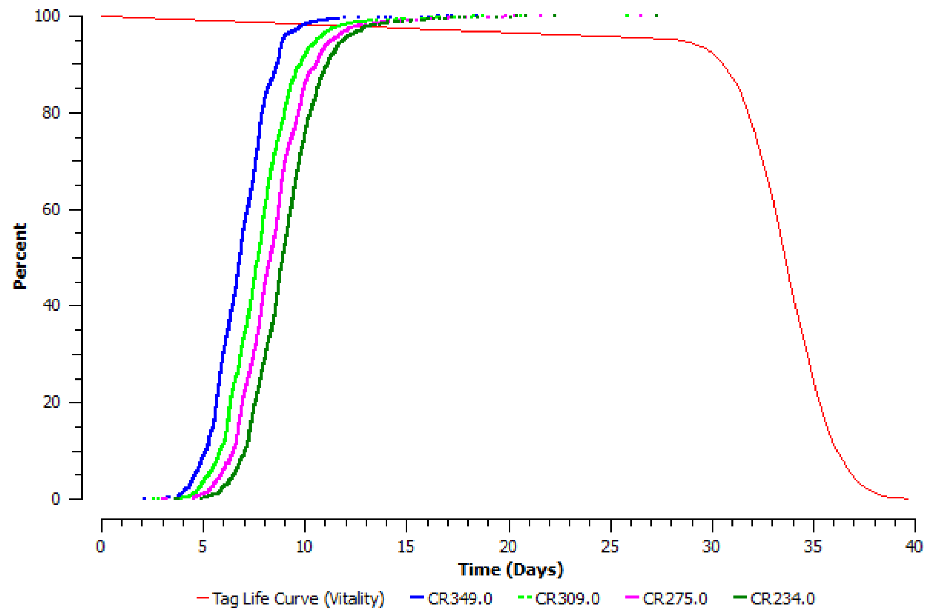

Figure C.8. Cumulative time of arrival of tagged juvenile STH regrouped at the JDA face to form a virtual dam passage release at all downstream detection sites versus tag-life curve.

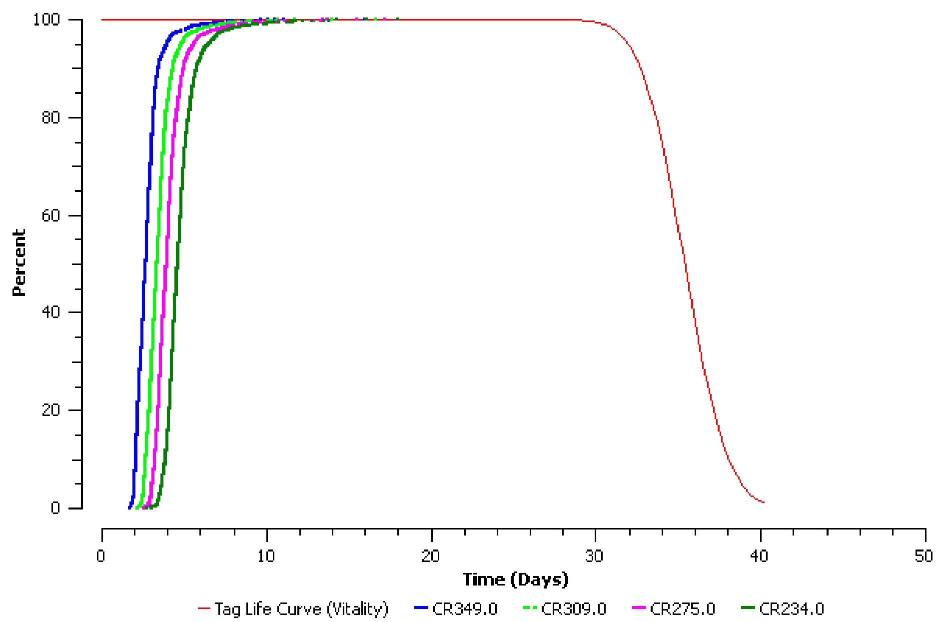

Figure C.9. Cumulative time of arrival of tagged CH0 juvenile salmonids regrouped at the JDA face to form a virtual dam passage release at all downstream detection sites versus tag-life curve.

C.5 Examination of Tagger Effects

Having various surgeons tag similar proportions of fish for release helped minimize but did not necessarily eliminate handling effects in the survival study. The study was therefore designed to balance tagger effort across locations. Implementation produced near-perfect balance for CH1 (Table C.4), STH (Table C.5), and CH0 (Table C.6) releases.

To further assess whether tagger effects may have occurred, reach survivals for the fish tagged by the different surgeons were calculated using the Cormack-Jolly Seber single release-recapture model. For both CH1 (Table C.7) and STH (Table C.8) reach survivals were found to be homogeneous ($P > 0.05$) across all reaches examined. For this reason, all fish, regardless of fish tagger, were included in the survival analyses for CH1 and STH.

For CH0, significant ($P < 0.05$) heterogeneity was detected (Table C.9). However, further examination indicated that seasonal trends in survival were confounding attempts to assess the presence of tagger effects using the *F*-tests because the effect of the various taggers was not evenly distributed across the course of the study. Fish tagged by tagger G had lower survivals because that staff member only tagged fish towards the end of the season. Fish tagged by tagger B had very good survival because that staff member only tagged fish at the beginning of the study. The remaining taggers had fish with intermediate survivals because they tagged fish more or less across the breadth of the season. The fish tagged by different staff during the same time were examined; survivals were homogeneous with no obvious evidence of any tagger effect. Therefore, fish tagged by all taggers were included in the analyses for this report.

Table C.4. Number of CH1 tagged by each surgeon and balance assessment outcome.

Tagger						
#1	#2	#3	#4	#5	#6	**Total**
441	356	311	350	372	457	**2,287**
$\left(P\left(\chi^2_{10} \geq 1.0336\right) = 0.9998\right)$						

Table C.5. Number of STH tagged by each surgeon and balance assessment outcome.

Tagger						
#1	#2	#3	#4	#5	#6	**Total**
430	359	331	354	365	449	**2,288**
$\left(P\left(\chi^2_{10} \geq 0.5851\right) = 1.0000\right)$						

Table C.6. Number of CH0 tagged by each surgeon and balance assessment outcome.

Tagger							
A	B	C	D	E	F	G	**Total**
436	489	463	454	171	369	467	**2,849**
$\left(P\left(\chi^2_{12} \geq 8.6496\right) = 0.7325\right)$							

Table C.7. Cormack-Jolly-Seber estimates of reach survival by tagger for CH1. Standard errors are in parentheses. *F*-tests of homogeneity and associated *P*-values of survival of CH1 across taggers are provided below the survival estimates for each release location. No tests were significant (α < 0.05).

Tagger	Release to rkm 309	rkm 309 to 275	rkm 275 to 234
#1	0.8912 (0.0148)	0.9364 (0.0123)	0.9790 (0.0076)
#2	0.8934 (0.0164)	0.9527 (0.0119)	0.9910 (0.0057)
#3	0.8489 (0.0203)	0.9318 (0.0155)	0.9797 (0.0090)
#4	0.8943 (0.0164)	0.9457 (0.0128)	0.9767 (0.0088)
#5	0.9140 (0.0145)	0.9382 (0.0131)	0.9906 (0.0053)
#6	0.9059 (0.0137)	0.9348 (0.0121)	0.9798 (0.0072)
F-test	1.9448	0.3597	0.7243
P-value	0.0828	0.8763	0.6051

Table C.8. Cormack-Jolly-Seber estimates of reach survivals by tagger for STH. Standard errors in parentheses. *F*-tests of homogeneity and associated *P*-values of survival of CH1 across taggers are provided below the survival estimates for each release location. No tests were significant (α < 0.05).

Tagger	Release to rkm 309	rkm 309 to 275	rkm 275 to 234
#1	0.8930 (0.0149)	0.9505 (0.0111)	0.9699 (0.0089)
#2	0.8831 (0.0170)	0.9621 (0.0107)	0.9671 (0.0102)
#3	0.9063 (0.0160)	0.9600 (0.0113)	0.9831 (0.0077)
#4	0.8729 (0.0177)	0.9320 (0.0143)	0.9725 (0.0097)
#5	0.9151 (0.0146)	0.9372 (0.0133)	0.9776 (0.0084)
#6	0.9065 (0.0137)	0.9656 (0.0090)	0.9804 (0.0072)
F-test	1.0452	1.4044	0.5128
P-value	0.3890	0.2192	0.7668

Table C.9. Cormack-Jolly-Seber estimates of reach survivals by tagger for CH0. *F*-tests of homogeneity and associated *P*-values of survival of CH1 across taggers are provided below the survival estimates for each release location. No tests were significant ($\alpha < 0.05$).

Tagger		Release to rkm 309 Estimate	SE	rkm 309 to 275 Estimate	SE	rkm 275 to 234 Estimate	SE
A		0.8395 (5)	0.0177	0.9141 (4)	0.0147	0.9671 (5)	0.0104
B		0.8938 (2)	0.0141	0.9394 (3)	0.0115	1.0000 (2)	0.0044
C		0.8522 (4)	0.0165	0.9465 (2)	0.0114	1.0000 (2)	0.0000
D		0.8027 (6)	0.0187	0.9033 (5)	0.0155	0.9520 (6)	0.0124
E		0.9357 (1)	0.0188	0.9562 (1)	0.0162	1.0000 (2)	0.0000
F		0.8910 (3)	0.0163	0.9016 (6)	0.0165	0.9879 (4)	0.0068
G		0.7795 (7)	0.0194	0.8908 (7)	0.0165	0.9515 (7)	0.0138
All Taggers	*F*-test	9.8531		2.9625		6.8130	
	P-value	<0.0001		0.0068		<0.0001	
Tagger G Omitted	*F*-test	7.5949		2.6425		7.6624	
	P-value	<0.0001		0.0215		<0.0001	

Appendix D

Capture-History Data

Appendix D

Capture-History Data

Capture histories are presented for CH1 (Table D.1 and Table D.2), STH (Table D.3 and Table D.4) and CH1 (Table D.5 and Table D.6). In each of the tables, a "1" denotes detection, "0" non-detection, and "2" detection and censoring due to removal.

Table D.1. Forebay virtual-release capture histories for CH1 at sites D_0, D_1, D_2, and D_3 (CR351, CR309, CR275, and CR234, respectively; Figure 3.3).

D0: CR351.0	D1: CR309.0	D2: CR275.0	D3: CR234.0	N
1	1	1	1	1,874
0	1	1	1	0
1	0	1	1	0
0	0	1	1	0
1	1	0	1	1
0	1	0	1	0
1	0	0	1	0
0	0	0	1	0
1	1	1	0	43
0	1	1	0	0
1	0	1	0	0
0	0	1	0	0
1	1	0	0	123
0	1	0	0	0
1	0	0	0	149
0	0	0	0	0

Table D.2. JDA virtual-release capture histories by route and treatment for CH1 at sites D_0, D_1, D_2, and D_3 (CR351, CR309, CR275, and CR234, respectively; Figure 3.3).

Capture History	1111	0111	1011	0011	1101	0101	1001	0001	1110	0110	1010	0010	1100	0100	1000	0000	N
JDA Dam Face Overall	1,873	1	0	0	1	0	0	0	43	0	0	0	123	0	141	0	2,182
JDA Dam Face Day	1,449	0	0	0	1	0	0	0	36	0	0	0	83	0	102	0	1,671
JDA Dam Face Night	423	0	0	0	0	0	0	0	7	0	0	0	40	0	37	0	507
JDA Dam Face 30% Spill	902	0	0	0	1	0	0	0	28	0	0	0	64	0	71	0	1,066
JDA Dam Face 40% Spill	970	0	0	0	0	0	0	0	15	0	0	0	59	0	68	0	1,112
JDA Dam Face 30% Spill Day	692	0	0	0	1	0	0	0	23	0	0	0	38	0	46	0	800
JDA Dam Face_30% Spill Night	210	0	0	0	0	0	0	0	5	0	0	0	26	0	19	0	260
JDA Dam Face_40% Spill Day	757	0	0	0	0	0	0	0	13	0	0	0	45	0	52	0	867
JDA Dam Face_40% Spill Night	213	0	0	0	0	0	0	0	2	0	0	0	14	0	13	0	242
JDA JBS	111	0	0	0	0	0	0	0	6	0	0	0	10	0	15	0	142
JDA JBS Day	34	0	0	0	0	0	0	0	3	0	0	0	4	0	6	0	47
JDA JBS Night	77	0	0	0	0	0	0	0	3	0	0	0	6	0	9	0	95
JDA JBS 30% Spill	44	0	0	0	0	0	0	0	3	0	0	0	4	0	4	0	55
JDA JBS 40% Spill	67	0	0	0	0	0	0	0	3	0	0	0	6	0	11	0	87
JDA Turbine	59	0	0	0	0	0	0	0	1	0	0	0	2	0	18	0	80
JDA Turbine 30% Spill	21	0	0	0	0	0	0	0	1	0	0	0	1	0	10	0	33
JDA Turbine 40% Spill	38	0	0	0	0	0	0	0	0	0	0	0	1	0	7	0	46
JDA TSW	1,088	0	0	0	1	0	0	0	15	0	0	0	66	0	61	0	1,231
JDA TSW 30% Spill	616	0	0	0	1	0	0	0	13	0	0	0	41	0	31	0	702
JDA TSW 40% Spill	471	0	0	0	0	0	0	0	2	0	0	0	25	0	30	0	528
JDA TSW Day	865	0	0	0	1	0	0	0	15	0	0	0	42	0	51	0	974
JDA TSW Night	223	0	0	0	0	0	0	0	0	0	0	0	24	0	10	0	257
JDA Non TSW	615	0	0	0	0	0	0	0	21	0	0	0	45	0	37	0	718
JDA Non TSW 30% Spill	221	0	0	0	0	0	0	0	11	0	0	0	18	0	20	0	270
JDA Non TSW 40% Spill	394	0	0	0	0	0	0	0	10	0	0	0	27	0	17	0	448
JDA Bay 20	210	0	0	0	0	0	0	0	6	0	0	0	14	0	17	0	247
JDA Bay 20 30% Spill	118	0	0	0	0	0	0	0	5	0	0	0	7	0	10	0	140
JDA Bay 20 40% Spill	92	0	0	0	0	0	0	0	1	0	0	0	7	0	7	0	107

Table D.2. (contd)

Capture History	1111	0111	1011	0011	1101	0101	1001	0001	1110	0110	1010	0010	1100	0100	1000	0000	N
JDA Spillway	1,703	0	0	0	1	0	0	0	36	0	0	0	111	0	98	0	1,949
JDA Spillway 30% Spill	837	0	0	0	1	0	0	0	24	0	0	0	59	0	51	0	972
JDA Spillway 40% Spill	865	0	0	0	0	0	0	0	12	0	0	0	52	0	47	0	976
JDA Spillway Day	1,398	0	0	0	1	0	0	0	33	0	0	0	78	0	82	0	1,592
JDA Spillway Night	305	0	0	0	0	0	0	0	3	0	0	0	33	0	16	0	357
JDA Spillway 30% Spill Day	671	0	0	0	1	0	0	0	22	0	0	0	36	0	41	0	771
JDA Spillway 30% Spill Night	166	0	0	0	0	0	0	0	2	0	0	0	23	0	10	0	201
JDA Spillway 40% Spill Day	726	0	0	0	0	0	0	0	11	0	0	0	42	0	41	0	820
JDA Spillway 40% Spill Night	139	0	0	0	0	0	0	0	1	0	0	0	10	0	6	0	156
JDA JBS VR Bad Plate	76	0	0	0	0	0	0	0	5	0	0	0	6	0	10	0	97
JDA JBS VR Fixed Plate	30	0	0	0	0	0	0	0	1	0	0	0	4	0	4	0	39
JDA Forebay Entrance	1,874	0	0	0	1	0	0	0	43	0	0	0	123	0	149	0	2,190
JDA Forebay Entrance 30% Spill	902	0	0	0	1	0	0	0	28	0	0	0	64	0	71	0	1,066
JDA Forebay Entrance 40% Spill	970	0	0	0	0	0	0	0	15	0	0	0	59	0	68	0	1,112

Table D.3. Forebay virtual-release capture histories for juvenile STH at sites D_0, D_1, D_2, and D_3 (CR351, CR309, CR275, and CR234, respectively; Figure 3.3).

D0: CR351.0	D1: CR309.0	D2: CR275.0	D3: CR234.0	N
1	1	1	1	1,894
0	1	1	1	0
1	0	1	1	0
0	0	1	1	0
1	1	0	1	3
0	1	0	1	0
1	0	0	1	1
0	0	0	1	0
1	1	1	0	53
0	1	1	0	0
1	0	1	0	1
0	0	1	0	0
1	1	0	0	99
0	1	0	0	0
1	0	0	0	119
0	0	0	0	0

Table D.4. John Day Dam virtual-release capture histories by route and treatment for juvenile steelhead at sites D_0, D_1, D_2, and D_3 (CR351, CR309, CR275, and CR234, respectively; Figure 3.3).

Capture History	1111	0111	1011	0011	1101	0101	1001	0001	1110	0110	1010	0010	1100	0100	1000	0000	N
JDA Dam Face Overall	1,893	0	0	0	3	0	1	0	53	0	1	0	99	0	113	0	2,163
JDA Dam Face Day	1,383	0	0	0	1	0	0	0	36	0	1	0	70	0	63	0	1,554
JDA Dam Face Night	510	0	0	0	2	0	1	0	16	0	0	0	29	0	48	0	606
JDA Dam Face 30% Spill	850	0	0	0	1	0	0	0	21	0	1	0	42	0	70	0	985
JDA Dam Face 40% Spill	1,043	0	0	0	2	0	1	0	31	0	0	0	57	0	41	0	1,175
JDA Dam Face 30% Spill Day	612	0	0	0	0	0	0	0	16	0	1	0	29	0	33	0	691
JDA Dam Face_30% Spill Night	238	0	0	0	1	0	0	0	5	0	0	0	13	0	25	0	282
JDA Dam Face_40% Spill Day	771	0	0	0	1	0	0	0	20	0	0	0	41	0	14	0	847
JDA Dam Face_40% Spill Night	272	0	0	0	1	0	1	0	11	0	0	0	16	0	18	0	319
JDA JBS	174	0	0	0	0	0	0	0	6	0	0	0	9	0	13	0	202
JDA JBS Day	9	0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	13
JDA JBS Night	165	0	0	0	0	0	0	0	4	0	0	0	8	0	12	0	189
JDA JBS 30% Spill	93	0	0	0	0	0	0	0	1	0	0	0	7	0	7	0	108
JDA JBS 40% Spill	81	0	0	0	0	0	0	0	4	0	0	0	2	0	6	0	93
JDA Turbine	22	0	0	0	0	0	0	0	1	0	0	0	4	0	12	0	39
JDA Turbine 30% Spill	8	0	0	0	0	0	0	0	1	0	0	0	1	0	8	0	18
JDA Turbine 40% Spill	14	0	0	0	0	0	0	0	0	0	0	0	3	0	4	0	21
JDA TSW	1,389	0	0	0	1	0	0	0	34	0	1	0	68	0	45	0	1,538
JDA TSW 30% Spill	656	0	0	0	0	0	0	0	17	0	1	0	27	0	31	0	732
JDA TSW 40% Spill	733	0	0	0	1	0	0	0	17	0	0	0	41	0	13	0	805
JDA TSW Day	1,188	0	0	0	1	0	0	0	27	0	1	0	59	0	35	0	1,311
JDA TSW Night	201	0	0	0	0	0	0	0	7	0	0	0	9	0	10	0	227
JDA Non TSW	308	0	0	0	2	0	1	0	12	0	0	0	18	0	21	0	362
JDA Non TSW 30% Spill	93	0	0	0	1	0	0	0	2	0	0	0	7	0	12	0	115
JDA Non TSW 40% Spill	215	0	0	0	1	0	1	0	10	0	0	0	11	0	9	0	247
JDA Bay 20	76	0	0	0	0	0	0	0	4	0	0	0	5	0	4	0	89
JDA Bay 20 30% Spill	31	0	0	0	0	0	0	0	0	0	0	0	5	0	3	0	39
JDA Bay 20 40% Spill	45	0	0	0	0	0	0	0	4	0	0	0	0	0	1	0	50

Table D.4. (contd)

Capture History	1111	0111	1011	0011	1101	0101	1001	0001	1110	0110	1010	0010	1100	0100	1000	0000	N
JDA Spillway	1,697	0	0	0	3	0	1	0	46	0	1	0	86	0	66	0	1,900
JDA Spillway 30% Spill	749	0	0	0	1	0	0	0	19	0	1	0	34	0	43	0	847
JDA Spillway 40% Spill	948	0	0	0	2	0	1	0	27	0	0	0	52	0	22	0	1,052
JDA Spillway Day	1,369	0	0	0	1	0	0	0	34	0	1	0	69	0	43	0	1,517
JDA Spillway Night	328	0	0	0	2	0	1	0	12	0	0	0	17	0	23	0	383
JDA Spillway 30% Spill Day	607	0	0	0	0	0	0	0	16	0	1	0	28	0	30	0	682
JDA Spillway 30% Spill Night	142	0	0	0	1	0	0	0	3	0	0	0	6	0	13	0	165
JDA Spillway 40% Spill Day	762	0	0	0	1	0	0	0	18	0	0	0	41	0	12	0	834
JDA Spillway 40% Spill Night	186	0	0	0	1	0	1	0	9	0	0	0	11	0	10	0	218
JDA JBS VR Bad Plate	119	0	0	0	0	0	0	0	1	0	0	0	6	0	7	0	133
JDA JBS VR Fixed Plate	54	0	0	0	0	0	0	0	4	0	0	0	3	0	5	0	66
JDA Forebay Entrance	1,894	0	0	0	3	0	1	0	53	0	1	0	99	0	119	0	2,170
JDA Forebay Entrance 30% Spill	850	0	0	0	1	0	0	0	21	0	1	0	42	0	67	0	982
JDA Forebay Entrance 40% Spill	1,043	0	0	0	2	0	1	0	31	0	0	0	57	0	41	0	1,175

Table D.5. Forebay virtual-release capture histories for CH0 at sites D_0, D_1, D_2, and D_3 (CR351, CR309, CR275, and CR234, respectively; Figure 3.3).

D0: CR351.0	D1: CR309.0	D2: CR275.0	D3: CR234.0	N
1	1	1	2	31
1	1	1	1	2,031
0	1	1	1	0
1	0	1	1	0
0	0	1	1	0
1	1	0	1	1
0	1	0	1	0
1	0	0	1	1
0	0	0	1	0
1	1	2	0	0
0	1	2	0	0
1	0	2	0	0
0	0	2	0	0
1	1	1	0	163
0	1	1	0	0
1	0	1	0	0
0	0	1	0	0
1	2	0	0	0
0	2	0	0	0
1	1	0	0	191
0	1	0	0	0
2	0	0	0	1
1	0	0	0	256
0	0	0	0	0

Table D.6. John Day Dam virtual-release capture histories by route and treatment for CH0 at sites D_0, D_1, D_2, and D_3 (CR351, CR309, CR275, and CR234, respectively; Figure 3.3).

Capture History	1112	1111	0111	1011	0011	1101	0101	1001	0001	1110	0110	1010	0010	1100	0100	2000	1000	0000	N
JDA Dam Face Overall	31	2,028	0	0	0	1	0	1	0	163	0	0	0	191	0	1	245	0	2,661
JDA Dam Face Day	23	1,327	0	0	0	0	0	1	0	125	0	0	0	149	0	0	173	0	1,798
JDA Dam Face Night	8	701	0	0	0	1	0	0	0	38	0	0	0	42	0	1	72	0	863
JDA Dam Face 30% Spill	11	1,000	0	0	0	1	0	1	0	73	0	0	0	100	0	1	117	0	1,304
JDA Dam Face 40% Spill	20	1,028	0	0	0	0	0	0	0	90	0	0	0	91	0	0	128	0	1,357
JDA Dam Face 30% Spill Day	9	643	0	0	0	0	0	1	0	56	0	0	0	79	0	0	76	0	864
JDA Dam Face_30% Spill Night	2	357	0	0	0	1	0	0	0	17	0	0	0	21	0	1	29	0	428
JDA Dam Face_40% Spill Day	14	684	0	0	0	0	0	0	0	69	0	0	0	70	0	0	77	0	914
JDA Dam Face_40% Spill Night	6	344	0	0	0	0	0	0	0	21	0	0	0	21	0	0	38	0	430
JDA JBS	1	237	0	0	0	1	0	0	0	14	0	0	0	13	0	1	15	0	282
JDA JBS Day	0	75	0	0	0	0	0	0	0	11	0	0	0	9	0	0	7	0	102
JDA JBS Night	1	162	0	0	0	1	0	0	0	3	0	0	0	4	0	1	8	0	180
JDA JBS 30% Spill	1	130	0	0	0	1	0	0	0	5	0	0	0	9	0	1	4	0	151
JDA JBS 40% Spill	0	107	0	0	0	0	0	0	0	9	0	0	0	4	0	0	11	0	131
JDA Turbine	2	219	0	0	0	0	0	1	0	14	0	0	0	16	0	0	56	0	308
JDA Turbine 30% Spill	1	135	0	0	0	0	0	1	0	6	0	0	0	13	0	0	28	0	184

Table D.6. (contd)

Capture History	1112	1111	0111	1011	0011	1101	0101	1001	0001	1110	0110	1010	0010	1100	0100	2000	1000	0000	N
JDA Turbine 40% Spill	1	84	0	0	0	0	0	0	0	8	0	0	0	3	0	0	28	0	124
JDA TSW	10	588	0	0	0	0	0	0	0	85	0	0	0	65	0	0	72	0	820
JDA TSW 30% Spill	2	333	0	0	0	0	0	0	0	43	0	0	0	36	0	0	41	0	455
JDA TSW 40% Spill	8	255	0	0	0	0	0	0	0	42	0	0	0	29	0	0	31	0	365
JDA TSW Day	9	465	0	0	0	0	0	0	0	72	0	0	0	53	0	0	61	0	660
JDA TSW Night	1	123	0	0	0	0	0	0	0	13	0	0	0	12	0	0	11	0	160
JDA Non TSW	18	984	0	0	0	0	0	0	0	50	0	0	0	97	0	0	77	0	1,226
JDA Non TSW 30% Spill	7	402	0	0	0	0	0	0	0	19	0	0	0	42	0	0	32	0	502
JDA Non TSW 40% Spill	11	582	0	0	0	0	0	0	0	31	0	0	0	55	0	0	45	0	724
JDA Bay 20	3	104	0	0	0	0	0	0	0	5	0	0	0	10	0	0	15	0	137
JDA Bay 20 30% Spill	2	53	0	0	0	0	0	0	0	1	0	0	0	6	0	0	8	0	70
JDA Bay 20 40% Spill	1	51	0	0	0	0	0	0	0	4	0	0	0	4	0	0	7	0	67
JDA Spillway	28	1,572	0	0	0	0	0	0	0	135	0	0	0	162	0	0	149	0	2,046
JDA Spillway 30% Spill	9	735	0	0	0	0	0	0	0	62	0	0	0	78	0	0	73	0	957
JDA Spillway 40% Spill	19	837	0	0	0	0	0	0	0	73	0	0	0	84	0	0	76	0	1,089
JDA Spillway Day	23	1,173	0	0	0	0	0	0	0	109	0	0	0	135	0	0	120	0	1,560
JDA Spillway Night	5	399	0	0	0	0	0	0	0	26	0	0	0	27	0	0	29	0	486
JDA Spillway 30% Spill Day	9	557	0	0	0	0	0	0	0	49	0	0	0	69	0	0	60	0	744
JDA Spillway 30% Spill Night	0	178	0	0	0	0	0	0	0	13	0	0	0	9	0	0	13	0	213

Table D.6. (contd)

Capture History	1112	1111	0111	1011	0011	1101	0101	1001	0001	1110	0110	1010	0010	1100	0100	2000	1000	0000	N
JDA Spillway 40% Spill Day	14	616	0	0	0	0	0	0	0	60	0	0	0	66	0	0	60	0	816
JDA Spillway 40% Spill Night	5	221	0	0	0	0	0	0	0	13	0	0	0	18	0	0	16	0	273
JDA JBS VR Bad Plate	31	2,031	0	0	0	1	0	1	0	163	0	0	0	191	0	1	256	0	2,675
JDA JBS VR Fixed Plate	11	1,000	0	0	0	1	0	1	0	73	0	0	0	100	0	1	116	0	1,303
JDA Forebay Entrance	20	1,028	0	0	0	0	0	0	0	90	0	0	0	91	0	0	128	0	1,357

Appendix E

Tagging Tables

Appendix E

Tagging Tables

Table E.1. Yearling Chinook salmon tagged at the John Day Dam (JDA) smolt monitoring facility (SMF) and released near Roosevelt, Washington, in spring 2010.

Tag Date	Release Date	Number Tagged	Number Released
4/27/2010	4/28/2010	72	72
4/28/2010	4/29/2010	72	72
4/29/2010	4/30/2010	97	72
4/30/2010	5/1/2010	97	72
5/1/2010	5/2/2010	147	72
5/2/2010	5/3/2010	96	72
5/3/2010	5/4/2010	147	72
5/4/2010	5/5/2010	103	72
5/5/2010	5/6/2010	147	71
5/6/2010	5/7/2010	97	72
5/7/2010	5/8/2010	147	71
5/8/2010	5/9/2010	97	72
5/9/2010	5/10/2010	148	72
5/11/2010	5/12/2010	147	72
5/12/2010	5/13/2010	194	144
5/13/2010	5/14/2010	146	72
5/14/2010	5/15/2010	97	72
5/15/2010	5/16/2010	147	72
5/16/2010	5/17/2010	97	72
5/17/2010	5/18/2010	146	72
5/18/2010	5/19/2010	96	71
5/19/2010	5/20/2010	147	72
5/20/2010	5/21/2010	97	72
5/21/2010	5/22/2010	147	72
5/22/2010	5/23/2010	97	72
5/23/2010	5/24/2010	147	72
5/24/2010	5/25/2010	97	72
5/25/2010	5/26/2010	146	71
5/26/2010	5/27/2010	97	72
5/27/2010	5/28/2010	147	73
5/28/2010	5/29/2010	83	58

Table E.2. Juvenile steelhead tagged at the JDA SMF and released near Roosevelt, Washington, in spring 2010.

Tag Date	Release Date	Number Tagged	Number Released
4/27/2010	4/28/2010	72	71
4/28/2010	4/29/2010	72	72
4/29/2010	4/30/2010	97	72
4/30/2010	5/1/2010	97	72
5/1/2010	5/2/2010	147	72
5/2/2010	5/3/2010	96	72
5/3/2010	5/4/2010	150	75
5/4/2010	5/5/2010	105	71
5/5/2010	5/6/2010	147	72
5/6/2010	5/7/2010	97	72
5/7/2010	5/8/2010	147	72
5/8/2010	5/9/2010	97	72
5/9/2010	5/10/2010	147	72
5/11/2010	5/12/2010	147	72
5/12/2010	5/13/2010	192	142
5/13/2010	5/14/2010	146	72
5/14/2010	5/15/2010	97	72
5/15/2010	5/16/2010	146	71
5/16/2010	5/17/2010	97	72
5/17/2010	5/18/2010	147	72
5/18/2010	5/19/2010	97	72
5/19/2010	5/20/2010	147	72
5/20/2010	5/21/2010	97	72
5/21/2010	5/22/2010	147	72
5/22/2010	5/23/2010	97	72
5/23/2010	5/24/2010	147	72
5/24/2010	5/25/2010	97	72
5/25/2010	5/26/2010	147	72
5/26/2010	5/27/2010	97	72
5/27/2010	5/28/2010	147	72
5/28/2010	5/29/2010	83	58

Table E.3. Subyearling Chinook salmon tagged at the JDA SMF and released near Roosevelt, Washington, in summer 2010.

Tag Date	Release Date	Number Tagged	Number Released
6/12/2010	6/13/2010	89	89
6/13/2010	6/14/2010	88	88
6/14/2010	6/15/2010	114	89
6/15/2010	6/16/2010	114	89
6/16/2010	6/17/2010	165	89
6/17/2010	6/18/2010	114	89
6/18/2010	6/19/2010	177	88
6/19/2010	6/20/2010	114	89
6/20/2010	6/21/2010	164	89
6/21/2010	6/22/2010	113	89
6/22/2010	6/23/2010	164	89
6/23/2010	6/24/2010	115	89
6/24/2010	6/25/2010	135	75
6/25/2010	6/26/2010	128	89
6/26/2010	6/27/2010	162	89
6/27/2010	6/28/2010	116	90
6/28/2010	6/29/2010	165	90
6/29/2010	6/30/2010	114	89
6/30/2010	7/1/2010	193	103
7/1/2010	7/2/2010	113	89
7/2/2010	7/3/2010	164	89
7/3/2010	7/4/2010	114	89
7/4/2010	7/5/2010	164	89
7/5/2010	7/6/2010	125	88
7/6/2010	7/7/2010	164	89
7/7/2010	7/8/2010	114	89
7/8/2010	7/9/2010	163	88
7/9/2010	7/10/2010	129	89
7/10/2010	7/11/2010	163	89
7/11/2010	7/12/2010	115	90
7/12/2010	7/13/2010	166	90
7/13/2010	7/14/2010	115	90

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