PNNL-22788 Final

US Army Corps
of Engineers®

Prepared for the U.S. Army Corps of Engineers, Portland District,
Under an Interagency Agreement with the U.S. Department of Energy
Contract DE-AC05-76RL01830

Survival and Passage of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead at McNary Dam, 2012

Final Report

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

December 2013

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <http://www.ntis.gov/about/form.aspx>
Online ordering: http://www.ntis.gov

This document was printed on recycled paper.
(8/2010)

PNNL-22788 Final

Survival and Passage of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead at McNary Dam, 2012

JH Hughes
MA Weiland
CM Woodley
GR Ploskey
SM Carpenter[b]
MJ Hennen[b]
ES Fischer
GW Batten III[b]
TJ Carlson
AW Cushing[b]
Z Deng
DJ Etherington[b]
T Fu
MJ Greiner
M Ingraham
J Kim
X Li
J Martinez
TD Mitchell[b]
B Rayamajh
A Seaburg[a]
JR Skalski[a]
RL Townsend[a]
KA Wagner
SA Zimmerman

Final Report
December 2013

Prepared for
U.S. Army Corps of Engineers, Portland District
Under a Government Order with the U.S. Department of Energy
Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

(a) University of Washington, Seattle, Washington.
(b) Pacific States Marine Fisheries Commission, Portland, Oregon.

Preface

Pacific Northwest National Laboratory (PNNL) and subcontractors conducted an acoustic-telemetry study at McNary Dam in 2012 for the U.S. Army Corps of Engineers (USACE) Portland District and Walla Walla District. The project managers were Dr. Thomas J. Carlson, Gene R. Ploskey, and Mark A. Weiland, PNNL; and Dr. John R. Skalski, University of Washington. The USACE technical leads were Mr. Brad Eppard and Mr. Fred Higginbotham. The study was designed to evaluate the passage and survival of yearling and subyearling Chinook salmon and juvenile steelhead at McNary Dam as stipulated by the 2008 Biological Opinion and Fish Accords and to assess performance measures including route-specific fish passage proportions, travel times, and survival based upon a virtual/paired-release model. This study supports the USACE's continual effort to improve conditions for juvenile anadromous fish passing through Columbia River dams.

This report should be cited as follows:

Hughes, JS, MA Weiland, CM Woodley, GR Ploskey, SM Carpenter, MJ Hennen, EF Fischer, GW Batten III, TJ Carlson, AW Cushing, Z Deng, DJ Etherington, T Fu, MJ Greiner, M Ingraham, J Kim, X Li, J Martinez, TD Mitchell, B Rayamajhi, A Seaburg, JR Skalski, RL Townsend, KA Wagner, and SA Zimmerman. 2013. *Survival and Passage of Yearling and Subyearling Chinook Salmon and Steelhead at McNary Dam, 2012.* PNNL-22788. Draft report submitted by the Pacific Northwest National Laboratory to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Executive Summary

Researchers at the Pacific Northwest National Laboratory (PNNL) collaborated with the Pacific States Marine Fisheries Commission (PSMFC), U.S. Army Corps of Engineers Portland District and Walla Walla District, and the University of Washington to conduct a 2012 study to estimate dam passage survival and other performance metrics for yearling and subyearling Chinook salmon (*Oncorhynchus tshawytscha*) and juvenile steelhead (*O. mykiss*) at McNary Dam. The study addressed the 2008 Biological Opinion (BiOp) stipulations and 2008 Columbia Basin Fish Accords on the operation of the Federal Columbia River Power System (FCRPS). Under the 2008 FCRPS BiOp, dam passage survival should be ≥0.96 for yearling Chinook salmon and steelhead, and ≥0.93 for subyearling Chinook salmon, with standard error (SE) values of ≤0.015. Results presented focus on performance measures, route-specific survival, and horizontal and vertical distributions of yearling and subyearling Chinook salmon and juvenile steelhead surgically implanted with Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic micro-transmitters (AMTs).

A virtual/paired-release (VPR) design was used to estimate dam passage survival at McNary Dam (MCN). The approach relied on releases of yearling and subyearling Chinook salmon and juvenile steelhead implanted with AMTs at Port Kelley, Washington, upriver from MCN, that contributed to the formation of a virtual-release group at the face of the dam and a paired-release group below the dam. Dam passage survival was estimated as the quotient of the survival estimates for the virtual release to that of the paired release.

A total of 3,797 yearling Chinook salmon, 3,797 steelhead, and 6,501 subyearling Chinook salmon were implanted with AMTs and released for this study. This report is a comprehensive summary of 2012 results. Study results are summarized in the following tables.

Table ES.1. Summary of Methods and Conditions at MCN During 2012

<table>
<tr><td colspan="4">Year: 2012</td></tr>
<tr><td colspan="4">Study Site(s): McNary Dam</td></tr>
<tr><td colspan="4">Objective(s) of study: Estimate dam passage survival and other performance measures for yearling Chinook salmon, steelhead, and subyearling Chinook salmon.</td></tr>
<tr><td colspan="4">Hypothesis (if applicable): Not applicable; this is a compliance study.</td></tr>
<tr><td colspan="2">Fish:
Species-race: yearling Chinook salmon (CH1), steelhead (STH), subyearling Chinook salmon (CH0)
Source: John Day Dam Smolt Monitoring Facility</td><td colspan="2">Implant Procedure:
Surgical: Yes
Injected: No</td></tr>
<tr><td colspan="2">Size (median): CH1 / STH / CH0
Weight (g): 28.2 / 75.6 / 14.4
Length (mm): 144 / 207 / 113</td><td colspan="2">Sample Size: CH1 / STH / CH0
Release Sites: 3 / 3 / 3
Total # Released: 3797 / 3797 / 6501</td></tr>
<tr><td>Tag Type: Advanced Telemetry Systems (ATS)-156dB
Model / Weight (air)
CH1/CH0: SS300 / 0.304 g
STH: SS130 / 0.438 g</td><td>Analytical Model: VPR</td><td colspan="2">Characteristics of Estimate:
Effects Reflected (direct, total, etc.): Direct
Absolute or Relative: Absolute</td></tr>
<tr><td colspan="4">Environmental/Operating Conditions (daily from 27 April 2012 through 30 May 2012):
Discharge (kcfs): mean 354.1, minimum 295.0, maximum 398.8
Spill Levels: Targeted – 40%; Actual – mean 50.9%, minimum 41.1%,, maximum 60.8%
Temperature (°C): mean 11.7, minimum 9.6, maximum 13.4
Total Dissolved Gas (tailrace): mean 119.5%, minimum 116.0%, maximum 122.3%
Treatment(s): None
Unique Study Characteristics: Temporary Spillway Weirs (TSWs) located in Spill Bays 19 and 20</td></tr>
<tr><td colspan="4">Environmental/Operating Conditions (daily from 14 June 2012 through 16 July 2012):
Discharge (kcfs): mean 355.6, minimum 308.3, maximum 414.4
Spill Levels: Targeted – 50%; Actual – mean 61.6%, minimum 52.1%,, maximum 73.2%
Temperature (°C): mean 15.7, minimum 14.0, maximum 17.8
Total Dissolved Gas (tailrace): mean 121.8%, minimum 119.6%, maximum 126.0%
Treatment(s): None
Unique Study Characteristics: TSWs not installed during summer tagging season</td></tr>
</table>

Table ES.2. Compliance Results Summary of Virtual/Paired Release Survival and Other Performance Metrics at MCN, 2012 with Standard Errors in Parentheses and Travel Times Presented in Hours

Metric	CH1	STH	CH0
Dam passage survival	0.9616 (0.0140)	0.9908 (0.0183)	0.9747 (0.0114)
Forebay-to-tailrace survival (boat-restricted zone [BRZ] to BRZ)	0.9595 (0.0140)	0.9880 (0.0183)	0.9729 (0.0114)
Forebay residence time (median; mean)	1.76; 3.01 (0.3045)	1.78; 2.67 (0.0838)	1.77; 2.86 (0.135)
Tailrace egress time (median; mean)	0.41; 2.87 (0.3293)	0.34; 1.85 (0.3712)	0.385; 3.01 (0.294)
Spill passage efficiency	0.7246 (0.0121)	0.8315 (0.0104)	0.7832 (0.0083)
Fish passage efficiency	0.9676 (0.0048)	0.9768 (0.0042)	0.9089 (0.0058)

Table ES.3. Route-Specific Dam Passage Virtual/Paired Release Survival Estimates

	CH1			STH			CH0		
Route	Survival	SE	n	Survival	SE	n	Survival	SE	n
Spillway	0.9712	0.0146	984	0.994	0.019	1076	0.9803	0.0118	1925
Temporary Spillway Weir (TSW)	0.9758	0.0279	113	0.976	0.025	301	*	*	*
Non-TSW	0.9706	0.0150	871	1.001	0.019	775	*	*	*
Juvenile bypass system (JBS)	0.9355	0.0213	328	1.015	0.026	187	1.0078	0.0171	308
Turbine	0.9552	0.0470	44	0.831	0.085	30	0.8806	0..0284	224

*TSWs were removed during summer period of the study

Table ES.4. Summary of Juvenile Salmonid Distributions

Metric	CH1	STH	CH0
Percent first approaching at the powerhouse	34.0	39.0	42.0
Percent first approaching at the powerhouse but passed at the spillway	6.0	22.0	13.0
Percent passing through turbines	3.2	2.3	9.1
Percent passing through the JBS	24.2	14.5	12.5
Percent passing through non-TSWs spill bays	64.2	59.9	78.4
Percent passing through TSW spill bays	8.3	23.3	N/A
Percent passing through a fish ladder	0.1	0.0	0.0

Acknowledgments

This study was the result of hard work by dedicated scientists from Pacific Northwest National Laboratory (PNNL), the Pacific States Marine Fisheries Commission (PSMFC), Cascade Aquatics, the U.S. Army Corps of Engineers (USACE) Portland District (CENWP) and Walla Walla District (CENWW), and University of Washington (UW). Their teamwork and attention to detail, schedule, and budget were essential for the study to succeed in providing high quality and timely results to decision-makers.

- PNNL: T Abel, C Brandt, A Bryson, E Choi, G Dirkes, J Duncan, A Flory, D Geist, G Gill, K Hall, K Ham, R Herrington, J Horner, R Karls, R Kaufman, B Lamarche, K Lavender, S Matzner, A Miracle, A Phillips, N Phillips, G Roesijadi, D Saunders, S Southard, G Squeochs, A Thronas, N Trimble, J Varvinec, C Vernon, and Y Yuan.
- PSMFC: R Martinson, G Kolvachuk, and D Ballenger, along with the helpful staff at the John Day Dam and Bonneville Dam juvenile smolt facilities. We also thank those at PTAGIS for their continued assistance and N Tancreto for her help with the Bonneville sort-by-code system. In addition, A Ajmani, M Bahnick, A Barnes, C Beyer, R Blanchard, A Collins, A Cook, J Cox, L Cushing, R Davis, T Elder, G George, D Grugett, B Harkleroad, T Levandowsky, S Marvin, M Neumann, G Ottoway, K Paine, K Prather, J Robertson, T Royal, G Schilperoort, G Seybert, D Spiteri, P Tramel, D Trott, R Wall, and L Wood.
- Cascade Aquatics: B James, P James, E Anderson, C Green, E Green, J Herdman, K Martin, and H Watson.
- USACE: B Eppard and M Langeslay with the CENWP; F Higginbotham, T Wik, D Fryer, T Roberts with CENWW; electricians, mechanics, riggers, operators; and the biologists at McNary Dam (C Dugger) and John Day Dam (M Zyndol, E Grosvenor).
- UW: J Lady and P Westhagen.

We also acknowledge the manufacturers of the tags, hydrophones, and hardware required to accomplish testing:

- Advanced Telemetry Systems (ATS, Isanti, Minnesota), Inc. manufactured the Juvenile Salmon Acoustic Telemetry System acoustic micro-transmitters.
- Autonomous and dam-mounted hydrophones were produced by Sonic Concepts (Bothell, Washington).
- The Dalles Ironworks (The Dalles, Oregon) provided anchors for autonomous nodes and various components required for successful completion of this project.

Acronyms and Abbreviations

°C	degree(s) Celsius
3D	three-dimensional (or dimensionally, dimensions)
AMT	acoustic micro-transmitter
ANOVA	analyses of variance
AT	acoustic telemetry
ATLAS	Active Tag-Life Survival
ATS	Advanced Telemetry Systems, Inc.
BiOp	Biological Opinion
BON	Bonneville Dam
BPSK	binary phase-shift keying
BRZ	boat-restricted zone
CENWP	Corps of Engineers, Northwest, Portland District
CENWW	Corps of Engineers, Northwest, Walla Walla District
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
CF	compact flash
CR	Columbia River
d	day(s)
DART	Data Access in Real Time
DSP	digital signal processing
FCRPS	Federal Columbia River Power System
FGE	fish guidance efficiency
FL	fork length
FPE	fish passage efficiency
FPGA	field-programmable logic gate array
ft	foot(feet)
g	gram(s)
GPS	global positioning system
h	hour(s)
HSD	(Tukey's) honestly significant difference
JBS	juvenile bypass system
JBSE	juvenile bypass system efficiency
JDA	John Day Dam
JSATS	Juvenile Salmon Acoustic Telemetry System
kcfs	thousand cubic feet per second
km	kilometer(s)

L	liter(s)
LCR	lower Columbia River
m	meter(s)
MCN	McNary Dam
mg	milligram(s)
ml	milliliter(s)
mm	millimeter(s)
MS-222	tricaine methanesulfonate
MSL	mean sea level
MW	megawatt(s)
n	number
N	absolute abundance
NOAA	National Oceanic and Atmospheric Administration
OR	Oregon
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
PRI	pulse repetition interval
PRT	pre-tagged
PSMFC	Pacific States Marine Fisheries Commission
PTAGIS	PIT Tag Information System
PUD	public utility district
R	release
rkm	river kilometer(s)
RME	research, monitoring, and evaluation
ROR	run-of-river
RPA	Reasonable and Prudent Alternative
RT	radio telemetry
SBC	sort-by-code
SE	standard error
SMF	Smolt Monitoring Facility
SPE	spill passage efficiency
SRWG	Studies Review Work Group
STH	juvenile steelhead
TDA	The Dalles Dam
TGD	tagged
TOAD	time-of-arrival difference(s)
TSW	temporary spillway weir
µs	microsecond(s)

USACE	U.S. Army Corps of Engineers
UW	University of Washington
VPR	virtual/paired release
WA	Washington
wk	week(s)
WW	wet weight

Contents

Figures

Tables

1.0 Introduction

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

This report describes research conducted using acoustic telemetry (AT) to evaluate juvenile salmonid passage and survival during 2012 at McNary Dam (MCN) (Figure 1.1). Researchers at the Pacific Northwest National Laboratory (PNNL) in collaboration with the Pacific States Marine Fisheries Commission (PSMFC), CENWP, CENWW, and the University of Washington (UW) conducted this juvenile fish passage and survival study.

Figure 1.1. McNary Dam on the Columbia River

The purpose of this study was to estimate dam passage survival at MCN as stipulated by the 2008 FCRPS Biological Opinion (BiOp; NOAA 2008) and to provide additional performance measures at the dam as stipulated in the Columbia Basin Fish Accords (3 Treaty Tribes-Action Agencies 2008) for yearling Chinook salmon (CH1), subyearling Chinook salmon (CH0), and juvenile steelhead (STH). The spring study period extended from 27 April through 30 May 2012, followed by the summer study period from 14 June through 16 July 2012. Data collection ended on 9 August 2012, when 90% of the acoustic micro-transmitters (AMTs) implanted in fish had likely expired, as estimated from the AMTs performance ("tag life") study conducted concurrent with the field season. This report includes a comprehensive description of the methods and additional measures including 1) route-specific survival and passage metrics for the entire season and for day and night periods, 2) horizontal and vertical approach and passage distributions, and 3) reach survival rates upstream and downstream of the dam.

1.1 Study Objectives

This 2012 study estimated performance measures for CH1 and CH0 and STH as outlined in the FCRPS BiOp and Fish Accords. Additional results are provided such as survival rates and passage distributions of juvenile salmonids passing through various routes including the powerhouse, JBS, spillway, and TSW routes at MCN.

The study objectives and sub-objectives, applied to each run of fish studied included the following:

1. Estimate survival rates
   a. Dam passage for the total project
   b. Forebay-to-tailrace for the total project
   c. Dam passage by route (turbines, JBS, TSW, non-TSW, and spillway).
2. Estimate passage efficiency metrics
   a. Fish passage efficiency
   b. Spillway passage efficiency
   c. TSW passage efficiency relative to the total project
   d. TSW passage efficiency relative to the spillway.
3. Compute the mean, standard error, and median travel times for
   d. Forebay residence
   e. Tailrace egress.
4. Estimate passage distributions
   a. Horizontal
   b. Vertical
   c. Diel.
5. Observe the forebay approach paths of implanted fish and relate them to passage distribution
   a. Compare forebay approach paths of turbine vs. bypass vs. spill vs. TSW passed fish.

1.2 Report Contents and Organization

This report contains 10 chapters and 7 appendices, including Chapter 3.0, methods and calculations; Chapter 4.0, environmental conditions; Chapter 5, results of fish collection and tagging efforts; Chapters 6.0 through 8.0, which address survival, travel time, passage efficiency, and distribution results for CH1, STH, and CH0, respectively; Chapter 9.0, discussion and conclusions; and Chapter 10.0, which contains references. The appendices contain a report titled Review of Fish Condition Associated with Juvenile Salmon Collected and Tagged for the Lower River Survival Study, 2012 (Appendix A); Assessment of Survival Model Assumptions (Appendix B); Tagging Table (Appendix C); Hydrophone and Autonomous Node Deployment Tables (Appendix D); Capture Histories (Appendix E); Detection and Survival Probabilities (Appendix F); and Juvenile Salmon Acoustic Telemetry System (JSATS) Hydrophone Array Performances (Appendix G).

2.0 Study Background and Area

Historically, both AT and radio telemetry (RT) have been used to estimate survival rates and passage efficiencies for CH1, STH, and CH0 passing MCN (Adams et al. 2011). In the early 2000s, RT was the primary method employed for monitoring fish passage and estimating survival rates throughout the lower Columbia River (Axel and Dey 2001; Axel et al. 2003; Absolon et al. 2003). RT technology provides general location information and is highly successful in shallow freshwater depths of less than 3.0 m; however, the RT signals attenuate with greater depth.

Acoustic tags emit sound waves, which are less affected by depth and conductivity than radio waves. JSATS technology was developed by PNNL and CENWP for monitoring fish movements and estimating survival of salmonids through the Columbia River to the Pacific Ocean. The JSATS AMT design allows for the evaluation of fish ≥95 mm fork length (≥8 g), which is representative of most immigrating salmonids, and therefore is representative of the majority of the migrant population.

During the 2006 through 2009 study years, AT became the primary technique employed to produce estimates of fish survival and passage efficiencies at MCN (Adams et al. 2008, 2011; Adams and Evans 2011; Evans et al. 2010). Fish implanted with AMTs were released upstream of MCN in the Columbia River and used for estimating paired- and single-release dam passage survival rates (Table 2.1). Paired-release survival rates for studies conducted from 2006 through 2009 ranged from 0.926 (SE = 0.013) to 0.973 (SE = 0.009) for CH1, and from 0.894 (SE = 0.013) to 0.973 (SE = 0.013) for CH0. STH paired-release survival estimates were reported for 2008 and 2009 only, and were 0.991 (SE = 0.015) and 0.996 (SE = 0.012), for those years, respectively (Table 2.1; Adams and Evans 2011).

Table 2.1. Paired- and Single-release Dam Passage Survival Estimates for CH1, STH, and CH0 at MCN from 2006 through 2009 (Adams and Evans 2011) and 2012 Results for this Project. Standard errors are in parentheses.

	Yearling Chinook		Steelhead		Subyearling Chinook	
Year	Paired	Single	Paired	Single	Paired	Single
2006	0.959 (0.009)	0.938 (0.007)	NA	0.973 (0.010)	0.948 (0.012)	0.885 (0.009)
2007	0.926 (0.013)	0.921 (0.011)	NA	0.897 (0.013)	0.928 (0.018)	0.863 (0.013)
2008	0.954 (0.009)	0.943 (0.007)	0.991 (0.015)	0.954 (0.011)	0.973 (0.013)	0.875 (0.009)
2009	0.973 (0.009)	0.946 (0.006)	0.996 (0.012)	0.943 (0.007)	0.894 (0.013)	0.823 (0.010)
2012	0.962 (0.014)	0.917 (0.008)	0.991 (0.018)	0.914 (0.008)	0.975 (0.011)	0.915 (0.006)

Fish passage efficiency (FPE) and spill passage efficiency (SPE) have ranged widely among and within species at MCN. The estimated FPE and SPE for STH were higher than estimates reported for Chinook stocks; FPE ranged from 0.898 (SE = 0.010) to 0.957 (SE = 0.006), and SPE ranged from 0.648 (SE = 0.016) to 0.785 (SE = 0.013) for studies conducted from 2006 to 2009 (Table 2.2; Adams and

Evans 2011). During the same study years, CH1 FPE ranged from 0.853 (SE = 0.010) to 0.875 (SE = 0.008), and SPE ranged from 0.538 (SE was not reported due to the small sample size) to 0.657 (SE = 0.012). CH0 FPE ranged from 0.735 (SE = 0.011) to 0.822 (SE = 0.009), while SPE ranged from 0.540 (SE = 0.012) to 0.669 (SE was not reported due to the small sample size; Adams and Evans 2011).

Table 2.2. Estimates of FPE and SPE for CH1, STH, and CH0 at MCN from 2006 through 2009 (Adams and Evans 2011). Standard errors are in parentheses.

	Yearling Chinook		Steelhead		Subyearling Chinook	
Year	FPE	SPE	FPE	SPE	FPE	SPE
2006	0.875 (0.008)	0.635 (0.012)	0.898 (0.010)	0.648 (0.016)	0.735 (0.011)	0.540 (0.012)
2007	0.858 (0.008)	0.571 (0.015)	0.957 (0.006)	0.785 (0.022)	0.822 (0.009)	0.611 (0.017)
2008	0.869 (0.009)	0.657 (0.017)	0.917 (0.011)	0.745 (0.022)	0.810 (0.010)	0.669 (0.016)
2009	0.853 (0.010)	0.538 (0.016)	0.930 (0.008)	0.688 (0.021)	0.812 (0.010)	0.645 (0.017)

The temporary spillway weirs (TSWs) at MCN provide surface-oriented passage routes through the dam, which are thought to be safer than other routes for salmonid passage. The TSWs were originally installed in 2007 at Spill Bays 20 and 22. Over the years the TSWs have been moved within the spillway configuration in an attempt to find the safest and most advantageous route for salmonid passage.

2.1 Performance Standards and Definitions

The FCRPS 2008 BiOp contains a reasonable and prudent alternative (RPA) that includes actions calling for measurements of juvenile salmonid survival (RPAs 52.1 and 58.1). These RPAs are being addressed as part of the federal research, monitoring, and evaluation (RME) effort for the FCRPS BiOp. Most importantly, the FCRPS BiOp includes performance standards for juvenile salmonid survival in the FCRPS against which the Action Agencies (Bonneville Power Administration, Bureau of Reclamation, and USACE) must compare their estimates, as follows (after the RME Strategy 2 of the RPA):

> Juvenile Dam Passage Performance Standards – The Action Agencies juvenile performance standards are an average across Snake River and lower Columbia River dams of 96% dam passage survival for spring Chinook and steelhead and 93% average across all dams for Snake River subyearling Chinook. Dam passage survival is defined as survival from the upstream face of the dam to a standardized reference point in the tailrace.

The Memorandum of Agreement between the three lower river tribes and the Action Agencies (known informally as the Fish Accords), contains three additional requirements relevant to the 2012 survival studies (after Attachment A to the Memorandum of Agreement):

> Dam Survival Performance Standard – Meet the 96% dam passage survival standard for yearling Chinook and steelhead and the 93% standard for subyearling Chinook. Achievement of the standard is based on 2 years of empirical survival data. . . . .

Spill Passage Efficiency and Delay Metrics − Spill passage efficiency (SPE) and delay metrics under current spill conditions . . . are not expected to be degraded ("no backsliding") with installation of new fish passage facilities at the dams . . . .

Future RME − The Action Agencies' dam survival studies for purposes of determining juvenile dam passage performance will also collect information about SPE, BRZ-to-BRZ (boat-restricted zone) survival and delay, as well as other distribution and survival information. SPE and delay metrics will be considered in the performance check-ins or with Configuration and Operations Plan updates, but not as principal or priority metrics over dam survival performance standards. Once a dam meets the survival performance standard, SPE and delay metrics may be monitored coincidentally with dam survival testing.

This report summarizes the results of the 2012 AT studies of CH1, STH, and CH0 at MCN to assess the Action Agencies' compliance with the performance criteria of the BiOp and Fish Accords (Table 2.3).

Table 2.3. Definitions of BiOp and Fish Accords Performance Measures

Measure	Definition
BiOp Performance Standard	
Dam passage survival	Survival from the upstream face of the dam to a standardized reference point in the tailrace.
Fish Accord Performance Standards	
Forebay-to-tailrace survival	Survival from a forebay array 2 km upstream of the dam to a tailrace array 2 km downstream from the dam. This metric satisfies the BRZ-to-BRZ survival estimate.
Forebay residence time	Average time smolts take to travel from the first detection on the forebay entrance array 2 km upstream of MCN to the time of last detection on the dam-face array.
Tailrace egress time	Average time smolts take to travel from the time of last detection on the dam-face array to the time of last detection on the downstream tailrace array.
Spill passage efficiency	Proportion of fish passing through the dam via the spillway.
Fish passage efficiency	Proportion of fish passing through the dam via non-turbine routes (i.e., the spillway and the juvenile bypass system.

2.2 Study Area Description

MCN is located at river kilometer (rkm) 470 on the Columbia River approximately 2.5 km east of Umatilla, Oregon, downstream from the confluence of the Snake River with the Columbia River. The reservoir behind MCN, Lake Wallula, extends approximately 98 rkm upstream to the Hanford Reach on the Columbia River, as well as 16 rkm upstream into the Snake River to Ice Harbor Dam (Adams and Evans 2011). MCN is the fourth dam upstream from the ocean on the Columbia River. The dams downstream from MCN include John Day Dam (JDA), The Dalles Dam (TDA), and Bonneville Dam (BON). MCN is a multipurpose dam that provides hydroelectric power generation, river navigation, recreation, irrigation, and flood control.

MCN is 2,245 m long and approximately 56 m high. The spillway is 399 m long and has 22 bays, each with a 15-m by 15.5-m vertical lift gate and a hydraulic capacity of 2,200 kcfs. The spillway crest is located at 88.7 m above mean sea level (MSL). Spill Bays 3 through 20 have 3.8-m-long flat transition deflectors at 78 m above MSL on each spillway chute. Spill Bays 1, 2, 21, and 22 have 4.5-m-radius transition deflectors located at 78 m above MSL. These four bays also have guide walls that limit the hydraulic interaction of the spill flow with adjacent bays until spill flow is downstream of the deflectors. TSWs were installed at Spill Bays 19 and 20 for this study.

The MCN powerhouse has 14 main units with a generator nameplate capacity of 70 MW each and a total powerhouse capacity of 980 MW. Two station service units are each capable of generating 3 MW of power. There are two fish ladders, one on each shore of the dam, and a juvenile fish collection facility at the powerhouse. The juvenile bypass outfall in winter 2011-2012 was relocated approximately 335 m downstream from the dam, approximately 366 m from the bank, near mid-river (Figure 2.1).

In 2012, the MCN study area for the AT evaluation of survival and passage covered approximately 178 rkm of the Columbia River from the primary release location at Port Kelley, Washington (rkm 503), to the tertiary autonomous hydrophone array at Celilo, Oregon (rkm 325) (Figure 2.2). MCN is located 33 rkm downstream from the fish release transect at Port Kelley. A list of release locations, description of each release location, and distance upstream from the mouth of the Columbia River are provided in Table 2.4.

Table 2.4. Release Location, Description, and Columbia River Kilometer for the MCN Passage and Survival Study, 2012

Release Location	Release Description	Columbia River Kilometer
Port Kelley, WA	Release 1 (R_1)	CR503
MCN Upstream BRZ	Forebay virtual release	CR472
MCN Dam	Dam face virtual release	CR470
MCN Tailrace	Tailrace reference release (R_2) and tailrace egress array	CR468
Crow Butte, WA	Tailwater reference release (R_3) and primary survival array	CR422
John Day Dam	Secondary survival array	CR349
Celilo, OR	Tertiary survival array	CR325

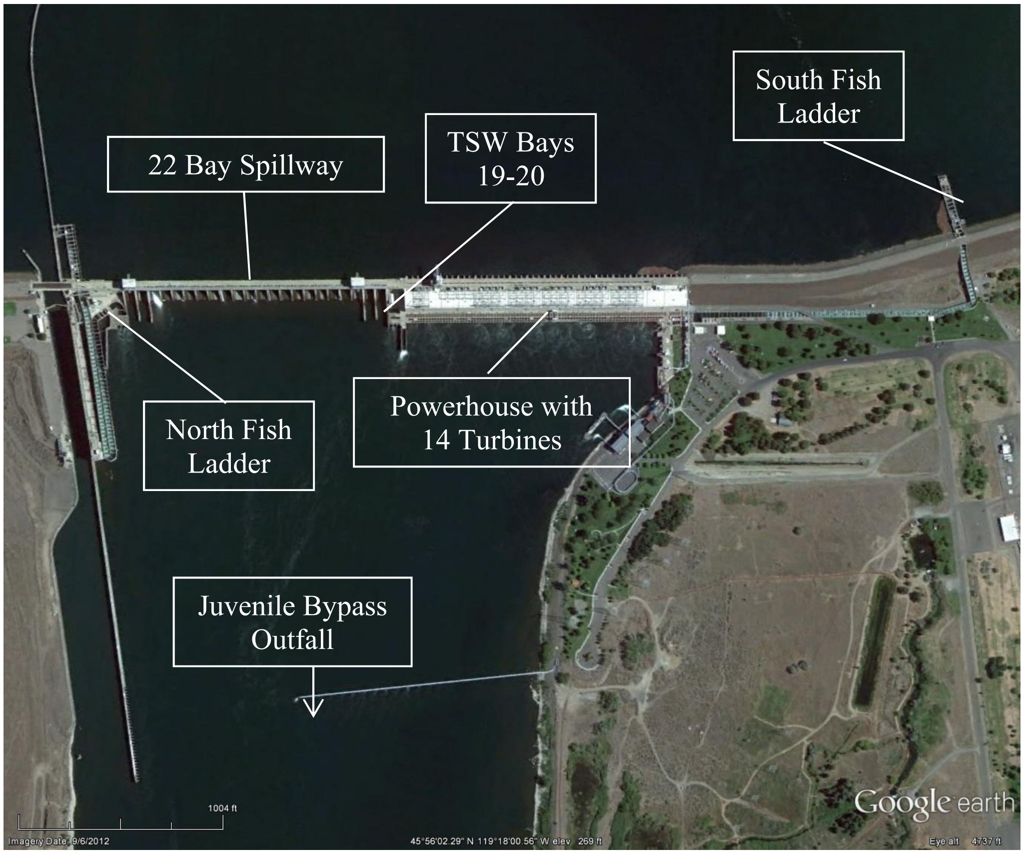


Figure 2.1. Aerial View of MCN (Modified image from Google Earth™, © 2012 Google Inc.)

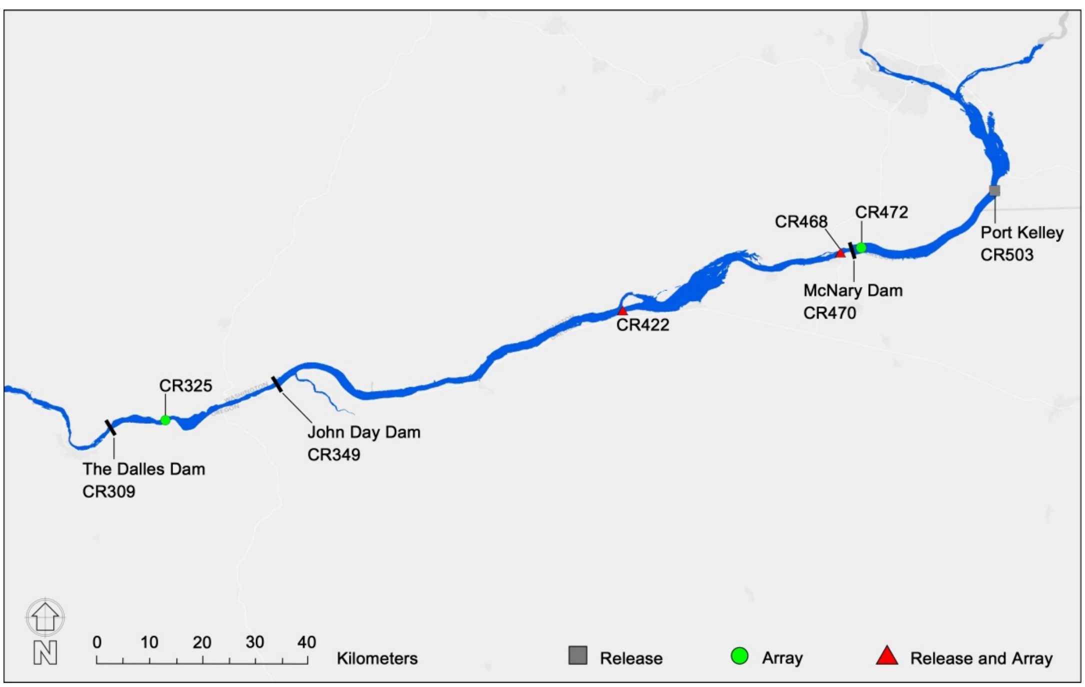


Figure 2.2. MCN Study Area Map

3.0 Methods

Study methods include information regarding environmental conditions during the study period; release-recapture experimental design; tag specifications; fish collection, handling, tagging, and release procedures; ATM detection; acoustic signal processing; and the statistical approach to data analyses. The primary research tool was the JSATS.

3.1 Environmental Conditions

Environmental conditions relevant to this study include water discharge (spillway and turbine), projected spring and summer spill levels (40% and 50%, respectively), and water temperature.

3.1.1 River Discharge and Temperature

Water discharge data by spill bay and turbine unit and elevation data for the forebay and tailrace were acquired by the USACE in 5-min increments by an automated data-acquisition system at MCN. To provide historical context for 2012 observations of discharge and temperature, 2012 data were pooled, averaged by day, and plotted with diel averages for the previous 10-year period. Average water discharge and forebay water temperature data from 2002 through 2011 were downloaded from the UW Data Access in Real Time (DART) website (http://www.cbr.washington.edu/dart).

3.1.2 Spill Conditions

The 2012 USACE Fish Passage Plan called for MCN spill discharge levels to be 40% for the spring (10 April through 19 June) and 50% for the summer (20 June through 31 August; USACE 2012b). These discharge levels were defined as the percentage of total dam discharge that passes over the spillway. In addition, TSWs were scheduled to be operated at Spill Bays 19 and 20 from 10 April through 6 June, during spring migrant salmonid passage and removed prior to 8 June and the start of the summer study; therefore, no surface-flow outlets were active during the summer study period.

3.2 Release-Recapture Design and Sample Size

The release-recapture design used to estimate dam passage survival at MCN consisted of a virtual release (V_1) of tagged fish detected at the face of the dam and a paired release (R_2 and R_3) below the dam (Figure 3.1) (Skalski et al. 2009, 2010) (herein referred to as the virtual/paired release [VPR] model). Fish implanted with AMTs (herein referred to as "tagged fish") released upstream of MCN (R_1) provided a source of fish known to have arrived alive at the dam face. Tagged fish were released 31 rkm upstream so that they should have arrived at the dam in a spatial pattern typical of run-of-river (ROR) fish. Virtual-release groups composed of these tagged fish were used to estimate survival through MCN and down to the tailrace egress array at rkm 468. To account and adjust for cumulative reach mortality, a paired release below MCN (i.e., R_2 and R_3; Figure 3.1) was used to estimate survival in the segment of the reservoir downstream of the tailrace egress. Dam passage survival was estimated as the quotient of the survival estimates for the virtual release to that of the paired release (Equation 3.1). The same release-recapture design was used to estimate forebay-to-tailrace survival, except that the virtual-release group was composed only of fish detected by the forebay array at rkm 472. The same below-dam paired release was used to adjust for the extra reach mortality below the dam as was used to estimate dam passage survival. The total numbers of fish tagged with AMTs used in survival estimates are summarized by release locale and species in Table 3.1.

The cabled double-detection arrays at the face of the dam were analyzed as two independent arrays to allow estimation of detection probabilities. Subsequently, the arrays were combined into one array for use in further analyses. In addition to obtaining estimates of dam passage survival, the combined dam-face array allowed researchers to assign a route of passage from the location of the last detection of tagged fish. Passage-route data were used to calculate route-specific survival estimates, various passage efficiencies (e.g., FPE, SPE), and construct distribution information. The passage-route data also included information about passage-time that was used to examine day/night trends along with travel and residence times.

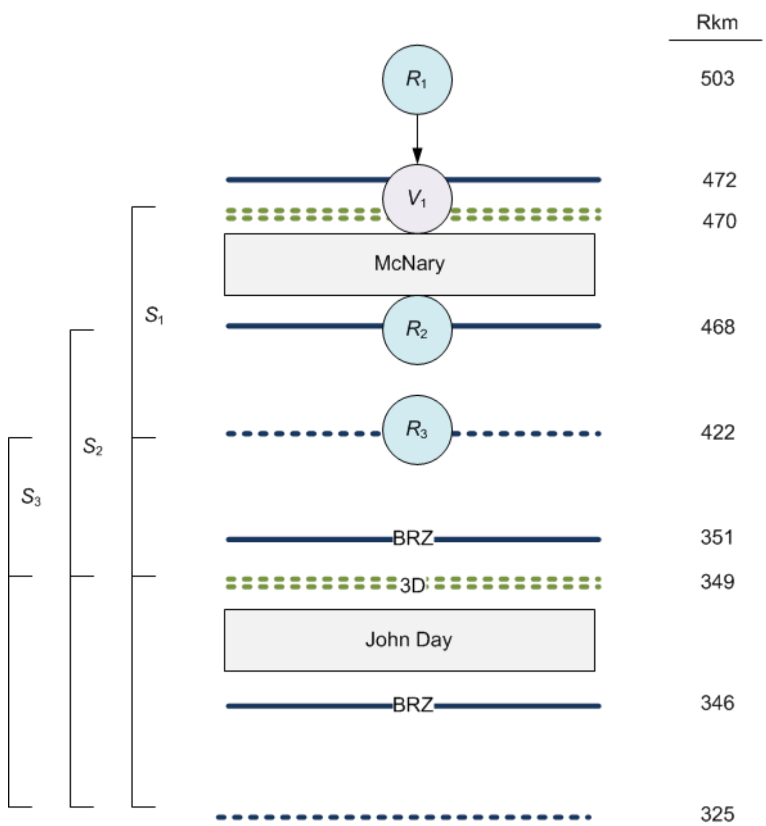


Figure 3.1. Schematic of the VPR Model used to Estimate Dam Passage Survival at MCN. The virtual release (V_1) for various passage metrics was composed of fish that arrived at the dam face from releases at rkm 503. The paired-release below the dam was composed of releases R_2 and R_3 with detection arrays used in the survival analysis denoted by dashed lines.

$$\hat{S}_{\text{Dam}} = \frac{\hat{S}_1 \cdot \hat{S}_3}{\hat{S}_2} \tag{3.1}$$

Table 3.1. Numbers of Fish Tagged with AMTs and Passive Integrated Transponders (PITs) used in Survival Studies at MCN in 2012

Release Location	Yearling Chinook Salmon	Steelhead	Subyearling Chinook Salmon
Above McNary Dam (R_1)	1399	1400	2524
Virtual Release–McNary Dam (V_1)	1360	1297	2459
McNary Dam Tailrace (R_2)	1198	1199	1993
Crow Butte, WA (R_3)	1200	1198	1984

3.3 Tag Specifications and Tag Life

Two models of JSATS AMTs manufactured by Advanced Telemetry Systems, Inc. (ATS) were used in the 2012 study (Figure 3.2) to minimize fish tag burden and to use surplus tags from a previous survival study. Both tags functioned in the same fashion using a binary phase-shift keyed (BPSK) code pulse at a frequency of 416.7 kHz (Weiland et al. 2011). The larger double-battery AMT implanted in STH, Model SS130, measured 12.00 mm in length, 5.21 mm in width, 3.77 mm in thickness, and weighed 0.438 g in air. These tags had a nominal transmission rate of 1 pulse every 3 s and AMT life was expected to be about 32 d. The smaller single-battery AMT implanted in CH1 and CH0, Model SS300, measured 10.79 mm in length, 5.26 mm in width, 3.44 mm in thickness, and weighed 0.304 g in air. The tags had a nominal transmission rate of 1 pulse every 3 s and AMT life was expected to be about 23 d.

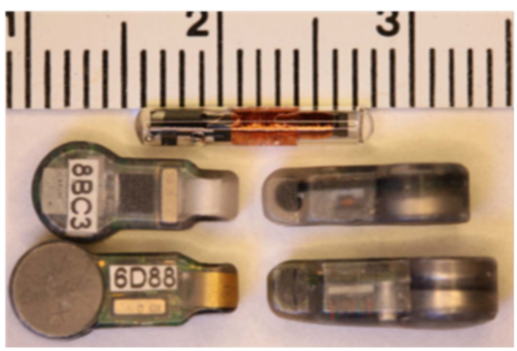


Figure 3.2. JSATS AMTs Model SS300 (middle) and Model SS130 (bottom) and PIT (top) Surgically Implanted in CH1, CH0, and STH in 2012

A total of 297 JSATS AMTs were randomly sampled from the two AMT types (SS300, SS310) and their production lots for assessment of AMT life. The AMTs were activated, held in river water, and monitored continuously until they failed. All AMTs were enclosed in water-filled plastic bags and suspended from a rotating foam ring within a 2-m-diameter fiberglass tank. Two 90° × 180° hydrophones were positioned 90° apart in the bottom of the tank and angled upward at approximately 60° to maximize coverage for detecting acoustic signals. Hydrophones were cabled to a quad-channel receiver that amplified all acoustic signals. All acoustic signals were then saved, decoded, and processed. Post-processing software calculated the number of hourly decodes for each AMT, allowing AMT failure times to be determined within ±1 h.

3.4 Handling, Tagging, and Release Procedures

Procedures for the handling, tagging, and releasing of fish to be used in this study followed USACE protocols set forth by Axel et al. (2011). Fish obtained from the John Day Dam (JDA) JBS were held for 18 to 30 h before being surgically implanted with JSATS tags, held for an additional 12 to 36 h for recovery, and then transported to three different release locations on the Columbia River, as described in the following sections. A total of 3,797 CH1, 6,501 CH0, and 3,797 STH were tagged and released for use in estimating survival and various passage metrics at MCN. Tagging and release data are presented in Appendix C.

3.4.1 Fish Source and Collection Methods

The juvenile salmonids used in the study were obtained via the JDA JBS and diverted to the Smolt Monitoring Facility (SMF) at JDA. The SMF is situated on the Oregon shore at the downriver edge of the fish bypass system where juvenile salmonids and other fishes diverted from turbine intakes can be routed through a series of gates, chutes, flumes, and dewatering structures. Fish in the JBS were diverted into the SMF as part of routine monitoring or directed into the tailrace through an outfall pipe located downstream of the facility (Martinson et al. 2010). Fish sampled in the SMF were examined, enumerated, and either selected for tagging as part of this study or released into the tailrace outfall.

PSMFC employees systematically diverted fish from the bypass system into a 6,795-L holding tank in the SMF as described by Martinson et al. 2010. Using a panel net, approximately 150 to 200 fish were crowded into a 51.20 cm × 6.14 cm pre-anesthetic chamber. Water levels in the chamber were lowered to about 20.5 cm at which point fish were anesthetized with 60 ml of a stock tricaine methanesulfonate (MS-222) solution prepared at a concentration of 50 g/L. Once anesthetized, fish were routed into the examination trough for identification and enumeration. PSMFC 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 to ensure temperatures in the trough were maintained within 2°C of the main holding tank.

After sorting and initial identification of the fish, PNNL staff further examined the external condition and other characteristics of each pre-candidate fish. Candidate fish conditions were based on the general recommendations set forth by Axel et al. (2011) and confirmed by the Studies Review Work Group (SRWG) and National Oceanic and Atmospheric Administration (NOAA) representatives in meetings during spring 2012. PNNL broadened the criteria to minimize the rejection rate in accordance with Axel et al. (2011). Fish with the following characteristics were considered to be non-candidates and were "excluded" from the study:

- previously tagged fish containing a PIT, RT, or AMT
- fork length <95 mm or ≥300 mm
- non-target species

- handling issue (e.g., fish jumped out of tank)
- moribund.

Fish with the following malady(ies) were excluded from the study:

- descaling ≥20% on either side with no indication of scale regrowth or slime coat present
- disease or symptoms of disease: distended belly; ulcerations and furunculosis that was >5% on either side, >2 copepod parasites on gill filaments
- fungus >5% on either side
- skeletal deformities that inhibit AMT implantation or swimming ability
- severe caudal fin erosion (e.g., no caudal fin present)
- injury defined as open wounds with active hemorrhaging >5% on either side or injuries at the site of AMT/PIT implantation.

The CH0, CH1, and STH were representative of fish within the river and thus the collection process was adaptive. If a specific malady/physical anomaly was observed in more than 5% of the sample on a specific day, the next day's fish with similar conditions were accepted in the collection after approval by the fish condition study manager.

External conditions for all non-candidate and excluded fish were recorded using FishEye! software and digital photos were taken using FishBooth! software. Non-candidate and excluded fish were released to the river through the SMF holding system after recovery from anesthesia. Accepted fish were counted and transferred into 302.8-L pre-surgery holding tanks (<50 g/L holding density), where they were held for 18 to 30 h prior to surgery. The pre-surgery holding duration was dependent on the collection time and the scheduled tagging time the next day. Any extra fish collected but not used for tagging due to daily tagging quotas being met, were released to the river through the JDA JBS outfall.

3.4.2 Tagging Procedure

The surgical team followed the latest guidelines for surgical implantation of AMTs in juvenile salmonids (Axel et al. 2011). Numerous steps were taken to minimize the handling impacts of collection and surgical procedures on study fish. The majority of CH0, CH1, and STH used for tagging were part of the routine fish collection of the smolt monitoring program and additional fish did not have to be collected to meet the tagging quota on most days.

Fish were netted in small groups from the 302.8-L holding tanks and placed in a 24.6-L bucket containing an 80-mg/L concentration of MS-222 anesthetic and river water. Once a fish lost equilibrium, it was transferred to a data collection/processing table in a small container of river water and anesthetic. Each fish was assigned a species type, surgeon, release location, code indicating whether the adipose fin was intact or clipped, a fork length measurement (±1 mm), and fish condition comments (e.g., <20% descaling) on a GTCO CalComp Drawing Board® VI™ digitizer board. Fish were then weighed (±0.1 g) on a 2,000 g Ohaus® Scout *Pro* scale and returned to the small transfer container along with their assigned PIT and AMT. Information collected was added automatically to the tagging database by PIT Tag Information System (PTAGIS) P3 software to minimize human error. The transfer container, fish, and tags were then passed to the photo table where photographs of each side of the fish were taken to document their external appearance. Finally, fish were transferred to their assigned surgeon for AMT implantation.

During surgery (Figure 3.3), each fish was placed ventral side up and a gravity-fed "maintenance" anesthetic (40 mg/L) and fresh river water supply line was placed into its mouth. Using a 15-degree, 3.0-mm depth microsurgical stab blade, a 5- to 7-mm incision was made along the *linea alba* 3- to 5-mm anterior of the pelvic girdle. A PIT was inserted followed by an AMT with the acoustic element pointing posterior. Both tags were inserted at an angle toward the anterior end of the fish to minimize internal damage. The incision was closed with two interrupted stitches using 5-0 Ethicon Monocryl® monofilament sutures with a reverse cutting needle and secured with a knot consisting of four single-wrap throws in alternating directions.

An established protocol was used to help minimize negative impacts that may occur from surgical procedures and handling. Each surgeon systematically rotated between three complete sets of instruments during each day's tagging. When a set was not being used, all metal surgical implements were placed in hot bead sterilizers for at least 15 s and all nonmetal implements were soaked in a 2% stock solution of chlorohexidine diacetate (Nolvasan®) for approximately 10 min. The instruments were then transferred to a distilled water bath for 10 min to remove residual chlorohexidine and to cool the metal implements before being used again. PolyAqua® was used to protect the fish's mucus membrane, thereby reducing the possibility of infection and aid in healing. Water in anesthesia and recovery buckets was refreshed repeatedly to maintain temperatures within ±1°C of river water temperature and sodium bicarbonate was added to anesthesia buckets to act as a pH buffer. After completion of daily tagging operations, all surgical instruments were sterilized in an autoclave and surgical work surfaces (e.g., surgery tables) were disinfected with Virkon® Aquatic.

The tagging process required a team of 11 or more people to conduct daily operations and to ensure that all collected and tagged fish were handled as efficiently and carefully as possible. Individuals were assigned to specific tasks within the tagging process. One individual was responsible for anesthetizing fish; another for delivering fish to and from the various stations; two people assigned tagging information and recorded data; one person took photographs with a high-resolution digital camera; four people performed surgeries to implant tags in the fish; one person attended to the post-surgical transport buckets, making sure only the correct fish made it into each bucket; and one or two people were responsible for scanning each bucket with a PIT scanner before moving tagged fish in transport buckets to post-surgery holding tanks.

Figure 3.3. Surgical Setup and Process

3.4.3 Recovery and Holding

Following surgery, a maximum of five tagged fish were placed in 24.6-L transport buckets filled with aerated river water. Each bucket held one to five fish depending on the number to be released at each release site. Transport buckets were taken to a second data station where FishBucket! software was used to verify the tagged fish were assigned to their specified transport buckets. A unique barcode on each bucket lid was scanned into the software using a Motorola Symbol DS6707 scanner and all implanted PITs within each bucket were scanned using a Biomark 0.9 m PIT stick reader. This process provided a quality assurance that fish were in the assigned transport bucket, and that buckets could be tracked prior to release. All fish were monitored until equilibrium was regained before being transferred to an outdoor post-surgery holding tank continuously supplied with fresh river water (Figure 3.4), where they were held for 12 to 36 h prior to being released at their assigned locations. Dissolved oxygen and water temperature were closely monitored in the insulated holding tanks to ensure holding conditions were within acceptable limits.

Figure 3.4. Example of Post-surgery Holding Tank with Recovery Buckets Containing Tagged Fish

3.4.4 Fish Transport and Release

Prior to transport, buckets with tagged fish were placed in an insulated Bonar tote lined with acoustic absorbing material where two JSATS hydrophones were mounted to identify all AMTs signals. Information was collected using FishBucket! software as a quality assurance/quality control procedure to ensure that the assigned ATM to a fish was in the assigned transport bucket and all AMTs were functioning. Once all AMTs were identified, the bucket lid barcodes were scanned using FreeWilly! software loaded onto Opticon H-21 handheld scanners, which were set up to take a global positioning system (GPS) location every time a bucket lid was scanned into the software. Fish were transported from JDA to one of three release locations on the Columbia River (Figure 3.1). Transportation routes were adjusted to provide equal travel times from JDA to each release location. To transport tagged fish, ¾-ton trucks were outfitted with two 681-L insulated Bonar totes filled half to three-quarters full with fresh river water prior to each release (Figure 3.5). Transport buckets were removed from the post-surgery holding tanks and placed in the totes, which can hold up to nine fish buckets. A network of valves and plastic tubing was attached to an oxygen tank for delivering oxygen to the totes from a 2,200-psi oxygen tank during transport. A YSI meter was used to monitor dissolved oxygen concentration and water temperature in the totes before and during transport to ensure that water-quality parameters remained within acceptable limits of 80 to 120% saturation and water temperature ±2°C. When measures approached unacceptable limits, staff adjusted the flow of oxygen to the tanks or added river-water ice to the river water in tanks to reduce the water temperature.

Figure 3.5. Fish Release Transport Truck and Totes

Upon arriving at a release site, fish buckets were transferred to a boat for transport to in-river release locations at each release cross section. Generally, equal numbers of fish were released at each of five locations for a given cross section. Releases occurred day and night for 34 consecutive days for spring (27 April to 30 May) and summer (13 June to 16 July), and the timing of the releases at successive downstream locations was staggered to facilitate downstream mixing in the common tailwater (Table 3.2).

Just before fish were released in the river, fish bucket lid barcodes were scanned into FreeWilly! software and buckets were opened to check for dead or moribund fish. If dead or moribund fish were observed, they 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 that recorded all pairs of PIT and AMTs implanted in fish the previous day. Dead or moribund fish were returned to the tagging facility and subsequently released as dead tagged fish at the MCN or JDA spillway. Staff made releases of dead tagged fish so that the assumption that all fish detected on downstream survival detection arrays were alive when detected and no dead tagged fish were detected on those arrays, which would bias high associated survival estimates.

Table 3.2. Relative Release Times for the Acoustic-tagged Fish to Accommodate Downstream Mixing. Releases were timed to accommodate the approximately 24-h travel time between R_1 and R_2 and 32-h travel time between R_2 and R_3.

	Relative Release Times	
Release Location	Daytime Start	Nighttime Start
R_1 (rkm 503)	Day 2: 1000 h	Day 1: 2200 h
R_2 (rkm 468)	Day 3: 1000 h	Day 2: 2200 h
R_3 (rkm 422)	Day 4: 1800 h	Day 4: 0600 h

3.5 Detection of Tagged Fish

Detections of tagged fish were obtained via arrays of JSATS receivers at multiple locations in the Columbia River and each array had specific functions for the study at MCN. The JSATS arrays included cabled and star arrays fixed to dam structures and autonomous node arrays anchored in river cross-sections including the MCN forebay, tailrace, and the downstream survival detection arrays.

3.5.1 Array Locations and Study Functions

Two types of JSATS arrays—cabled and autonomous—were deployed to detect fish tagged with JSATS AMTs as they passed downstream through the study reach between the MCN forebay at rkm 472 and Celilo, Oregon, at rkm 325 (Table 3.3). The MCN forebay array was used to create virtual-release groups of fish known to have survived from initial release into the river to the entrance of the forebay, 2 rkm upstream of MCN. These forebay virtual-release groups were used to estimate forebay-to-tailrace survival (BRZ-to-BRZ) and forebay residence time. The dam-face array at MCN (rkm 470) was used to create virtual-release groups of fish known to have arrived alive at the dam face. These release groups were used to estimate dam passage and route-specific survival rates, passage efficiencies, residence times, and horizontal and vertical distributions. Estimates were based on 3D tracking combined with observations of the timing and location of the last detection of tagged fish prior to dam passage (Deng et al. 2011). The time of last detection on the dam-face array minus the time of first detection on the forebay entrance array at MCN was used to estimate forebay residence time for each fish. The MCN tailrace array (rkm 468) was used as one of the sites for the paired reference releases and to calculate tailrace egress time. The time of last detection by the MCN tailrace array minus the time of last detection on the dam-face array provided an estimate of egress time. The Crow Butte array (rkm 422) near Crow Butte State Park, Washington, was used as the primary survival-detection array for virtual releases of fish at MCN and as the second location for the paired reference releases below the dam. The JDA dam-face array (rkm 349) was used as the secondary survival-detection array for estimating the survival of virtual releases of fish passing MCN. The Celilo array (rkm 325), near Celilo Village, Oregon, was a tertiary survival-detection array for estimating the product of survival and detection probabilities used in estimating MCN passage survival rates. Hydrophone deployment locations are listed in Appendix C.

Table 3.3. Description, Location, Name, and Survival Model Function of Arrays Deployed in 2012. Array names were a concatenation of "CR" for Columbia River and the nearest whole rkm.

Array Description	Location	Array Name	Array Function(s)
MCN forebay	2 km upstream of MCN	CR472	Virtual release; forebay residence and project passage time; forebay-to-tailrace survival
MCN dam-face	MCN	CR470	Virtual release; dam passage survival; passage efficiencies; tailrace egress and forebay residence times; vertical and horizontal distributions
MCN tailrace	2 km downstream of MCN	CR468	Paired fish release site; tailrace egress
Crow Butte	Crow Butte State Park, WA	CR422	Primary survival array for virtual releases of fish at MCN (forebay entrance or dam face), paired fish release site
JDA dam-face	JDA	CR349	Secondary survival array for MCN virtual releases
Celilo	Celilo Village, OR	CR325	Tertiary survival array for MCN virtual releases

3.5.2 Cabled Dam-Face and Star Arrays

The cabled dam-face receivers used in the 2012 study at MCN were designed by PNNL for the CENWP using an off-the-shelf user-build system design (Weiland et al. 2011). Each cabled receiver system includes a computer, data-acquisition software, digital signal processing cards with field-programmable logic gate array (DSP+FPGA), a global positioning system card, a four-channel signal-conditioning receiver with gain control, hydrophones, and cables (Figure 3.6). Components of the cabled receiver system were tested for performance in an anechoic tank prior to deployment (Deng et al. 2010).

A modular, time-synchronized JSATS cabled array was deployed along the upstream face of MCN to detect CH0, CH1, and STH implanted with JSATS AMTs approaching the dam (Figure 3.7). The dam-face cabled array consisted of 23 cabled receivers, each supporting up to 4 hydrophones (Sonic Concepts, Inc.). The receivers were housed in trailers on the forebay deck and the hydrophones were deployed on the main piers at the powerhouse and spillway in a known fixed geometry. Hydrophones were deployed in a double-detection array pattern where two cabled receivers alternate across four pier noses (Figure 3.8), providing data redundancy and data gap reduction. In addition, two star arrays were deployed on the south fish ladder and one between the Public Utility District (PUD) units and Spill Bay 1 (Figure 3.7). A single hydrophone was also deployed near the Washington shore fish ladder exit near the navigational lock.

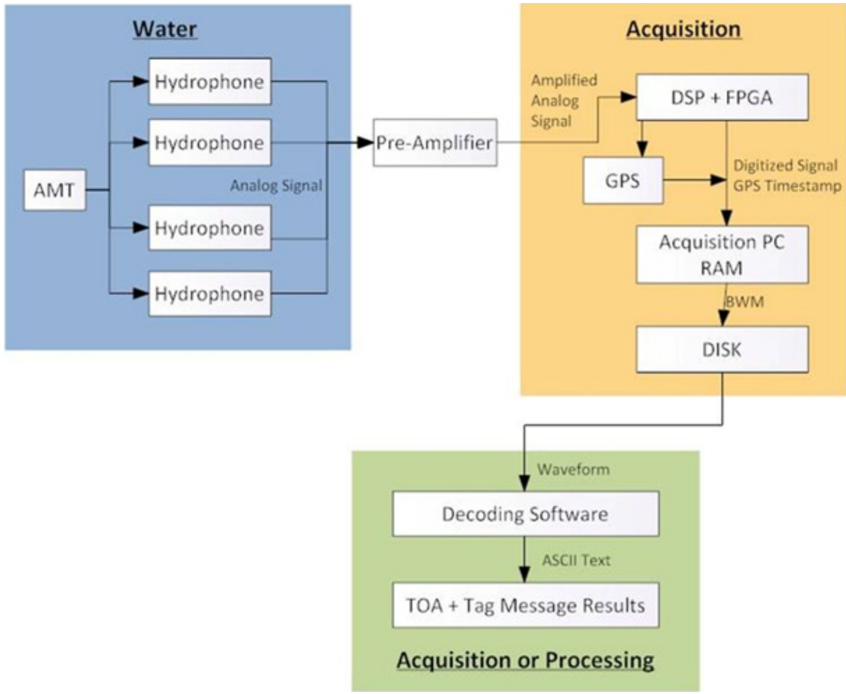


Figure 3.6. Schematic of Modular Cabled Receiver System Showing the Main Components and the Direction of Signal Acquisition and Processing. AMT = acoustic micro-transmitter implanted in fish; DSP = digital signal processing card; FPGA = field-programmable gate array; GPS = global positioning system; PC = personal computer; RAM = random access memory; BWM = binary waveform; TOA = time of arrival.

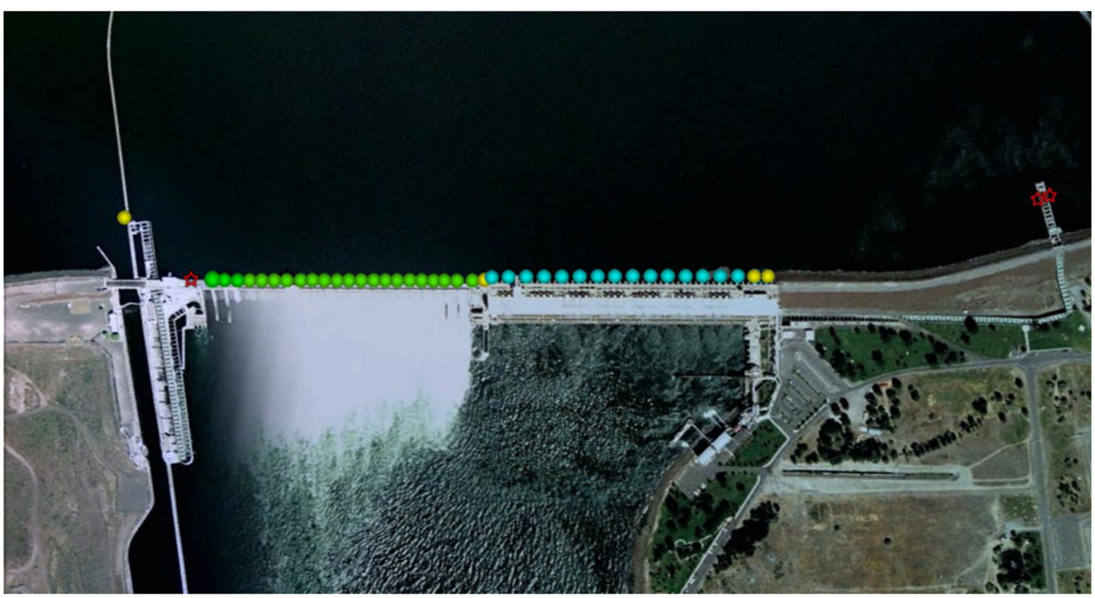


Figure 3.7. JSATS Cabled Array Deployment at the Dam Face of McNary Dam, 2012. The green circles represent shallow and deep hydrophones at spillway locations; blue circles represent shallow and deep hydrophones at powerhouse locations; yellow circles represent shallow hydrophones near the navigation lock entrance, near Spill Bay 22, and at the south end of the powerhouse; and the red stars represent star arrays at the south fish ladder and between the PUD units and Spill Bay 1.

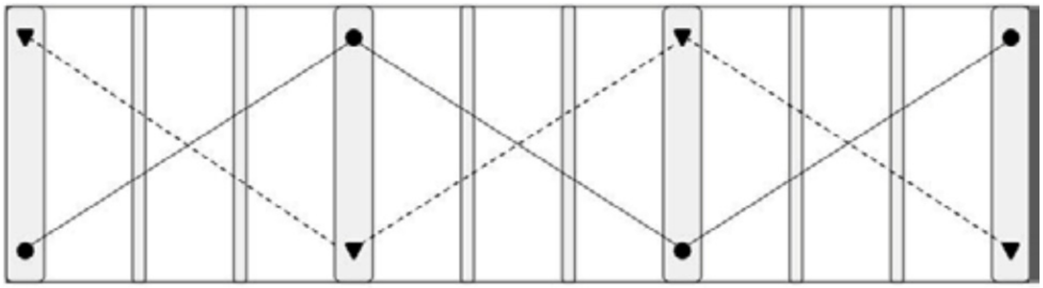


Figure 3.8. Front View Schematic of Hydrophone Deployments at Three Turbines Showing the Double-detection Arrays. The circles denote the hydrophones of Array 1 and the triangles denote the hydrophones of Array 2.

A total of 76 hydrophones were deployed on trolleys in pipes attached to MCN powerhouse and spillway piers (Figure 3.9). The trolley pipes, made of powder-coated, schedule-40 steel, had a 10.16-cm internal diameter and 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. Each steel trolley glided inside the pipe, directed by an extension arm that protruded from the slot. This arm positioned the baffled hydrophone perpendicular to the face of the dam (Figure 3.10). Anechoic material was used to line a plastic cone surrounding the hydrophone to reduce reflections of sound waves. Pipes at the powerhouse were 36.58 m long and extended from deck level at elevation 110.0 m above MSL down to a mid-intake depth at elevation 74.1 m above MSL. Of the 32 hydrophones deployed at the powerhouse, one hydrophone on each pier was deployed at a shallow elevation (~99.9 m above MSL) and another was deployed at a deep elevation (~82.3 m above MSL) except at the south end of the powerhouse where only one node was deployed at a shallow elevation. At the spillway, 44 hydrophones were mounted on trolleys that were deployed in 25.4-m long, 10.2-cm internal diameter slotted pipes. At each spillway pier, one hydrophone was deployed at a shallow elevation (~99.9 m above MSL) and the other at a deep elevation (~91.7 m above MSL) except near Spill Bay 22 where two single hydrophones were deployed at a shallow elevation. Hydrophones were deployed at different elevations to provide acceptable geometries for 3D tracking. A single shallow hydrophone was deployed near the navigation wall and near the Washington fish ladder exit to determine passage estimates of juvenile salmonids that used the ladder as a downstream migration pathway.

Figure 3.9. Slotted Trolley Pipes Mounted on Main Piers of the McNary Dam Powerhouse

Figure 3.10. Trolleys used to Deploy Anechoic Baffled Hydrophones at the McNary Dam Powerhouse and Spillway

In addition to the trolley pipe-deployed hydrophones at the spillway and powerhouse, PNNL designed and built “star” arrays to deploy hydrophones in areas where fixed trolley pipes were not available or feasible (Figure 3.11). The star arrays functioned as a stand-alone cabled receiver system. The arrays consist of four baffled hydrophones positioned in a specific fixed configuration on an aluminum frame, which was mounted to the face of a dam structure using rock anchors. The three outer hydrophones were set in the same plane equidistant from each other while the interior hydrophone in the star array was offset but equidistant from the outer hydrophones. Spacing between all four hydrophones was approximately 2 m to potentially allow for 3D tracking (Deng et al. 2011). Two star arrays were deployed on the south fish ladder, and one between Spill Bay 1 and the PUD units, to account for all possible methods of passage at MCN (Figure 3.7).

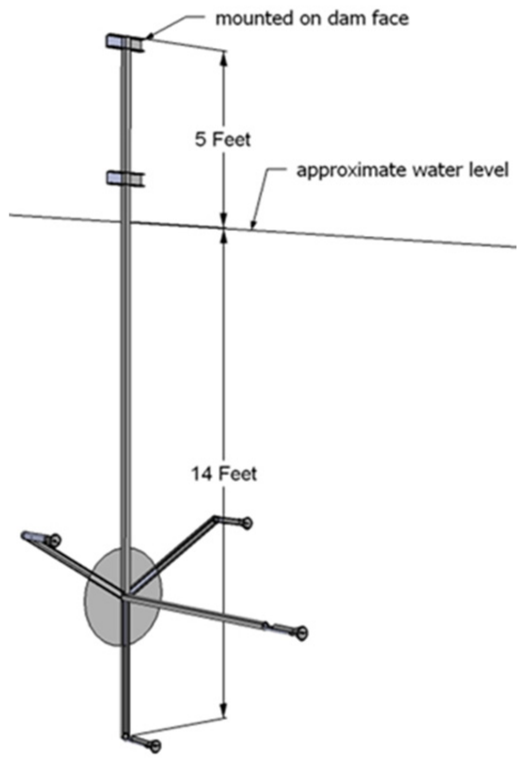


Figure 3.11. Diagram of Star Arrays Deployed at MCN Fish Ladders, 2012

3.5.3 Three-Dimensional Tracking

The cabled dam-face array and star arrays deployed at MCN allowed fish behavior and route of passage through the dam to be assessed via 3D tracking of fish implanted with JSATS AMTs. Assigning spatial locations using acoustic tracking is a common technique in bioacoustics based on time-of-arrival differences (TOADs) among different hydrophones (Watkins and Schevill 1972). At a minimum, the process requires detections on a four-hydrophone array (see Deng at al. 2011 for 3D tracking details).

3.5.4 Autonomous Receiver Arrays

The autonomous AT receiver (herein referred to as an “autonomous node” or “node”), was designed and developed by ATS and PNNL for the USACE to detect JSATS AMTs in a riverine environment. Each node—an independent, self-contained data acquisition instrument that may be anchored in the river where necessary—consists of a node top that houses a hydrophone (Sonic Concepts, Inc.), a data processing circuit board, a compact flash card (CF card) for data storage, an internal battery pack and battery, and USB cable connectors (Figure 3.12). The outside of the housing supports an external beacon tag and stabilizing fin to help keep the detecting hydrophone tip upright in the water column. A computer installed with custom software may be directly connected to a node for configuring and assessing its operation, in addition to viewing data collection in real time. All hydrophones were tested for acceptable detection performance in a specialized anechoic testing tank prior to deployment (Deng et al. 2010).

Figure 3.12. Outer (left) and Internal (right) Views of an Autonomous Node

Autonomous nodes were deployed in six separate arrays located at specific sites for the MCN study (Figure 3.13). An autonomous node array is defined as a line of autonomous nodes deployed on the riverbed, across the entire width of a river cross section, perpendicular to the river flow. Each array acts as a “passage gate” that detects passing JSATS AMT-implanted fish. Autonomous nodes in most of the arrays were deployed within 150 m of each adjacent node and less than about 75 m from shore. Each array was named by concatenating CR (Columbia River) with the nearest whole rkm upstream from the mouth of the river. For example, the first and farthest upriver node array was in the MCN forebay near rkm 472 and was named CR472.

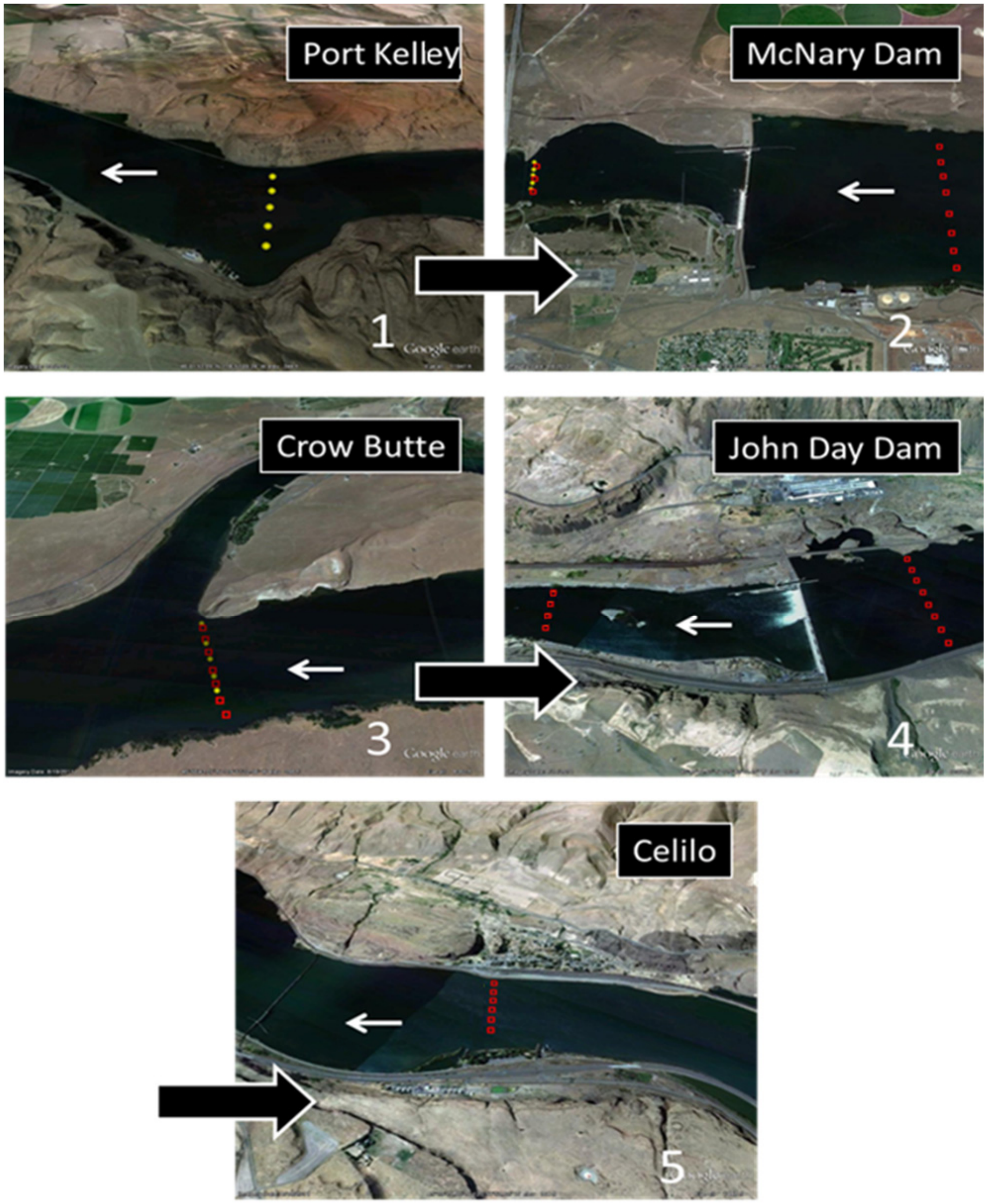


Figure 3.13. Location of the Fish Release Transects (yellow dots in images) and Six Autonomous Node Arrays (red squares). Black arrows with white borders between Google Earth images indicate the order of images from upstream to downstream. Water flow direction within each image is indicated by white arrows. Image 1: fish release location R_1 at rkm 503 near Port Kelley, Washington; Image 2: MCN forebay array at CR472 (right of dam) and MCN tailrace array at CR468 (left of dam). Tailrace reference releases of fish (R_2) were on top of the tailrace node array; Image 3: Crow Butte array at CR422 with fish release location R_3; Image 4: JDA forebay array at CR351 (right of dam) and the JDA tailrace array at CR346 (left of dam); Image 5: Celilo array at CR325.

Autonomous nodes were deployed in a configuration similar to that described by Titzler et al. (2010; Figure 3.14). Nodes were attached to an acoustic release (Model 111, InterOcean Systems, San Diego, California) using a 1.5-m section of rope with three 2.7-kg buoyancy floats. The rope was secured to the node via an eyebolt located on the compression strap around the node housing at its balance point. Lengths of wire rope measuring 0.3, 1.0, or 2.0 m connected the acoustic release to a 34-kg steel anchor. The shorter 0.3-m lengths of wire rope were used in depths less than approximately 7.0 m; 1.0-m lengths were used in depths between 7.0 and 20.0 m; and 2.0-m lengths were used in deeper locations.

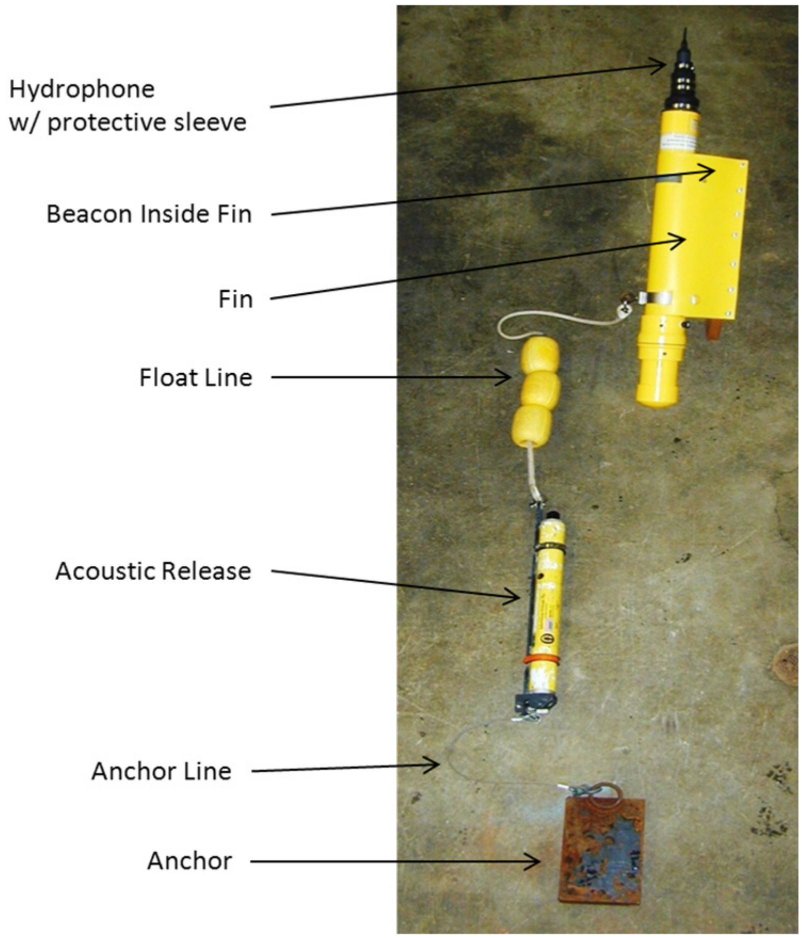


Figure 3.14. Autonomous Node Deployment Rigging with an Inter-Ocean Acoustic Release

Autonomous nodes were recovered, serviced, and redeployed individually by boat once every 2 weeks, and batteries were changed monthly. Staff recovered nodes by communicating with the attached acoustic release by generating a specific acoustic signal into the river through a transducer connected to a mobile command module. Upon successful receipt of the coded signal, the acoustic release's latch mechanism opened, freeing the node and acoustic release to rise to the water surface for retrieval. Each node was serviced by recording the node's internal clock time drift for the deployment period, downloading collected data, syncing the node clock back to the correct satellite time, and confirming the proper functionality of each node before its redeployment. Data files were reviewed to verify that information was collected during the entire deployment, records were continuous, and records included correct date/time stamps and beacon AMT detections. If any operational issues or data corruption were noticed, the node was removed from service and tested for performance. The most common problems experienced during the field study included damage to the exposed hydrophone tip, occasional acoustic release malfunctions, and nodes entangled in commercial drifting gillnets—primarily in the JDA tailrace and BON tailwaters.

For the 2012 survival studies, all autonomous node arrays were deployed and collecting data by 26 April and serviced through mid-August to ensure data acquisition for the entire period that JSATS tags were active.

3.6 Acoustic Signal Processing

Acoustic signal processing, for the cabled arrays, consisted of decoding binary waveform data files, filtering the decoded signals, and tracking fish movements using the decoded data. Autonomous array signals were processed by filtering decoded signals, and using the decoded signals to determine if fish tagged with an AMT passed through the array.

3.6.1 Signal Decoding

Encoded candidate messages detected on the JSATS cabled hydrophones that met certain criteria were saved in binary time-domain waveform files (Figure 3.15). The waveform files were then processed by a decoding utility (JSATS Decoder developed by the CENWP and PNNL) that identifies valid tag signals and computes the tag code and time of arrival using BPSK. BPSK is a digital-modulation technique that transmits messages by altering the phase of the carrier wave (Weiland et al. 2011). Several filtering algorithms were then applied to the raw results from the decoding utilities to exclude spurious data and false positive detections. Encoded messages detected on the JSATS autonomous receiver hydrophones and meeting the criteria were decoded in real time and the decoded signal was recorded to a CF card in the autonomous receiver.

3.6.2 Filtering Decoded Data

Receptions of AMT codes decoded from raw waveforms were further processed using several filtering algorithms to exclude spurious data and false positive detections and produce a data set of accepted AMT-detection events. For cabled arrays, detections from all hydrophones at a 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 AMT-code receptions that occur within 0.156 s after an initial identical AMT 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 s, 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 AMT 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 AMT transmission.

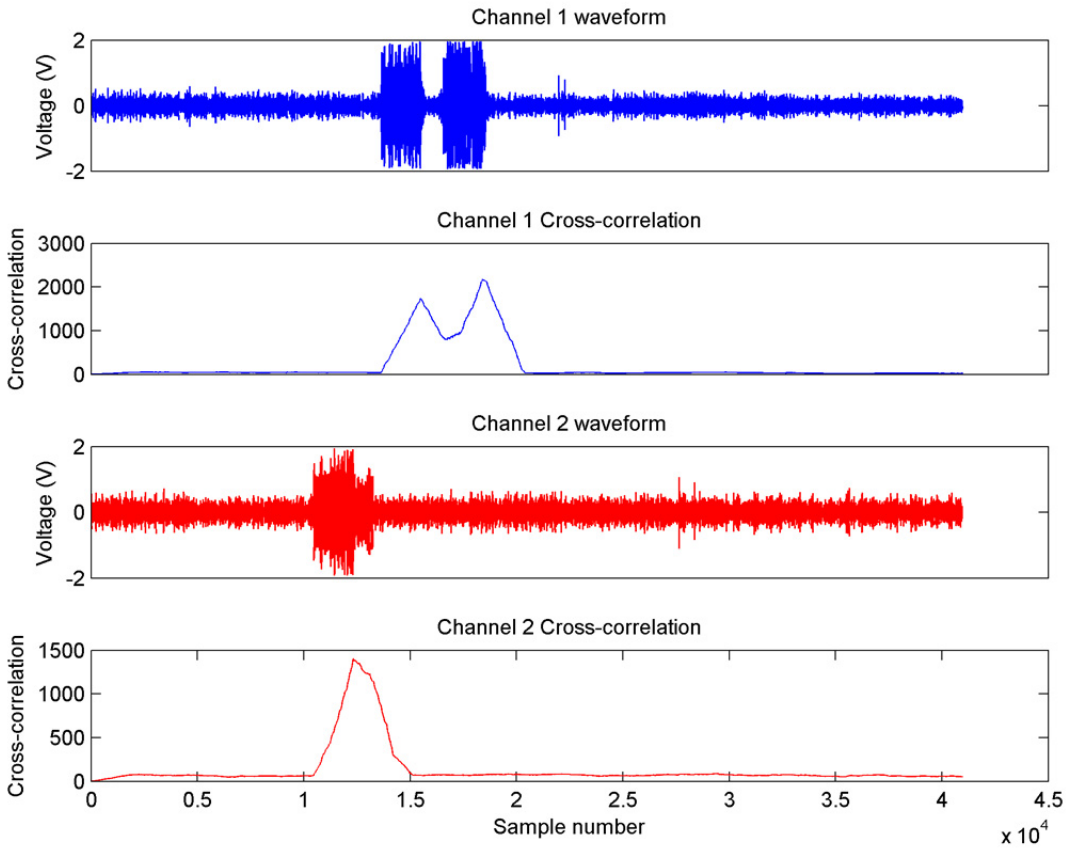


Figure 3.15. Example of Time-domain Waveforms and Corresponding Cross-correlations. The message portion was 1,860 samples (744 µs long). Note that multipath components were present in both channels. Decodes from the multipath components were filtered out in post-processing.

- PRI filter. Only those series of receptions of an AMT code (or "messages") consistent with the pattern of transmissions from a properly functioning JSATS AMT were retained. Filtering rules were evaluated for each AMT code individually, and it was assumed that only a single AMT would be transmitting that code at any given time. For the cabled system, the PRI filter operated on a message, which 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 the cabled-array data, receptions of JSATS AMT recorded to the CF card in the autonomous node are processed to produce a data set of accepted AMT detection events. A 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 an AMT code (or "hits") that were consistent with the pattern of transmissions from a properly functioning JSATS AMT were retained. Each AMT code

was processed individually, and it was assumed that only a single AMT would be transmitting that code at any given time. At least four messages passing the PRI filter were required for an acceptable AMT-detection event.

The output of the filtering processes for both cabled and autonomous hydrophones was a data set of events that summarized accepted AMT detections for all times and locations where hydrophones were operating. Each unique event record included a basic set of fields that indicated the unique identification number of the fish, the first and last detection time for the event, the location of detection, and the number of messages detected within the event. This list was combined with accepted AMT detections from PIT detections for additional quality assurance/quality control measures prior to survival analysis. Additional fields also captured specialized information where available. One such example was route of passage, which was assigned a value for events that immediately precede 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 were used to triangulate successive AMT 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 have close to the minimum number of messages and were deleted from the event data set before survival analysis.

3.7 Statistical Methods

Statistical methods include tests of model assumptions and estimation of dam passage survival, forebay-to-tailrace survival, travel times, SPE, and FPE, as described below.

3.7.1 Tests of Survival Model Assumptions

3.7.1.1 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 of fish implanted with PITs going through the JBS. However, AT studies do not use physical recaptures to detect fish. Consequently, these tests have little or no relevance to 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.

3.7.1.2 Detection of Dead Fish on Downstream Arrays

Dead fish with active AMTs were released throughout the spring season from the MCN spillway deck into the tailrace to ensure detection arrays were far enough downstream so as not to detect fish that either were released dead or died during passage through MCN.

3.7.1.3 Tests of Mixing

The scheduled timing of releases was designed to induce downstream mixing of release groups. 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.

3.7.1.4 Surgeon Effects

Subtle differences in handling and tagging techniques can have an effect on the survival of CH0, CH1, and STH implanted with AMTs used in the estimation of dam passage survival. For this reason, surgeon effects were evaluated using the *F*-test. The single release-recapture model was used to estimate reach survivals for fish implanted with AMTs by different surgeons. The analysis evaluated whether any consistent pattern of reduced reach survivals existed for fish implanted with AMTs by any of the surgeons.

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

$$F_{k-1,\infty} = \frac{s_{\hat{S}}^2}{\left(\frac{\sum_{i=1}^{k} \widehat{\mathrm{Var}}\left(\hat{S}_i \middle| S_i \right)}{k} \right)} \tag{3.2}$$

where

$$s_{\hat{S}}^2 = \frac{\sum_{i=1}^{k} \left(\hat{S}_i - \hat{\bar{S}} \right)^2}{k-1} \tag{3.3}$$

and

$$\hat{\bar{S}} = \frac{\sum_{i=1}^{k} \hat{S}_i}{k} \tag{3.4}$$

3.7.1.5 AMTs-Life Analysis

JSATS AMTs were randomly sampled from the two AMT types (SS300, SS130), which were in three production lots (lot 1 = 98 tags; tag lot 2 = 100 tags; tag lot 3 = 99 tags) for an assessment of AMT life. Various models can be fit to failure-time data, including both the vitality and three-parameter Weibull models (Elandt-Johnson and Johnson 1980; Li and Anderson 2009; Lady et al. 2012). For the JSATS

Model SS300 tags implanted in CH1 and CH0, failure times best fit the four-parameter vitality model of Li and Anderson (2009). The probability density function for the vitality model can be rewritten as

$$f(t)=1-\left(\Phi\left(\frac{1-rt}{\sqrt{u^2+s^2t}}\right)-e^{\left(\frac{2u^2r^2}{s^4}+\frac{2r}{s^2}\right)}\Phi\left(\frac{2u^2r+rt+1}{\sqrt{u^2+s^2t}}\right)\right)^{e^{-kt}} \tag{3.5}$$

where Φ = cumulative normal distribution,
r = average wear rate of components,
s = standard deviation in wear rate,
k = rate of accidental failure,
u = standard deviation in quality of original components.

The vitality model tends to fit AMT failure times, because it takes into account the early onset of random failures due to manufacturing and systematic battery failure. This gives the vitality model additional latitude to fit AMT-life data not found in other failure-time distributions such as the Weibull or Gompertz (Lady et al. 2012). Parameter estimation was based on maximum likelihood estimation.

For the STH AMT-life study using Model SS130 tags, the failure times best fit the three-parameter Weibull distribution (Elandt-Johnson and Johnson 1980; Lady et al. 2010), because there were no observed early AMT failures prior to battery failure that would cause the shoulder of the AMT-life curve to drop. The three-parameter Weibull distribution with scale (λ), shape (β), and shift (γ) parameters has a probability density function of

$$f(t)=\frac{\beta}{\lambda}\left(\frac{t-\gamma}{\lambda}\right)^{\beta-1}e^{-\left(\frac{t-\gamma}{\lambda}\right)^{\beta}}, \tag{3.6}$$

with survivorship function

$$S(t)=e^{-\left(\frac{t-\gamma}{\lambda}\right)^{\beta}}, \tag{3.7}$$

cumulative density function

$$F(t)=1-e^{-\left(\frac{t-\gamma}{\lambda}\right)^{\beta}}, \tag{3.8}$$

and hazard function

$$h(t)=\frac{\beta}{\lambda}\left(\frac{t-\gamma}{\lambda}\right)^{\beta-1}. \tag{3.9}$$

The three-parameter Weibull reduces to the two-parameter Weibull when $\gamma = 0$; it reduces to the exponential distribution when $\beta = 1$ and $\gamma = 0$.

The estimated probability that an AMT is active at a detection array depends on the AMT-life curve and fish travel time to the array (Townsend et al. 2006). For the virtual-release group (V_1) based on fish known to have arrived at the dam and with active AMTs, the conditional probability of AMT activation, given the AMT was active at the detection array at rkm 470, was used in the AMT-life adjustment for that release group. The conditional probability of AMT activation at time t_1, given it was active at time t_0, was computed by the quotient

$$P\left(t_1 \middle| t_0\right) = \frac{S\left(t_1\right)}{S\left(t_0\right)} \tag{3.10}$$

where $S(t_1)$ is the average unconditional probability that the AMT is active when detected at the first downriver detection array (rkm 422), and $S(t_0)$ is the average unconditional probability that the AMT is active when detected at the virtual-release array (rkm 470).

3.7.1.6 Tag Lot Effects

AMT lot effects were assessed by examining the distribution of different AMT lots among the release locations using chi-square tests of homogeneity. In addition, reach and cumulative survivals for JSATS AMT-implanted fish were analyzed across AMT lots by release location using *F*-tests.

3.7.1.7 Delayed Handling/Time In-River Effects

F-tests were used to compare the reach and cumulative survivals of JSATS AMT-implanted fish by release location. These tests assessed whether the downstream reach survivals were affected by the various upstream locations of released smolts. The results of these tests were used to determine the release groups included in the sample population of the downstream virtual-release group. If tests of tag-lot and surgeon effects were not significant, data were pooled across surgeons and AMT lots for analyses.

3.7.1.8 Run Timing and Size Distribution

To ensure that CH0, CH1, and STH implanted with JSATS AMTs were a representative sample of the population of interest, we compared the run timings and length of fish collected during routine smolt monitoring at JDA in 2012 with that of fish implanted with AMTs for the survival study. The goal was to include the middle 80% of the run and closely match length distributions for each species.

3.7.1.9 Tailrace and Tailwater Release Location Effects

A comparison of single-release survival estimates for fish released at each of the five reference release sites at the MCN tailrace array (CR468) and the five reference release sites at the MCN tailwater array (CR422) was intended to alleviate concerns about some sites having excessive predation that might bias the VPR estimates of dam passage survival. Single-release survival rates were compared by regrouping CH1, STH, and CH0 at three adjacent sites across the tailrace on the tailrace array (R_2) for dam-passed fish and then comparing survival rates among the regrouped fish. This approach may be problematic given that fish that died during dam passage could be detected and regrouped on a tailrace node even though they would have very little chance of being detected on downstream survival detection arrays. Fish were also regrouped, by run, at five adjacent sites for reference release fish released across the tailrace array (R_2, CR468) and tailwater array (R_3, CR422) and survival estimates were compared across the release sites at each array.

3.7.2 Estimation of Dam Passage Survival and Route-Specific Survivals

Maximum likelihood estimation was used to estimate dam passage survival at MCN based on the VPR design. The capture histories from all the replicate releases, both daytime and nighttime, were pooled to produce the estimate of dam passage survival. A joint likelihood model was constructed of a product multinomial with separate multinomial distributions describing the capture histories of the separate release groups (i.e., V_1, R_2, and R_3).

The joint likelihood model used for analyzing the three release groups was initially fully parameterized. Each of the three releases was allowed to have unique survival and detection parameters. If precision was adequate with the fully parameterized model (i.e., $SE \le 0.015$), no further modeling was performed. If initial precision was inadequate, then likelihood ratio tests were used to assess the homogeneity of parameters across release groups to identify the best parsimonious model to describe the capture-history data. This approach was used to help preserve the precision and robustness of the survival results. All calculations were performed using Program ATLAS (Active Tag-Life Survival; http://www.cbr.washington.edu/paramest/atlas/).

Dam passage survival was estimated by the function

$$\hat{S}_{\text{Dam}} = \frac{\hat{S}_1}{\left(\dfrac{\hat{S}_2}{\hat{S}_3}\right)} = \frac{\hat{S}_1 \cdot \hat{S}_3}{\hat{S}_2} \tag{3.11}$$

where $\hat{S}_i$ is the AMT-life-corrected survival estimate for the ith release group $(i = 1,\ldots,3)$. The variance of $\hat{S}_{\text{Dam}}$ was estimated in a two-step process that incorporated both the uncertainty in the AMT-life corrections and the release-recapture processes.

The location of this paired-release procedure was based on the premise that the tailrace BRZ demarks the point below which tailrace conditions have no influence on fish survival or travel times. At MCN, the actual tailrace BRZ is approximately 2 rkm upstream of R_2, even though throughout this report we refer to BRZ-to-BRZ survival as forebay to tailrace (R_2).

The 3D hydrophone array in the MCN forebay was used to identify fish known to have passed through the spillway, powerhouse, and TSWs (Spill Bays 19 and 20). Smolts known to have passed through the various routes at MCN were detected by JSATS receivers on downstream arrays to obtain their capture histories. To estimate survival, the number of smolts passing by various routes must be quantified, as follows:

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

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

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

$$RS_{\mathrm{SP/PH}} = \frac{\left(\dfrac{n_{\mathrm{SP}}}{R_{\mathrm{SP}}}\right)}{\left(\dfrac{n_{\mathrm{PH}}}{R_{\mathrm{PH}}}\right)}. \qquad (3.12)$$

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

$$\widehat{\mathrm{Var}}\left(\widehat{RS}_{\mathrm{SP/PH}}\right) = \widehat{RS}^{2}_{\mathrm{SP/PH}}\left[\frac{1}{n_{\mathrm{PH}}} - \frac{1}{R_{\mathrm{PH}}} + \frac{1}{n_{\mathrm{SP}}} - \frac{1}{R_{\mathrm{SP}}}\right]. \qquad (3.13)$$

The estimators of relative survival rates for the other three routes are analogous to Equation (3.12) and their variances are analogous to Equation (3.13).

Using the smolts known to have passed through a specific route at the dam, absolute survival rates from the dam entrance to the tailrace release location were estimated using a VPR 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 VPR Cormack-Jolly-Seber algorithms in program ATLAS (Lady et al. 2012).

3.7.3 Forebay-to-Tailrace Survival

The same VPR methods used to estimate dam passage were also used to estimate forebay-to-tailrace survival. The only distinction was the virtual-release group was composed of fish known to have arrived alive at the forebay array (rkm 472) of MCN instead of at the dam-face array.

3.7.4 Estimation of Travel Times

Travel times associated with forebay residence time and tailrace egress were estimated using arithmetic averages as specified in the Fish Accords, i.e.,

$$\bar{t} = \frac{\sum_{i=1}^{n} t_i}{n}, \tag{3.14}$$

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

$$\widehat{\mathrm{Var}}(\bar{t}) = \frac{\sum_{i=1}^{n} (t_i - \bar{t})^2}{n(n-1)}, \tag{3.15}$$

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

The estimated tailrace egress time was based on the time from the last detection of a fish at the cabled array at the dam face at MCN to the last detection at the tailrace array 2 km downstream of the dam (rkm 468). The estimated forebay residence times were based on the time from the first detection at the MCN forebay array, 2 km above the dam, to the last detection at the cabled array on the MCN dam-face. Project passage time was estimated as the difference from the time of first detection on the forebay array to the time of last detection on the tailrace array.

3.7.5 Estimation of Passage Efficiencies

Spill passage efficiency was estimated by the fraction

$$\widehat{\mathrm{SPE}} = \frac{\hat{N}_{SP} + \hat{N}_{TSW}}{\hat{N}_{SP} + \hat{N}_{TSW} + \hat{N}_{TUR} + \hat{N}_{JBS} + \hat{N}_{AL}}, \tag{3.16}$$

where $\hat{N}_i$ is the estimated abundance of fish implanted with AMT through the *i*th route (i = spill [SP], temporary spillway weir [TSW], turbines [TUR], juvenile bypass system [JBS], and adult ladder [AL]). The double-detection array was used to estimate absolute abundance (*N*) through a route using the single mark-recapture model (Seber 1982) independently at each route. Calculating the variance in stages, the variance of $\widehat{\mathrm{SPE}}$ was estimated as

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

Fish passage efficiency was estimated by the fraction

$$\widehat{\mathrm{FPE}} = \frac{\hat{N}_{SP} + \hat{N}_{TSW} + \hat{N}_{JBS} + \hat{N}_{AL}}{\hat{N}_{SP} + \hat{N}_{TSW} + \hat{N}_{JBS} + \hat{N}_{TUR} + \hat{N}_{AL}}, \tag{3.18}$$

Calculating the variance in stages, the variance of $\widehat{\mathrm{FPE}}$ was estimated as

$$\mathrm{Var}\left(\widehat{\mathrm{FPE}}\right) \doteq \frac{\widehat{\mathrm{FPE}}\left(1-\widehat{\mathrm{FPE}}\right)}{\sum_{i=1}^{4}\hat{N}_i} + \widehat{\mathrm{FPE}}^2\left(1-\widehat{\mathrm{FPE}}\right)^2 \cdot \left[\frac{\mathrm{Var}\left(\hat{N}_{SP}\right) + \mathrm{Var}\left(\hat{N}_{TSW}\right) + \mathrm{Var}\left(\hat{N}_{JBS}\right) + \mathrm{Var}\left(\hat{N}_{AL}\right)}{\left(\hat{N}_{SP} + \hat{N}_{TSW} + \hat{N}_{JBS} + \hat{N}_{AL}\right)^2} + \frac{\widehat{\mathrm{Var}}\left(\hat{N}_{TUR}\right)}{\hat{N}_{TUR}^2}\right]. \tag{3.19}$$

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

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

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

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

3.7.6 Estimation of Distributions

Based on detections on the dam-face array and 3D tracking results, the horizontal distribution of passage of each stock of fish at MCN 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 smolts within 75 m of the dam.

For a broader picture of fish behavior in the forebay, the horizontal distribution of smolts detected on the forebay entrance array 2 km upstream of MCN was compared with the distribution of smolt passage at the dam. Smolt detections on the forebay array were assigned to horizontal blocks corresponding to locations upstream of dam structures, from south to north: PH1-7 = powerhouse units 1 to 7; PH8-14 = powerhouse units 8 to 14; SW22-17 = Spill Bays 22-17; SW16–1 = Spill Bays 16-1. Passage locations also were grouped into blocks of routes with the same names used to describe smolt arrivals. This approach allowed for examination of smolt behavioral response to the dam by their avoidance or selection of passage route blocks. Similar arrival and passage distributions would suggest that smolt responses to forebay conditions and operations were limited, whereas substantial shifts in those distributions would indicate that smolts were responding to forebay conditions or operations by selecting preferred blocks of routes.

Vertical distributions of CH1, CH0, and STH upon approach to MCN can be useful in determining the effectiveness of a surface-flow outlet for entraining juvenile salmonids in its flow field. Assigning a depth of forebay travel from approximately 100 m upstream of the dam face to the near field of the dam face at MCN (<5 m) is accomplished using 3D tracking. All references in this report to vertical distributions are related to the depth of the hydrophone located on the southern-most turbine unit pier-nose on the powerhouse (F02_P01S). This hydrophone was located at elevation 99.8 m above MSL, which was 3.5 m deeper than the average spring and summer pool elevation of 103.3 m above MSL.

4.0 Results – Environmental Conditions

Environmental conditions include river discharge, water temperature, dissolved gas, and spill conditions in the Columbia River at MCN. Unit discharge rates, forebay elevation, and spill conditions were provided by the MCN project on a weekly basis. Temperatures, dissolved gas, and any historical data were downloaded from the UW DART website (http://www.cbr.washington.edu/dart).

4.1 River Discharge and Temperature

The daily total discharge from MCN for the spring season (27 April–30 May 2012) ranged from 295 kcfs to 398.8 kcfs and averaged 354.1 kcfs. Daily total discharges were slightly higher in the summer season (14 June–16 July 2012), fluctuating between 308.3 kcfs to 414.4 kcfs and averaging 355.6 kcfs. For the duration of the study season the daily total discharges from MCN were above the 10-year average except for the last days of May and first days of June (Figure 4.1). River discharge in the Columbia River was above the 70-year average for the entire study period. The 70-year flow average at TDA was plotted against discharge in 2012 at TDA for Comparison (flows at TDA are slightly higher than MCN but proportionally similar) (Figure 4.2).

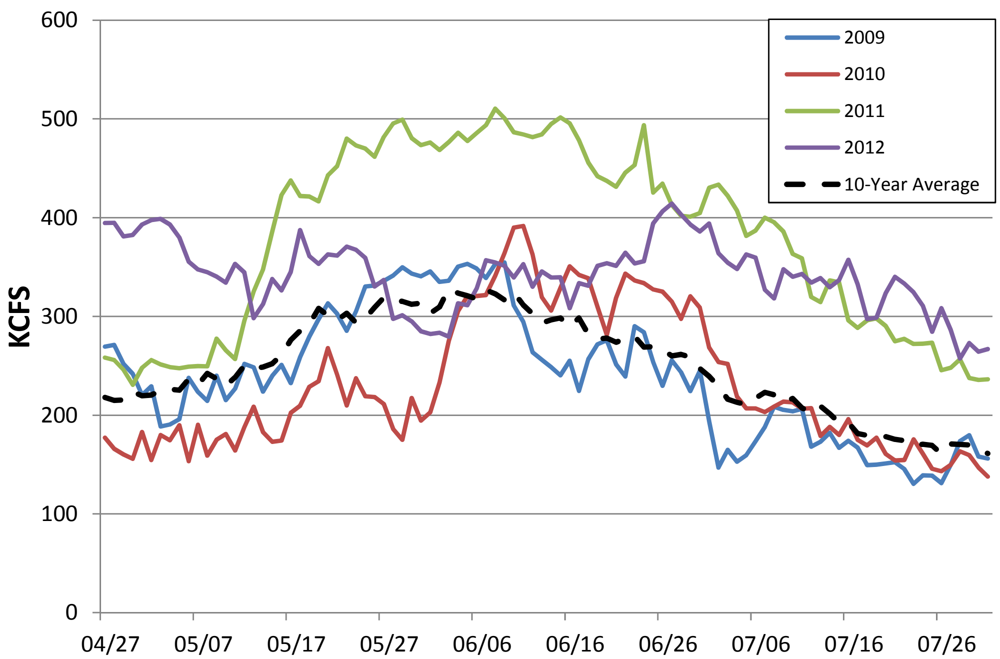


Figure 4.1. Average Daily Water Discharge (kcfs) from MCN During the 2012 Study and the Preceding 10-year Average (2002−2012)

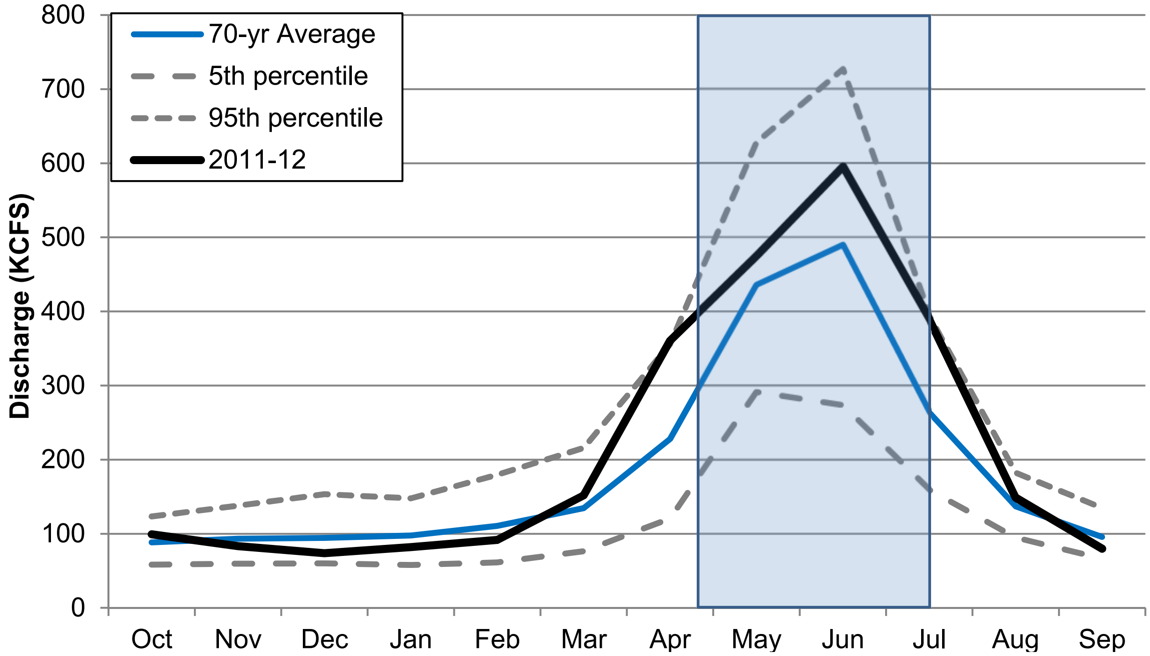


Figure 4.2. 70-year Average, 5th and 95th Percentile Discharge (kcfs) at TDA (1942-2011) and Average Discharge from October 2011-September 2012 at TDA. The blue box identifies the duration of the field season.

The daily average water temperature for the first day of the spring 2012 study period started at 10.5°C, 0.3°C above the 10-year average (Figure 4.3). This trend continued 5 d before the water temperature dropped below the 10-year average for nearly 2 weeks, not surpassing the average again until 14 May. Similar fluctuations continued throughout the study period, with the greatest deviation from the 10-year average occurring on 1 July, when the temperature was 2.39°C below the 10-year average. Mean water temperature for the spring 2012 study period was 11.7°C; ranging from 9.6°C to 13.4°C. The summer water temperature ranged from 14.0°C to 17.8°; the mean was 15.7°C.

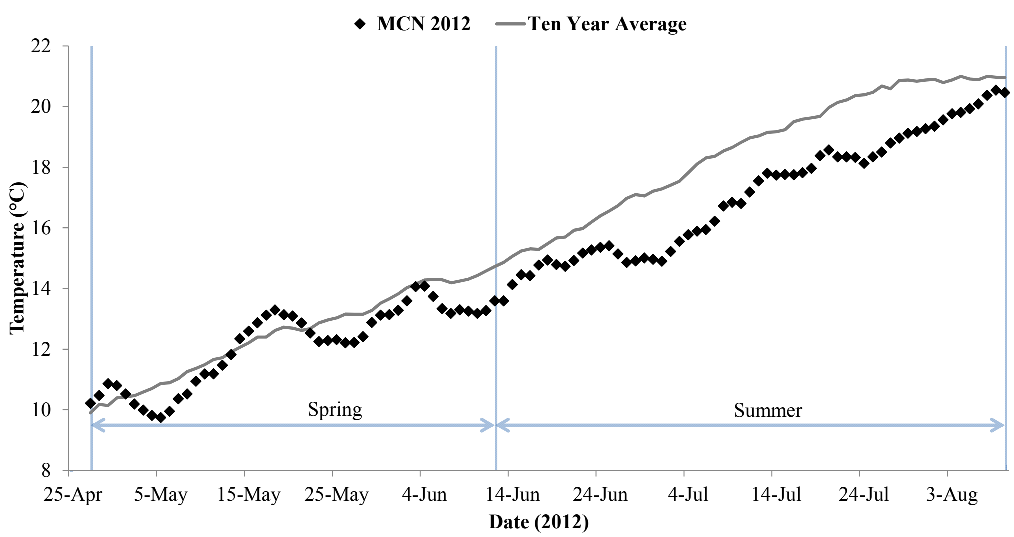


Figure 4.3. MCN Average Daily Water Temperature for the 2012 Field Season and for the Preceding 10-year Period

4.2 Spill Conditions

Percent spill during the spring season (27 April–30 May, 2012) ranged from 41.1% to 60.8%, and averaged 50.9%, exceeding the 40% ± 5% spill target for the entire spring study period (Figure 4.4). During the summer study period (14 June–16 July, 2012) percent spill ranged from 52.1% to 73.2% and averaged 61.6%, exceeding the 50% ± 5% spill target for the entire summer study period. Therefore, survival was estimated season-wide under prevailing conditions with no attempt to identify short periods of target conditions. During the greatest percent spill periods turbine flows were reduced to roughly two-thirds of normal operations.

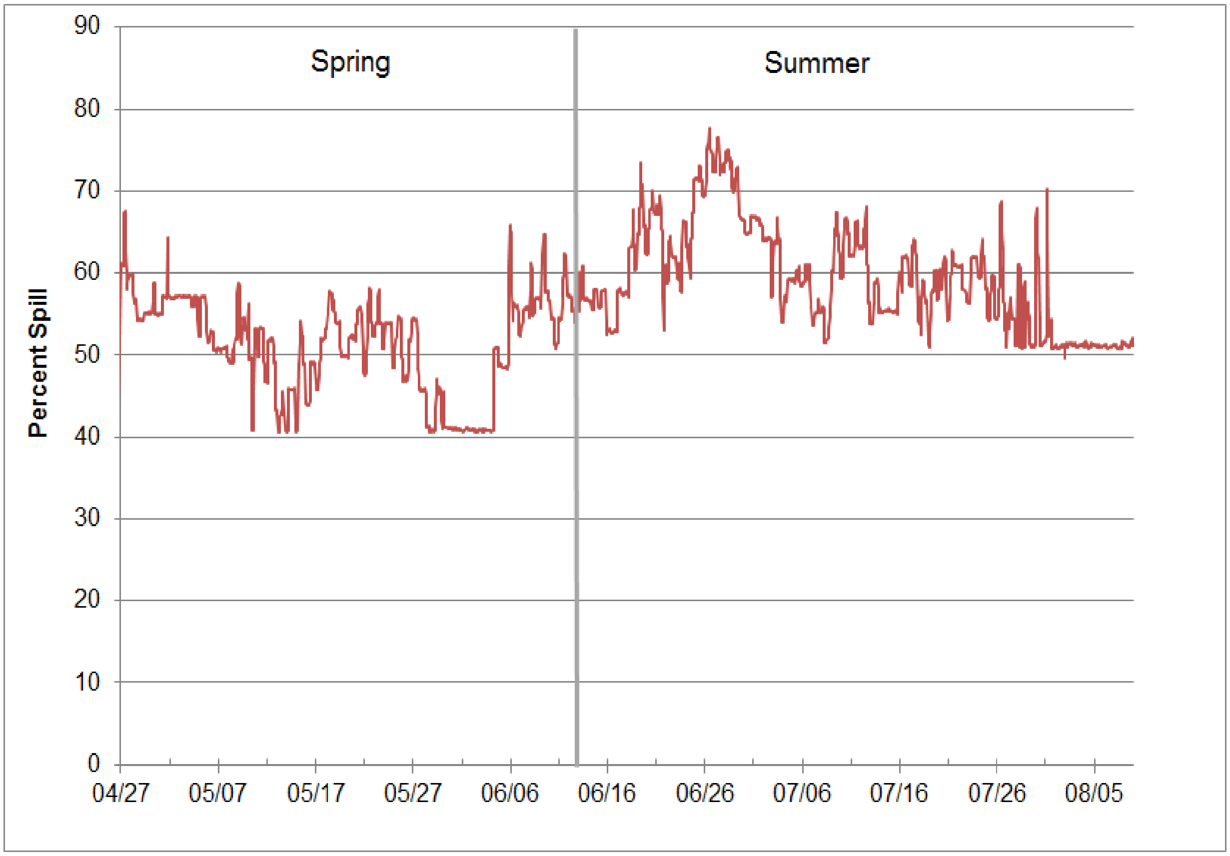


Figure 4.4. The Percent Spill by Study Season at MCN

5.0 Results – Fish Collection and Tagging

The total number of fish handled by PNNL in spring and summer 2012 and the counts and percentages of fish by handling category are listed in Table 5.1. During the study, 29,645 CH1, STH, and CH0 were handled.

Table 5.1. Total Number of Fish Handled by PNNL Staff During Spring and Summer 2012 and Fish Counts for Several Handling Categories

	CH1		STH		CH0	
Handling Category	N	Percent	N	Percent	N	Percent
Retained for Tagging	6555	96.3	6515	93.0	15,328	96.8
Non-Candidate Based on Condition	253	3.7	494	7.0	500	3.2
Total Handled	6808		7009		15,828	

Staff recorded fish excluded from surgeries by totaling observed maladies (Table 5.2). Post-implantation mortalities were low for each run of fish in 2012 (CH1 = 0.27%; STH = 0.02%; CH0=0.18%).

Table 5.2. Comparison of JDA SMF to PNNL Condition Data During Spring and Summer Studies at McNary Dam, 2012

	% CH1		% STH		% CH0	
Malady[a]	JDA SMF	PNNL	JDA SMF	PNNL	JDA SMF	PNNL
Descaling >20%	2.4	0.9	3.6	1.9	1.2	0.9
Diseases	1.1	1.4	3.9	4.8	1.0	1.8
Damage/Injury	7.0	6.8	11.1	6.8	4.6	3.3
Skeletal Deformity	0.8	0.3	0.7	0.3	0.3	0.0
Fish Sampled	1892	7041	3169	7309	3907	16,331

(a) Each species averaged >1 malady per fish; 11.5% for CH1, 15.9% for STH, and 10.8% for CH0.
CH1 = yearling Chinook salmon, STH = juvenile steelhead, CH0 = subyearling Chinook salmon.

6.0 Results – Yearling Chinook Salmon

This section contains estimates of survival, travel times, passage efficiencies, and both vertical and horizontal approach distributions for CH1 at MCN during spring 2012. Appendices (A−G) provide further information about fish condition (A), assessment of survival model assumptions (B), fish tagging and release tables (C), hydrophone and autonomous node locations (D), capture histories (E), detection and survival probabilities (F), and array performance (G).

Survival model assumptions were assessed to ensure that none of the assumptions of the survival model were violated. Tests of assumptions are detailed in Appendix B verifying that no survival model assumptions were violated, thereby allowing estimation of survival rates for CH1.

6.1 Dam Passage Survival Estimates

Dam passage survival was estimated using the VPR model. A total of 1,399 CH1 were released at CR503 (R_1) and regrouped at the MCN dam-face array (CR470) to create a virtual-release group (V_1). Estimated survival of V_1 fish that passed through the dam, 2 km of the tailrace, and 46 km of the tailwater ($\hat{S}_1$) was divided by the ratio of paired-reference-release-survival estimates $(\hat{S}_2 / \hat{S}_3)$, which accounts for survival in the 46-km tailwater portion between the tailrace (CR468) and Crow Butte State Park (CR422) and leaves an estimate of dam passage survival from the dam face to end of the tailrace 2 km downstream. The survival estimate for 46 km of tailwater $(\hat{S}_2 / \hat{S}_3)$ was based on paired releases of 1,198 CH1 at CR468 (R_2) and 1,200 at CR22 (R_3). Estimated dam passage survival for CH1 from the MCN dam face to tailrace array was

$$\hat{S}_{\text{Dam}} = \frac{0.9171}{\left(\frac{0.9050}{0.9489}\right)} = \frac{0.9171}{0.9537} = 0.9616 \tag{6.1}$$

with a standard error of $\widehat{\text{SE}} = 0.0140$. Dam passage survival exceeded the BiOp criterion of >96% survival with a standard error estimate of ≤ 0.015. Forebay-to-tailrace survival (BRZ-to-BRZ) was 0.9595 ± 0.0140 (Table 6.1).

Route-specific survival rates for CH1 were highest for the spillway TSWs, the spillway overall, and non-TSW spill bays and noticeably lower for the turbines and JBS (Table 6.2).

Table 6.1. Dam Passage and Forebay-to-Tailrace Survival Estimates for CH1 at MCN in 2012

Reach	Survival Estimate	Standard Error
Dam Passage Survival (CR470 to CR422)	0.9616	0.0140
Forebay-to-Tailrace Survival (CR472 to CR468)	0.9595	0.0140

Table 6.2. Virtual/Paired and Single Release Survival Estimates for CH1 at MCN in 2012

	Paired Release		Single Release		
Route	Estimate	Standard Error	Estimate	Standard Error	n
Spillway	0.9712	0.0146	0.9263	0.0084	984
TSW	0.9758	0.0279	0.9307	0.0242	113
Non-TSW	0.9706	0.0150	0.9257	0.0090	871
JBS	0.9355	0.0213	0.8922	0.0173	328
Turbines	0.9552	0.0470	0.9110	0.0434	44

TSW = Temporary Spillway Weir; JBS = Juvenile Bypass System

6.2 Travel Times

There were 1,361 tagged CH1 detected on the forebay array, with a median residence time of approximately 1.8 h (CR472 to CR 470; Table 6.3). Median egress time was about 0.41 h from the dam face (CR470) to the last tailrace array 2 km downstream of MCN (CR468). Mean travel times also are presented in Table 6.3, but those estimates are influenced by a few fish that experienced long delays.

Table 6.3. Estimated Mean and Median Forebay Residence and Tailrace Egress Times for CH1 at McNary Dam in 2012

Route	Median (h)	Mean (h)	Standard Error	n
Forebay (CR472 to CR470)	1.76	3.01	0.305	1361
MCN egress time (CR470 to CR468)	0.41	2.87	0.329	1336

6.3 Passage Efficiencies

Project passage metrics for CH1 were estimated for the entire season (Table 6.4) and were compared for day and night periods (Table 6.5). Relative to the entire dam, 97% of tagged CH1 passed MCN through non-turbine passage routes (Table 6.4). Of the CH1 passing by non-turbine routes, 73% passed through the spillway and 11.5% of those fish used the two TSWs installed in Spill Bays 19 and 20. FGE was 88.2% and juvenile bypass system efficiency (JBSE) relative to the dam was 24%.

Table 6.4. Passage Efficiencies for Yearling Chinook Salmon at MCN in 2012

Metric	Estimate	SE
FPE || Dam*	0.9676	0.0048
SPE || Dam*	0.7246	0.0121
TSW efficiency || Dam*	0.0832	0.0075
TSW efficiency || Spillway	0.1148	0.0102
FGE (powerhouse screen efficiency)	0.8820	0.0167
JBSE || Dam*	0.2423	0.0116

*If dam route is included, proportions will not add to 1.
FPE = fish passage efficiency; JBSE = juvenile bypass system efficiency; SPE = spill passage efficiency; TSW = temporary spillway weir.

Data were analyzed to determine any diel differences in survival for CH1. Daytime was from 0600 to 2200 hours; nighttime was from 2200 to 0600 hours. Diel differences in overall dam and forebay to tailrace survival of CH1 passing MCN did not appear to differ significantly based upon the overlap of 95% confidence intervals (Table 6.5).

Table 6.5. Estimated Diel Project and Forebay-to-tailrace Survival for CH1 at MCN in 2012

Survival Reach	Day			Night		
	Estimate	SE	n	Estimate	SE	n
Dam Passage	0.9587	0.0156	791	0.9655	0.0167	569
Forebay Array to Tailrace	0.9568	0.0156	807	0.9568	0.0156	807

SPE was higher during the day (76%) than it was at night (68%), whereas JBSE was higher at night (28%) than it was during the day (21%). All other passage metrics did not differ between day and night times (Table 6.6).

Table 6.6. Comparison of Season-wide Diel Passage Efficiencies at MCN in Spring 2012. Significant difference (*) is related to the 95% confidence intervals.

	Day		Night		
Metric	Estimate	SE	Estimate	SE	Sig. diff
FPE || Dam[a]	0.9682	0.0063	0.9667	0.0075	
SPE || Dam[a]	0.7560	0.0153	0.6825	0.0195	*
TSW efficiency || Dam[a]	0.0775	0.0095	0.0912	0.0121	
TSW efficiency || Spillway	0.1025	0.0124	0.1337	0.0173	
FGE (powerhouse screen efficiency)	0.8698	0.0243	0.8950	0.0228	
JBSE|| Dam[a]	0.2122	0.0146	0.2842	0.0189	*

(a) If dam route is included, proportions will not add to 1.
FPE = fish passage efficiency; SPE = spill passage efficiency; TSW = temporary spillway weir; JBS = juvenile bypass system efficiency

6.4 Fish Passage Distributions

Horizontal distribution, forebay approach, and forebay vertical distributions of CH1 at MCN in spring 2012 are summarized in the following sections.

6.4.1 Horizontal Distribution

More than 72% of the CH1 passing MCN during spring 2012 passed by way of the spillway, including both the TSW and non-TSW routes (Table 6.7). The TSW in Spill Bay 20 passed the largest percentage of fish at the spillway followed by Spill Bay 21 (Figure 6.1). The powerhouse, including both the JBS and turbine routes, passed 27.4% of all CH1. The JBS-passed CH1 composed 24.2% of all CH1 passing MCN. Distribution of CH1 passing at the powerhouse was higher toward the north, and turbine Unit 11 passed the highest percentage of fish (Figure 6.2).

Table 6.7. Percent Passage of CH1 by Route Relative to Total Passage of CH1 at MCN in Spring 2012. One fish (0.1 %) passed through the south fish ladder.

Parameter	Yearling Chinook Salmon
Percentage of total passage by TSW route (2 bays)	8.3
Percentage of total passage at spillway by non-TSW route (20 bays)	64.2
Percentage of total passage by JBS route	24.2
Percentage of total passage by turbine route	3.2

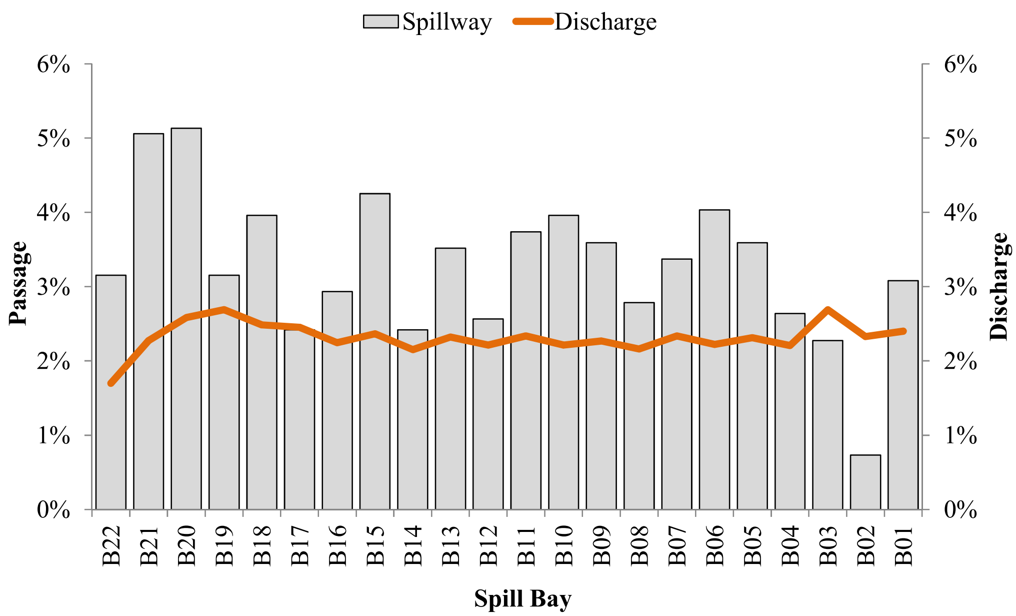


Figure 6.1. Horizontal Distribution of CH1 Passage at the Spillway of MCN in 2012

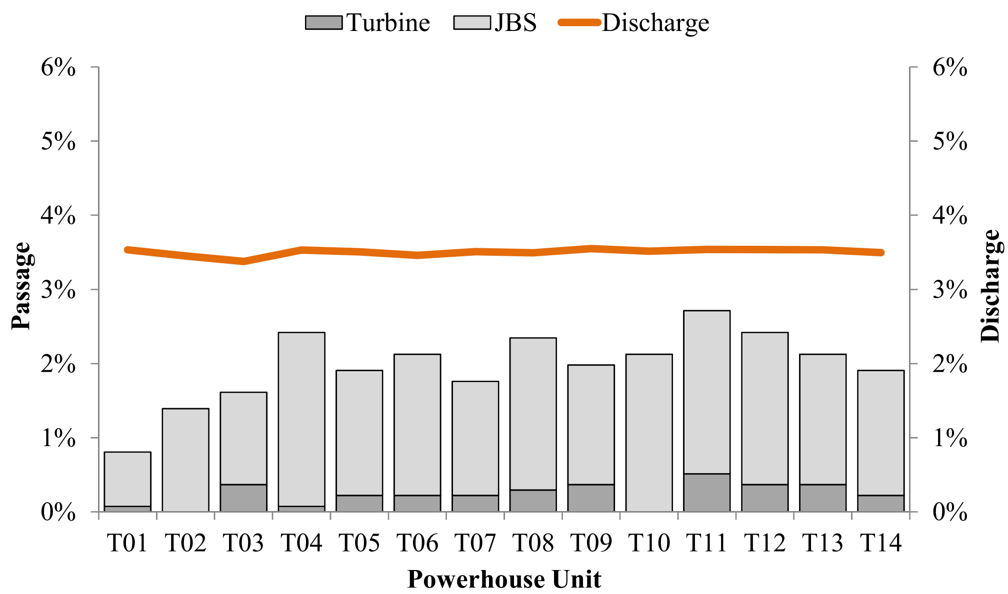


Figure 6.2. Horizontal Distribution of Turbine and JBS Passage for CH1 at MCN in 2012

6.4.2 Forebay Approach Distribution

Forebay approach distribution for CH1 based on time of first detection on the cabled array upstream of the dam to final detection at the dam showed that a majority of fish (64%) approached and passed through the spillway (Figure 6.3). More than 27% of fish that approached the powerhouse passed through the powerhouse. Diel approach distribution showed similar trends with more than 60% of all CH1 approaching and passing through the spillway (Figure 6.3). A slightly higher percentage of CH1 approached and passed through the powerhouse at night. Fish were slightly less likely to transfer between the powerhouse and the spillway at nighttime than they were during the daytime.

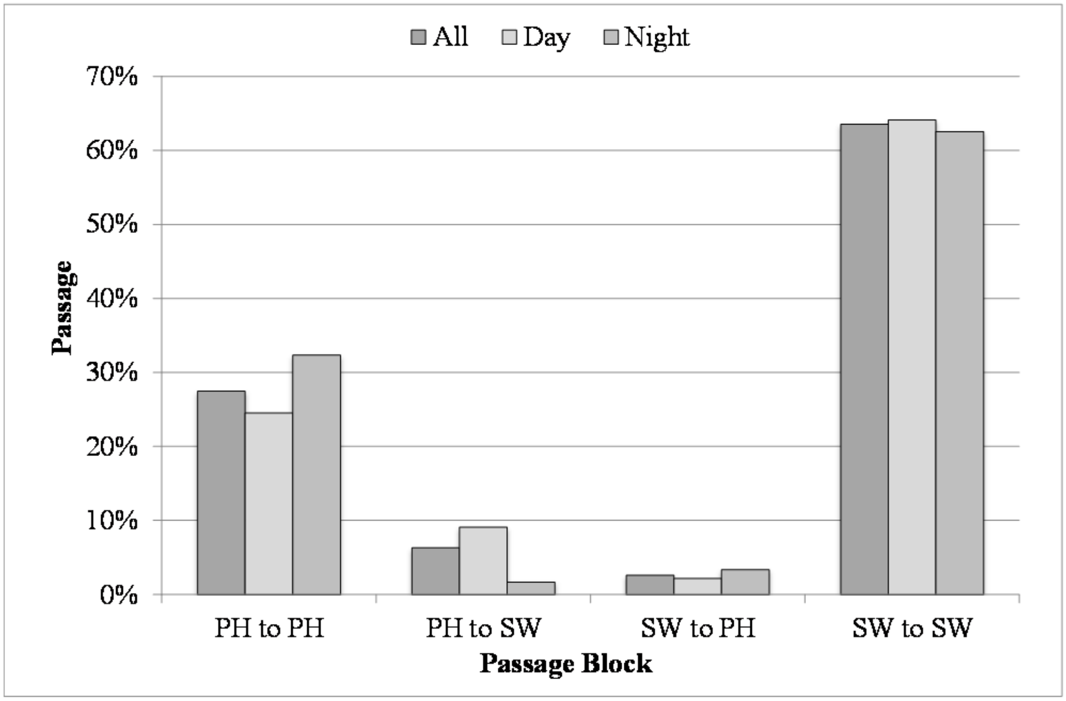


Figure 6.3. CH1 Approach and Passage Behavior Patterns at MCN During Day and Night Periods in Spring 2012

6.4.3 Forebay Vertical Distribution

Forebay vertical distribution, as indicated by the median depths of last detection by distance from the dam where fish passed, showed that as CH1 approached the dam most fish were within 6 m of the water surface (Figure 6.4). Only fish passing through the powerhouse showed a depth increase in the last few meters before passing. Vertical distribution patterns were similar between day and night; however, CH1 were more surface-oriented at night compared to day.

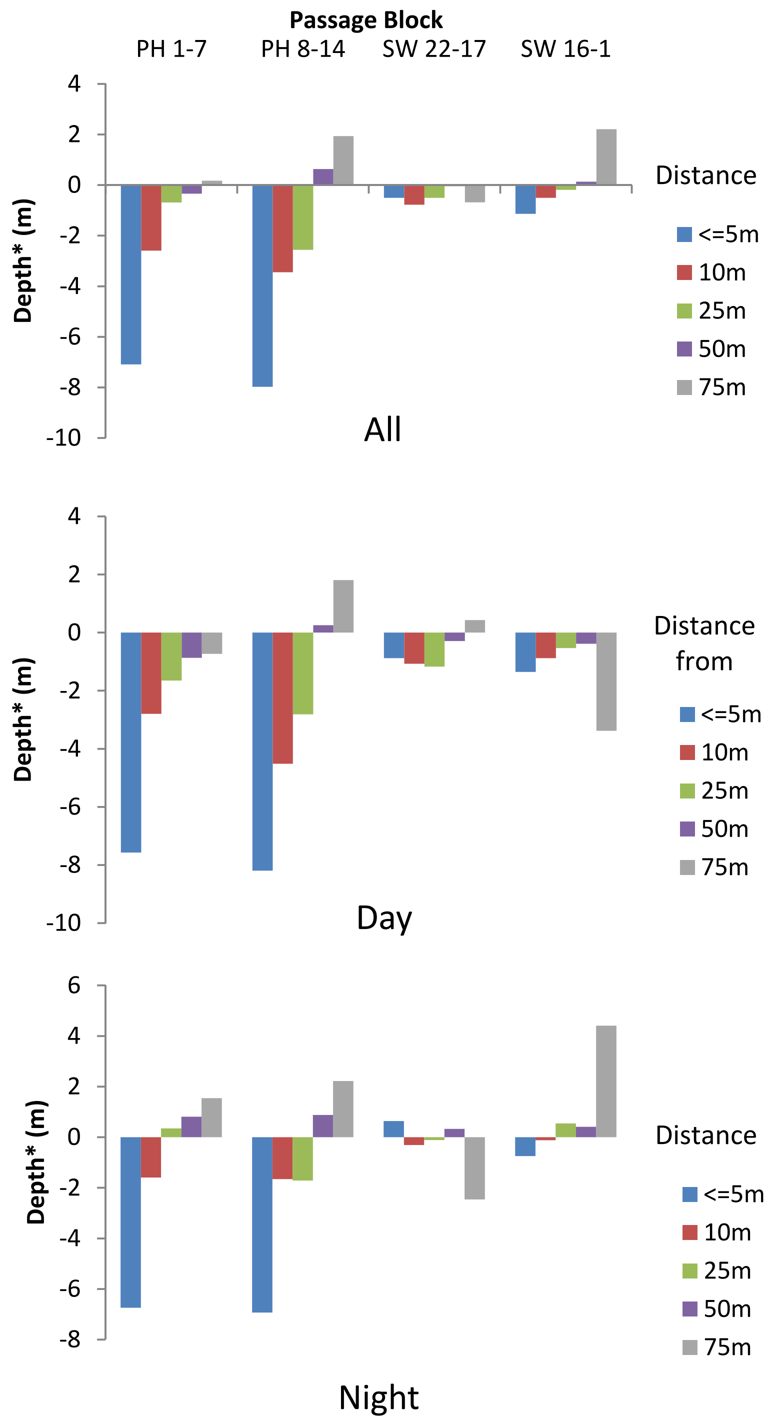


Figure 6.4. Median Forebay Vertical Distribution of CH1 Tagged with AMTs as Indicated by the Median Depth of the Last Detection by Distance from MCN During 2012. Depth (*) is relative to the elevation of shallow hydrophone F02_P01S at the powerhouse, at elevation 99.8 m above MSL. This was 3.5 m deeper than the average spring and summer pool elevation of 103.3 m above MSL. TSW passed fish are included in this vertical distribution.

7.0 Results – Juvenile Steelhead

This section contains estimates of survival, travel times, passage efficiencies, and both vertical and horizontal approach distributions for STH at MCN during spring 2012. Appendices (A−G) provide information about fish condition (A), assessment of survival model assumptions (B), fish tagging and release tables (C), hydrophone and autonomous node locations (D), capture histories (E), detection and survival probabilities (F), and array performance (G).

Survival model assumptions were assessed to ensure that none of the assumptions of the survival model were violated. Tests of assumptions are detailed in Appendix B verifying that no survival model assumptions were violated, thereby allowing estimation of survival rates for STH.

7.1 Dam Passage Survival Estimates

Dam passage survival was estimated using the VPR model for 1,400 STH released at Port Kelley, Washington (CR503 [R_1]), and regrouped at the MCN forebay entrance array (CR472) to create the MCN virtual-release group (V_1). Survival was estimated for the reach from the dam to the downstream edge of hydraulic influence in the MCN tailrace (CR468; R_2) by dividing estimated survival of fish that passed the dam, tailrace, and 46 km of tailwater down to Crow Butte State Park (CR422) by the ratio of the tailwater survivals for fish released in the MCN tailrace (CR468; n = 1,199) and near Crow Butte State Park, Washington (CR422; n = 1198), after those fish traveled downstream to Celilo, Oregon (CR325). Dam passage survival was

$$\hat{S}_{\text{Dam}} = \frac{\hat{S}_1}{\left(\frac{\hat{S}_2}{\hat{S}_3}\right)} = \frac{0.9136}{\left(\frac{0.8282}{0.8982}\right)} = \frac{0.9136}{0.9221} = 0.9908 \tag{7.1}$$

where $\hat{S}_1$ = 0.9136 (0.0078) [Dam + 2 km of tailrace + 46 km of tailwater]
$\hat{S}_2$ = 0.8286 (0.0109) [143 km reach from CR468 to CR325]
$\hat{S}_3$ = 0.8982 (0.0087) [97 km reach from CR422 to CR325].

The standard error on dam-passage survival was 0.0183. The point estimate for survival satisfied the BiOp requirement for $\hat{S}_{\text{Dam}} \geq 0.96$, and although the standard error exceeded 0.015, the point estimate not only exceeded 0.96 but was significantly greater than 0.9600, according to a one-tailed z-test (P [Z ≥ 1.6831] = 0.0462), which is a much more stringent requirement. The lower 95% confidence interval of $\hat{S}_{\text{Dam}}$ (0.9549) also exceeded 0.93 and therefore met secondary criteria in the 2012 White Paper (USACE 2012a) describing the FCRPS juvenile dam passage performance standard and metrics. Dam passage and forebay-to-tailrace (BRZ-to-BRZ) survival estimates are presented in Table 7.1.

Table 7.1. Estimated Dam Passage and Forebay-to-tailrace Survival Estimates for STH at MCN in 2012

Reach	Survival Estimate	SE
Dam Passage Survival (CR470 to CR422)	0.9908	0.0183
Forebay-to-Tailrace Survival (CR472 to CR468)	0.9880	0.0183

With the exception of turbine passage (83%), all route-specific dam passage survival estimates for STH were more than 97%. Survival estimates and standard errors are presented in Table 7.2.

Table 7.2. Virtual/Paired and Single Release Survival Estimates for Steelhead at MCN in 2012

	Paired Release		Single Release		
Route	Estimate	Standard Error	Estimate	Standard Error	n
Spillway	0.994	0.019	0.9164	0.0084	1076
TSW	0.976	0.025	0.9003	0.0173	301
Non-TSW	1.001	0.019	0.9226	0.0096	775
JBS	1.015	0.026	0.9358	0.0179	187
Turbines	0.831	0.085	0.7667	0.0772	30

TSW = Temporary Spillway Weir; JBS = Juvenile Bypass System

7.2 Travel Times

There were 1,295 tagged juvenile STH detected on the forebay array, with a median residence time of approximately 1.8 h (CR472 to CR 470; Table 7.3). Median egress time was about 0.34 h from the dam face (CR470) to the last tailrace array 2 km downstream of MCN (CR468). Mean travel times also are presented in Table 7.3, but those estimates are biased high by a few fish that experienced protracted travel periods like some that traveled through the JBS. Median travel time for total project passage (CR472 to CR468) was approximately 2.3 h.

Table 7.3. Estimated Mean and Median Forebay Residence Time, Tailrace Egress Time, and Project Passage Time for STH at MCN in 2012

Route	Median (h)	Mean (h)	SE	n
Forebay (CR472 to CR470)	1.78	2.67	0.084	1295
MCN egress time (CR470 to CR468)	0.34	1.85	0.371	1269

7.3 Passage Efficiencies

Project passage metrics for juvenile STH were estimated for the entire season (Table 7.4) and were compared for day and night periods (Table 7.5). Relative to the entire dam, nearly 98% of tagged STH passed MCN through non-turbine passage routes (Table 7.4). Of the STH passing by non-turbine routes, 83% passed through the spillway and 28% of those fish used the two TSWs installed in Spill Bays 19 and 20. FGE was 86% and JBSE was approximately 15% (Table 7.4).

Table 7.4. Passage Efficiencies for STH at MCN in 2012

Metric	Estimate	SE
FPE || Dam*	0.9768	0.0042
SPE || Dam*	0.8315	0.0104
TSW efficiency || Dam*	0.2326	0.0117
TSW efficiency || Spillway	0.2797	0.0137
FGE (powerhouse screen efficiency)	0.8624	0.0233
JBSE || Dam*	0.1453	0.0098

*If dam route is included, proportions will not add to 1.
FPE = fish passage efficiency; JBSE = juvenile bypass system efficiency;
SPE = spill passage efficiency; TSW = temporary spillway weir.

Data were analyzed to determine any diel differences in survival for juvenile STH (Table 7.5). Daytime was from 0600 until 2200 hours; nighttime was from 2200 to 0600 hours. Diel differences in overall dam and forebay-to-tailrace survival of STH passing MCN did not appear to be significant based on overlapping 95% confidence intervals (i.e., SE × 1.96). However, the passage efficiency metrics appeared to show significant diel differences in route of passage for all but FGE. Highest estimated efficiencies were observed during daytime passage for all metrics except JBSE, which was higher during night (Table 7.6).

Table 7.5. Estimated Diel Project and Forebay-to-tailrace Survival for Juvenile Steelhead at McNary Dam in 2012

	Day			Night		
Survival Reach	Estimate	SE	n	Estimate	SE	n
Dam Passage	0.9777	0.0198	762	1.0095	0.0204	535
Forebay Array to Tailrace	0.9823	0.0195	828	0.9979	0.0212	476

Table 7.6. Comparison of STH Season-wide Diel Passage Efficiencies at MCN in Spring 2012. Significant difference (*) is related to the 95% confidence intervals.

	Day		Night		
Metric	Estimate	SE	Estimate	SE	Sig diff
FPE || Dam[(a)]	0.9957	0.0025	0.9547	0.0085	*
SPE || Dam[(a)]	0.9312	0.0096	0.7148	0.0185	*
TSW efficiency || Dam[(a)]	0.3610	0.0182	0.0822	0.0113	*
TSW efficiency || Spillway	0.3877	0.0191	0.1150	0.0155	*
FGE (powerhouse screen efficiency)	0.9375	0.0349	0.8412	0.0280	
JBSE|| Dam[(a)]	0.0645	0.0093	0.2399	0.0175	*

(a) If dam route is included, proportions will not add to 1.
FGE = fish guidance efficiency; FPE = fish passage efficiency; JBSE = juvenile bypass system efficiency;
SPE = spill passage efficiency; TSW = temporary spillway weir.

7.4 Fish Passage Distributions

Horizontal distribution, forebay approach, and forebay vertical distributions of juvenile STH at MCN in spring 2012 are summarized in the following sections.

7.4.1 Horizontal Distributions

More than 83% of the STH passing MCN passed by way of the spillway, including both the TSW and non-TSW bays (Table 7.7). Total discharge through each of the TSW bays was comparable to most other spill bays; however, each TSW bay passed proportionally higher numbers of STH than did individual non-TSW bays (Figure 7.1).

The powerhouse, including both the JBS and turbine routes, passed nearly 17% of all STH. Approximately 14.5% of all tagged juvenile STH passed MCN through the JBS. The proportion of STH passing into turbines 1, 2, and 14 at either end of the powerhouse was lower than proportions passing through other turbines (Figure 7.2).

Table 7.7. Percent Passage of STH by Route Relative to Total Passage of STH at MCN in 2012

Parameter	Steelhead	Mean / Bay
Percentage of total passage by TSW route (2 bays)	23.3	11.65
Percentage of total passage at spillway by non-TSW route (20 bays)	59.9	3.33
Percentage of total passage by JBS route	14.5	NA
Percentage of total passage by turbine route	2.3	NA

TSW = temporary spillway weir; JBS = juvenile bypass system.

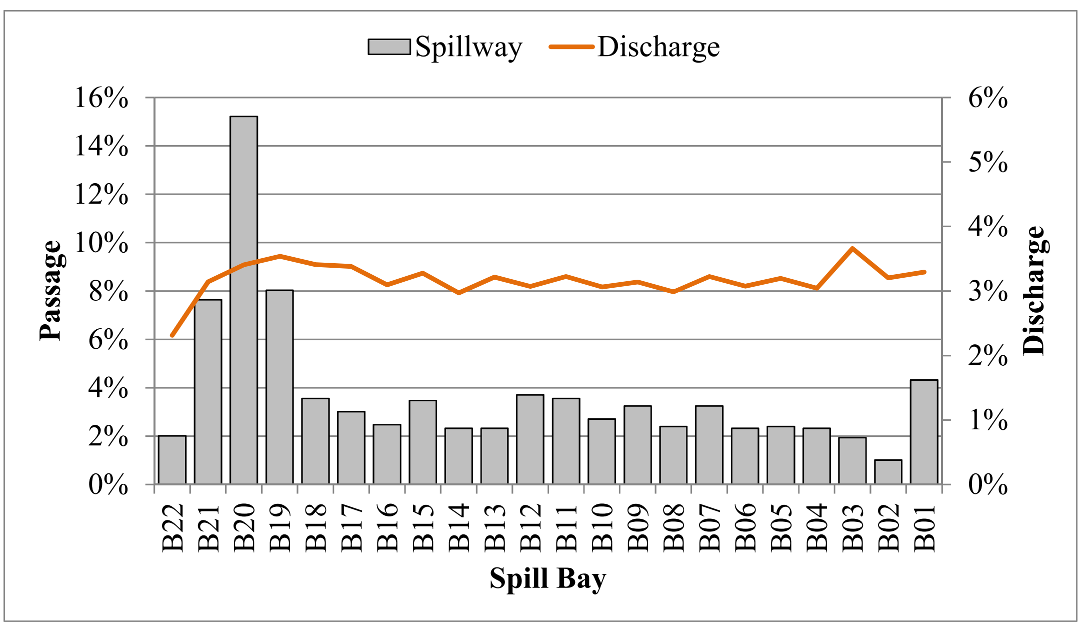


Figure 7.1. Horizontal Distribution of Juvenile STH Passage at the Spillway of MCN in 2012

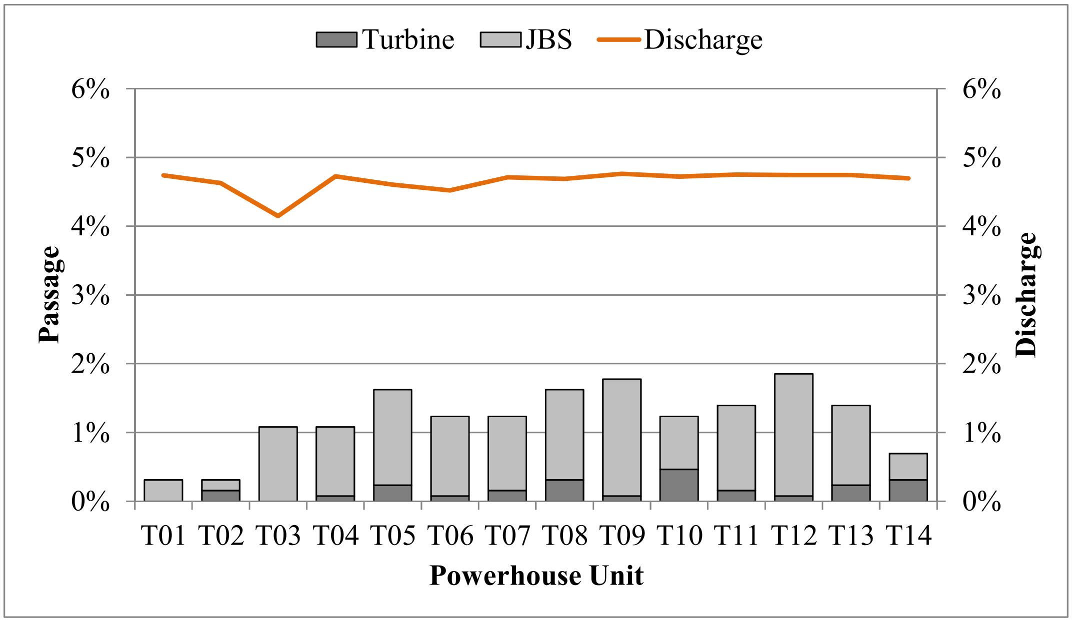


Figure 7.2. Horizontal Distribution of Passage for Juvenile STH at the MCN Powerhouse in 2012

7.4.2 Forebay Approach Distribution

Forebay approach distribution for juvenile STH based on time of first detection on the cabled array upstream of the dam to final detection at the dam showed that a majority of fish (59%) approached and passed through the spillway (Figure 7.3). More than 16% of the STH that approached the powerhouse passed through the powerhouse, while 22% approached within 100 m of the powerhouse before migrating to the spillway and passing there.

Diel approach distribution showed similar trends with nearly 60% of all juvenile STH approaching and passing through the spillway (Figure 7.3). A larger percentage (28%) of STH approached and passed the powerhouse at night, than during the day (8.6%); however, STH approached the powerhouse and passed at the spillway more frequently during the day than at night.

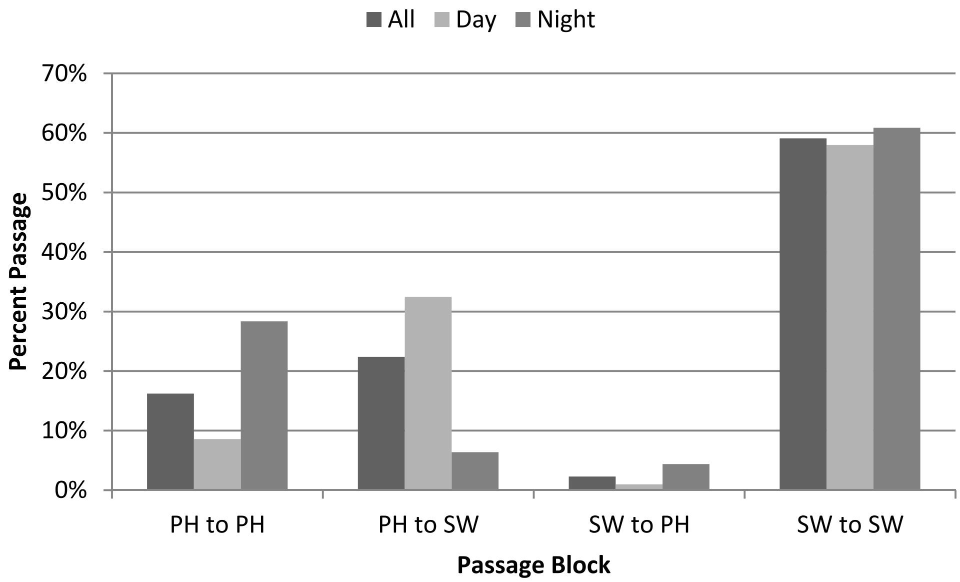


Figure 7.3. Juvenile STH Approach and Passage Behavior Patterns at MCN during Day and Night Periods in Spring 2012

7.4.3 Forebay Vertical Distribution

Forebay vertical distribution, as indicated by the median depths of last detection by distance from the dam where fish passed, showed a majority of the tagged STH were detected at a depth of <3 m in the water column in most locations (Figure 7.4). While it appears that STH approaching Spill Bays 1 to 16 detected at 75 m approached at much deeper depths, these results were likely spurious because of the small sample size (n = 10). The median depth was similar on approach to the spillway and the powerhouse, though powerhouse-passed fish predictably decreased rapidly in depth the last 5 m before passage. Vertical distributions were, in most cases, 2 to 3 m shallower during day than night (Figure 7.4).

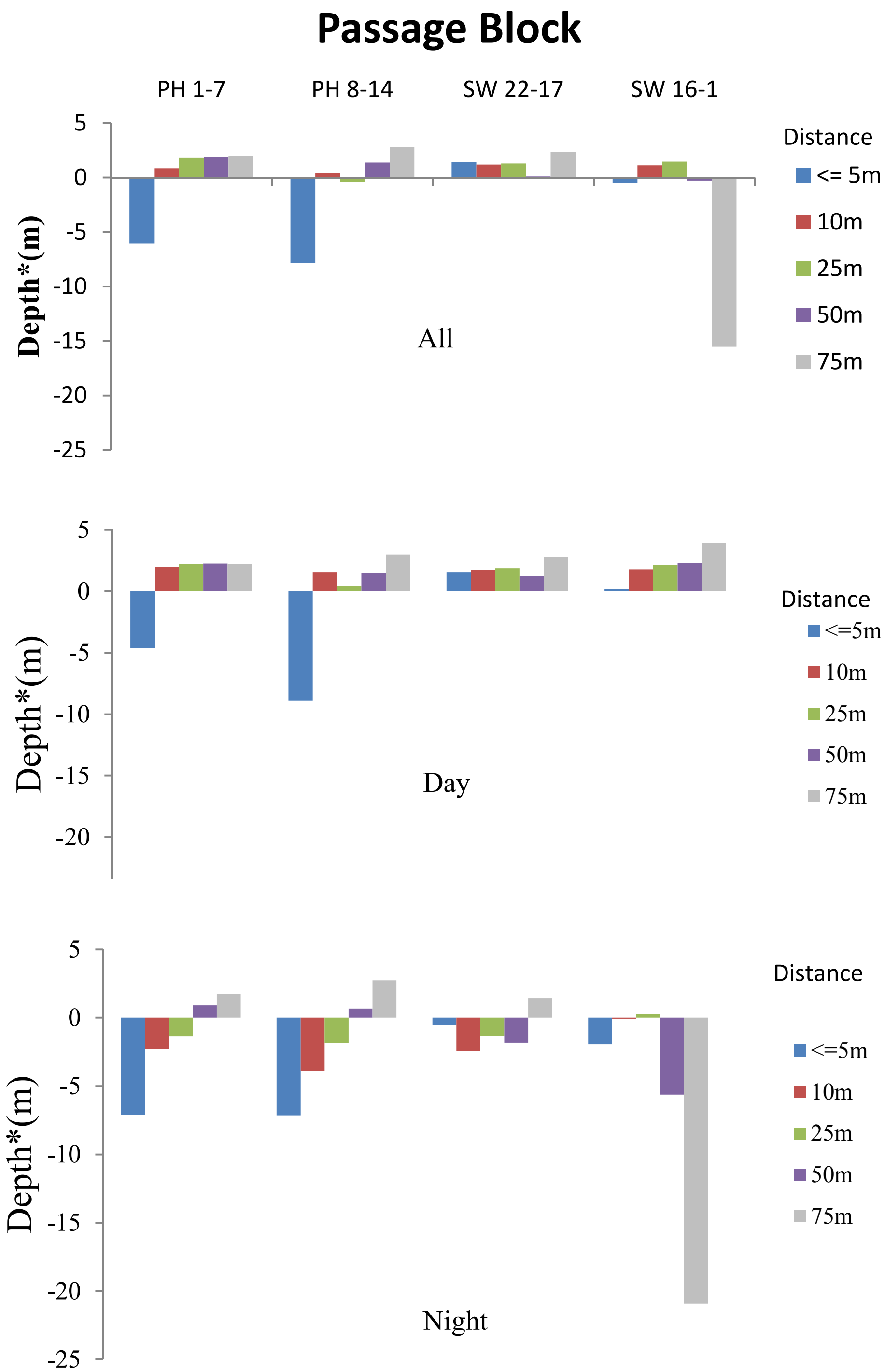


Figure 7.4. Median Forebay Vertical Distribution of STH Tagged with AMTs as Indicated by the Median Depth of the Last Detection by Distance from MCN during 2012. Depth (*) is relative to the elevation of shallow hydrophone F02_P01S at the powerhouse, at elevation 99.8 m above MSL. This was 3.5 m deeper than the average spring and summer pool elevation of 103.3 m above MSL. TSW passed fish are included in this vertical distribution.

8.0 Results – Subyearling Chinook Salmon

This section contains estimates of survival, travel times, passage efficiencies, and both vertical and horizontal approach distributions for CH0 at MCN during summer 2012. Appendices (A−G) provide information about fish condition (A), assessment of survival model assumptions (B), fish tagging and release tables (C), hydrophone and autonomous node locations (D), capture histories (E), detection and survival probabilities (F), and array performance (G).

Survival model assumptions were assessed to ensure that none of the assumptions of the survival model were violated. Tests of assumptions are detailed in Appendix B verifying that no survival model assumptions were violated, thereby allowing estimation of survival rates for CH0.

8.1 Survival Estimates

Dam passage survival was estimated using the VPR model. A total of 2,524 CH0 were released at CR503 (R_1) and regrouped at the MCN dam-face array (CR470) to create a virtual-release group (V_1). Estimated survival of V_1 fish that passed through the dam, 2 km of the tailrace, and 46 km of the tailwater ($\hat{S}_1$) was divided by the ratio of paired-reference-release-survival estimates $(\hat{S}_2 / \hat{S}_3)$, which accounts for survival in the 46-km tailwater portion between the tailrace (CR468) and Crow Butte State Park (CR422) and leaves an unbiased estimate of dam passage survival from the dam face to end of the tailrace 2 km downstream. The survival estimate for 46 km of tailwater $(\hat{S}_2 / \hat{S}_3)$ was based on paired releases of 1,993 CH0 at CR468 (R_2) and 1,984 at CR22 (R_3). Estimated dam passage survival for CH0 from the MCN dam face to tailrace array was

$$\hat{S}_{\text{Dam}} = \frac{\hat{S}_1}{\left(\frac{\hat{S}_2}{\hat{S}_3}\right)} = \frac{0.9149}{\left(\frac{0.8864}{0.9443}\right)} = \frac{0.9149}{0.9386} = 0.9747 \tag{8.1}$$

with an associated $\widehat{\text{SE}}$ of 0.0114. Dam passage survival exceeded the BiOp criterion of >93% survival with a standard error estimate of ≤1.5. Forebay-to-tailrace survival (BRZ-to-BRZ) survival and dam passage survival estimates are shown in Table 8.1.

Table 8.1. Estimated Dam Passage and Forebay-to-tailrace Survival Estimates for CH0 at MCN for 2012

Reach	Survival Estimate	SE
Dam Passage Survival (CR470 to CR349)	0.9747	0.0114
Forebay-to-Tailrace Survival (CR472 to CR349)	0.9729	0.0114

With the exception of the turbine with 88% survival, route-specific dam passage survival estimates for CH0 were greater than 98% for all routes, surpassing the BiOp criterion of >93% survival (Table 8.2). Standard error estimates were also within the precision standard of 0.015. The TSW was not operated during summer 2012 at MCN; therefore no data were acquired for that route.

Table 8.2. Virtual/Paired and Single Release Survival Estimates for CH0 at MCN in 2012

	Paired Release		Single Release		
Route	Estimate	Standard Error	Estimate	Standard Error	n
Spillway	0.9803	0.0118	0.9201	0.0062	1925
TSW	*	*	*	*	*
Non-TSW	*	*	*	*	*
JBS	1.0078	0.0171	0.9460	0.0131	308
Turbines	0.8806	0.0284	0.8265	0.0254	224

TSW = temporary spillway weir; JBS = juvenile bypass system
*TSWs were not operated during the summer season.

8.2 Travel Times

There were 2,464 tagged CH0 detected on the forebay array, with a median residence time of approximately 1.8 h (CR472 to CR 470; Table 8.3). Median egress time was about 0.39 h from the dam face (CR470) to the last tailrace array 2 km downstream of MCN (CR468). Mean travel times also are presented in Table 8.3, but those estimates are overly influenced by a few fish that experienced protracted travel periods. Median travel time for total project passage (CR472 to CR468) was approximately 2.25 h.

Table 8.3. Estimated Mean and Median Forebay Residence Time, Tailrace Egress Time, and Project Passage Time for CH0 at MCN in 2012

Route	Median (h)	Mean (h)	SE	n
Forebay (CR472 to CR470)	1.77	2.86	0.135	2464
MCN egress time (CR470 to CR468)	0.39	3.01	0.294	2404
Project passage time (CR472 to CR468)	2.25	5.86	0.328	2408

8.3 Passage Efficiencies

Project passage metrics for CH0 were estimated for the entire season (Table 8.4) and were compared for day and night periods (Table 8.5). Relative to the entire dam, 91% of tagged CH0 passed MCN through non-turbine passage routes (Table 8.4). SPE exceeded 78%, FGE was 58%, and JBSE was 12.5%.

Table 8.4. Passage Efficiencies for CH0 at MCN in 2012

Metric	Estimate	SE
FPE || Dam*	0.9085	0.0058
SPE || Dam*	0.7829	0.0083
TSW efficiency || Dam*	**	**
TSW efficiency || Spillway	**	**
FGE (powerhouse screen efficiency)	0.5779	0.0214
JBSE|| Dam*	0.1252	0.0067

* If dam route is included, proportions will not add to 1.
FPE = fish passage efficiency; JBSE = juvenile bypass system efficiency; SPE = spill passage efficiency; TSW = temporary spillway weir.
** TSW was not operated during the summer season.

Data were analyzed to determine any diel differences in survival for CH0. Daytime was from 0600 to 2200 hours; nighttime was from 2200 to 0600 hours. Diel differences in overall dam and forebay-to-tailrace survival of STH passing MCN did not appear to be significant (Table 8.5).

Both FPE and SPE displayed significant diel differences (Table 8.6). During daytime hours, 93% of CH0 traveled by non-turbine routes; 87% used these routes at night. Similarly, SPE during daylight hours was 82%, while the nighttime SPE was 73%. Other passage metrics do not show significant diel differences.

Table 8.5. Estimated Diel Project and Forebay-to-tailrace Survival for CH0 at MCN in Summer 2012

	Day			Night		
Survival Reach	Estimate	SE	n	Estimate	SE	n
Dam Passage	0.9722	0.0123	1542	0.9790	0.0137	917
Forebay Array to Tailrace	0.9775	0.0123	1538	0.9653	0.0140	929

Table 8.6. Comparison of CH0 Season-wide Diel Passage Efficiencies at MCN in Summer 2012. Significant difference (*) is related to the 95% confidence intervals.

	Day		Night		
Metric	Estimate	SE	Estimate	SE	Sig. diff
FPE || Dam[(a)]	0.9303	0.0065	0.8722	0.0110	*
SPE || Dam[(a)]	0.8177	0.0099	0.7259	0.0147	*
TSW efficiency || Dam[(a)]	NA	NA	NA	NA	
TSW efficiency || Spillway	NA	NA	NA	NA	
FGE (powerhouse screen efficiency)	0.6179	0.0290	0.5336	0.0314	
JBSE|| Dam[(a)]	0.1126	0.0081	0.1463	0.0116	

(a) If dam route is included, proportions will not add to 1.
FPE = fish passage efficiency; JBSE = juvenile bypass system efficiency; SPE = spill passage efficiency; TSW = temporary spillway weir.

8.4 Fish Passage Distributions

Horizontal distribution, forebay approach, and forebay vertical distributions of CH0 at MCN in summer 2012 are summarized in the following sections.

8.4.1 Horizontal Distributions

More than 78% of the CH0 passing MCN during summer 2012 passed by way of the spillway (Table 8.7). For the duration of the summer season TSWs were not in operation; however, Spill Bay 22, adjacent to the powerhouse, passed the largest percentage of fish at the spillway, although discharge was noticeably higher through Spill Bays 2 and 3 (Figure 8.1).

Powerhouse Units 3 and 8 were offline during the summer study. The powerhouse, including both the JBS and turbine routes, passed more than 21% of all CH0. Nearly 13% of all tagged CH0 passed MCN through the JBS. Distribution of fish at the powerhouse was toward the north end, with Main Unit 13 passing the largest percentage of fish (Figure 8.2). With the exception of powerhouse routes 11 and 12, the JBS passed more fish than the turbine units (Figure 8.2). CH0 passing by turbine routes were less likely to be diverted by the JBS than either CH1 or STH.

Table 8.7. Percent Passage of CH0 by Route Relative to Total Passage of CH0 at MCN in Summer 2012

Parameter	Subyearling Chinook Salmon
Percentage of total passage by TSW route	*
Percentage of total passage at spillway by non-TSW route (20 bays)	78.4
Percentage of total passage by JBS route	12.5
Percentage of total passage by turbine route	9.1

TSW = temporary spillway weir; JBS = juvenile bypass system.
* TSW was not operated during the summer season.

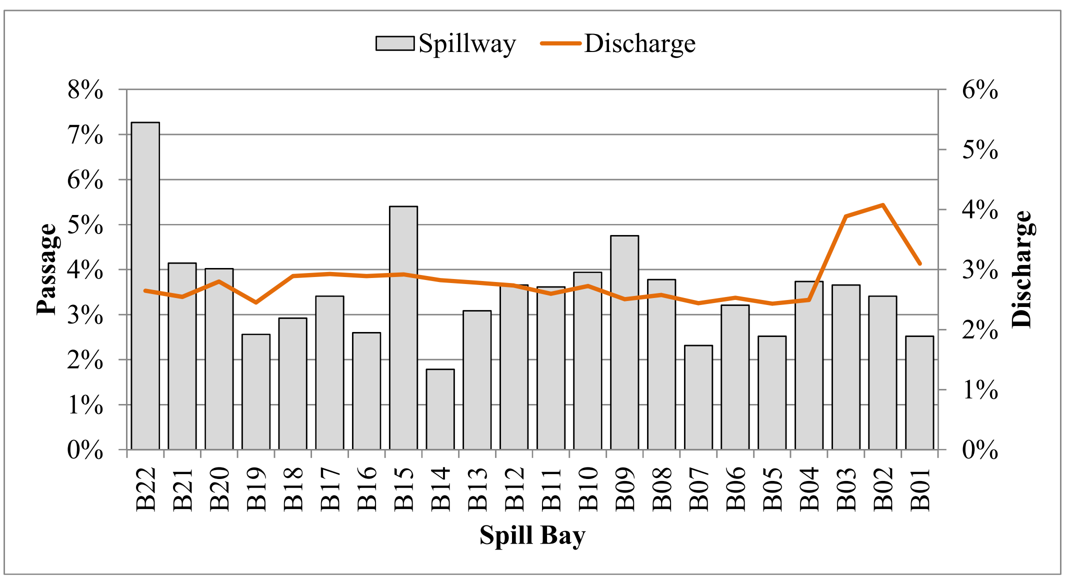


Figure 8.1. Horizontal Distribution of Passage for CH0 at the Spillway of MCN in 2012

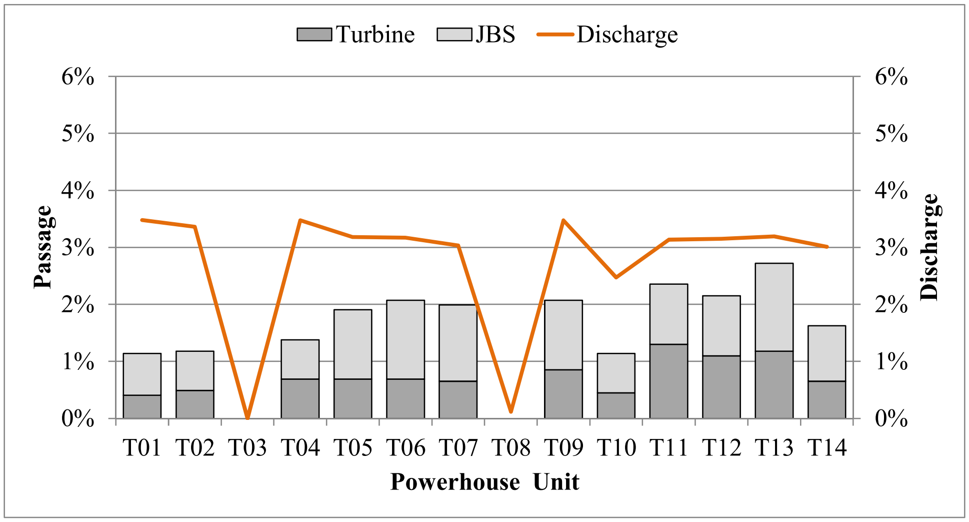


Figure 8.2. Horizontal Distribution of Passage for CH0 at the Powerhouse and JBS of MCN in 2012

8.4.2 Forebay Approach Distribution

Forebay approach distribution for CH0 based on time of the first detection on the cabled array upstream of the dam to the final detection at the dam showed that a majority of fish (58%) approached and passed through the spillway (Figure 8.3). CH0 implanted with AMTs approaching the spillway showed little diel variation. Nearly 29% of fish that approached the powerhouse passed through the powerhouse, while 13% approached within 100 m of the powerhouse before migrating to the spillway and passing there. A larger percentage (18%) of CH0 approached and passed through the powerhouse at night, than during the day (4%); however, they approached the powerhouse and passed at the spillway more frequently during the day than at night (Figure 8.3).

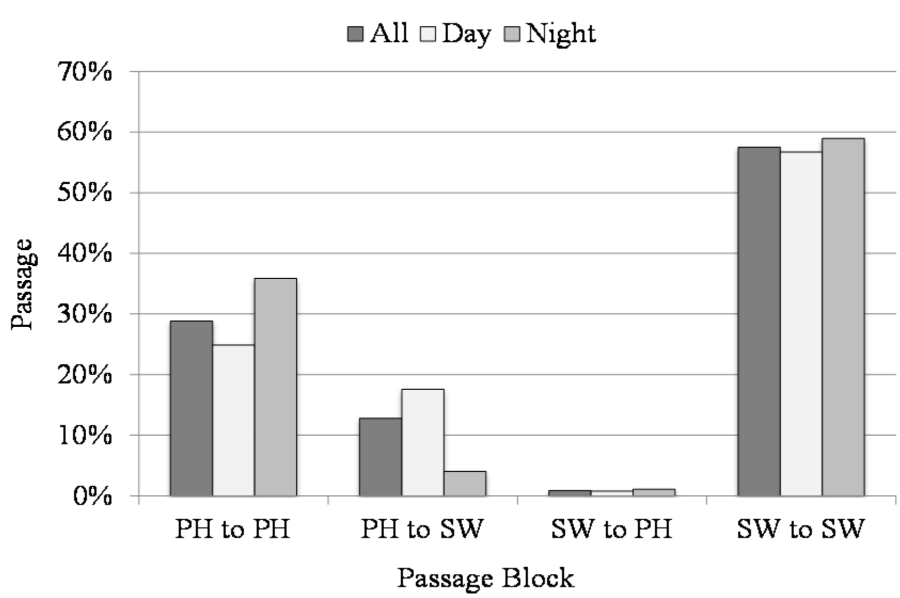


Figure 8.3. CH0 Approach and Passage Behavior Patterns at MCN during Day and Night Periods in Summer 2012

8.4.3 Forebay Vertical Distribution

Forebay vertical distribution, as indicated by the median depths of last detection by distance from the dam where fish passed, showed that as CH0 approached the dam most were within 3 to 8 m of the water surface (Figure 8.4). However, in the last 10 m prior to passing through the powerhouse, CH0 descend to depths greater than 12 m to enter the powerhouse intake. Vertical distribution patterns were similar between day and night; however, CH0 were more surface-oriented at night compared to day.

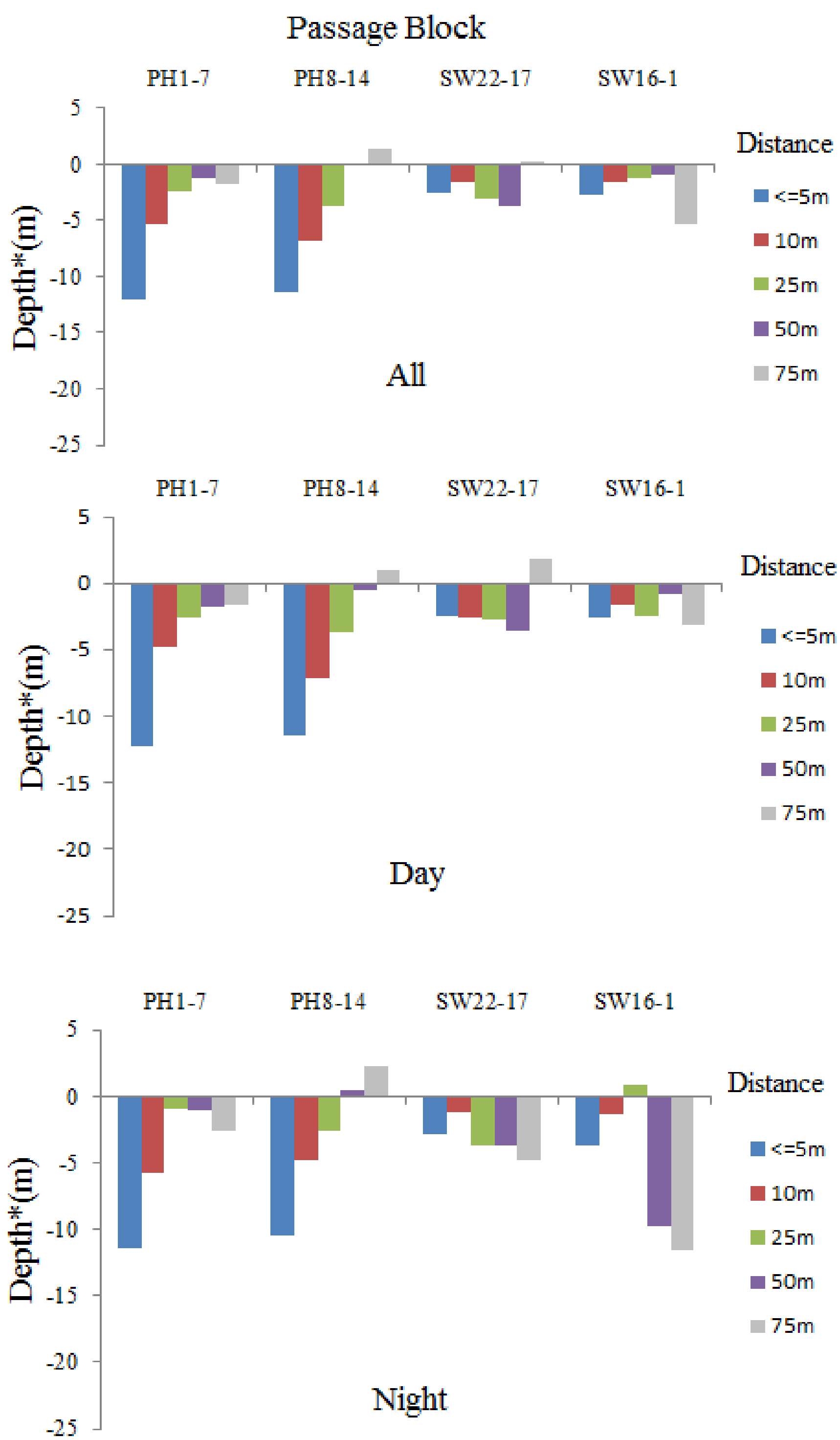


Figure 8.4. Median Forebay Vertical Distribution of CH0 Tagged with AMTs as Indicated by the Median Depth of the Last Detection by Distance from MCN during 2012. Depth (*) is relative to the elevation of shallow hydrophone F02_P01S at the powerhouse, at elevation 99.8 m above MSL. This was 3.5 m deeper than the average spring and summer pool elevation of 103.3 m above MSL. TSW passed fish are included in this vertical distribution.

9.0 Discussion

This section includes discussion of the statistical performance and survival model assumptions, tailwater mortality, historical context, TSW performance, JBS performance, and recommendations based on the comprehensive analysis of data collected in 2012.

9.1 Statistical Performance and Survival Model Assumptions

All survival model assumptions required to validate the model were met. Details of the assumption tests and results are provided in Appendix B.

Separate single AMT lots were used for CH1, STH, and CH0 in 2012; therefore, no AMT-life correction was required for application to survival estimates for this study. From each AMT lot, 98 to 100 AMTs were systematically sampled to conduct independent AMT-life studies. A three-parameter Weibull curve was used to fit the AMTs used in the STH study, and the vitality curve of Li and Anderson (2009) was used to fit the CH1 and CH0 data. Average AMT lives were 32.2 d, 23.0 d, and 23.3 d for the STH, CH1, and CH0 AMT lots, respectively.

Comparison of fish implanted with AMTs with ROR fish shows that the length frequency distributions were well matched for CH1, and STH; however, CH0 were somewhat larger than their smolt monitoring program counterparts. The mean fork length for CH1 tagged with AMTs was 143.7 mm; STH mean length was 206.7 mm, and CH0 median length was 112.9 mm. The median fork length ROR CH1, STH, and CH0 as sampled from the JDA smolt monitoring programs were 140.6, 204.1 and 104.9 mm, respectively.

Fish were held for 12 to 36 h prior to release. The 24-h tagging mortality was 0.2% during spring and 0.2% in summer. One AMT was shed during the 24-h holding period in spring and no AMTs were shed during the summer study.

Examination of the fish arrival distributions to the last detection array used in the survival analyses indicated all fish had passed through the study area before AMT failure became important. The probability that an AMT was active at a downstream detection site at rkm 325 was 99.25% for CH1, 100% for STH, and 99.63% for CH0.

To help induce downstream mixing of the release groups, the R_1 release was 24 h before the R_2 release, which, in turn, occurred 32 h before the R_3 release. The same release schedule was used for all three fish stocks. Graphs of arrival timing for each fish run (Appendix B) indicate the release timing of the different AMT groups was appropriate for adequate downstream mixing of fish. The arrival modes for V_1 and R_2 were synchronous and slightly earlier than the mode for R_3 for both CH1 and STH.

A total of eight different surgeons assisted in tagging all CH1, CH0, and STH associated with the JSATS survival studies at MCN in 2012. During the spring and summer studies, surgeon effort was found to be homogeneously distributed across all locations within a replicate release or within the project-specific releases within a replicate (Appendix C). Analyses found no surgeon effects that might confound estimation of dam passage survival; therefore, fish tagged by all surgeons were included in the estimation of survival and other performance measures.

9.2 Compliance Monitoring Summary

Estimates of dam passage survival for CH1, STH, and CH0 at MCN in spring and summer 2012 met the 2008 BiOp standards for the point estimates (i.e., ≥0.96 for spring stocks; ≥0.93 for summer stocks). The precision requirement (i.e., SE ≤ 0.015) was met for CH1 and CH0, but not for STH. A more stringent precision requirement is for the estimate of dam passage survival to be significantly greater than the requirement of $S_{Dam} \geq 0.96$. The estimate of STH survival is significantly greater than 0.96 at a P-value of 0.0462.

9.3 Reach Survival Rates

The single-release survival estimates of fish from Port Kelley to MCN exceeded 98% for CH1 and CH0, but it was only 93% for STH, and the difference likely is due to bird predation on STH upstream of the dam. At the dam, passage mortality for STH was 2.67% during the day when birds were feeding and 0% at night, when birds were not feeding. Differences between daytime and nighttime losses associated with dam passage were less for CH1 (day = 4.3%; night = 3.2%) and CH0 (day = 2.5%; night = 2.6%).

A common characteristic of V_1 and R_2 releases at MCN was low rates of survival in the tailwater downstream of the tailrace array at CR468 to Crow Butte State Park at CR422, a reach that includes the Blalock Islands (Figure 9.1). Survival rates from CR468 to CR422 were consistently the lowest observed for any reach downstream of MCN in 2012 (Table 9.1; Figure 9.2). Large gull populations were documented at the Blalock Islands near Boardman during the 2012 field season. Bird Research Northwest reported an estimated 1,700 ring-billed gulls on Straight Six Island and 7,200 mostly California gulls on Anvil Island during the 2012 season (BRNW 2013). This was a 550% increase from the 1,600 gulls reported in 2009; however, the Caspian tern population on the Blalock Island group declined from 79 breeding pairs in 2009 to 6 breeding pairs in 2012 (Roby et al. 2012). Survival estimates for V_1, V_1 regrouped at CR468, and R_2 were surprisingly consistent within common reaches downstream of the dam. Only one survival rate listed in Table 9.1 was significantly higher than all other estimates within the same reach and that was for CH1 in the R_2 release in the upper tailwater reach from CR468 to CR422 (Table 9.1; Figure 9.2). Cumulative survival estimates for each run of fish in three release groups (V_1, V_1 regrouped on CR468, and R_2) did not differ significantly at detection sites located 48, 121, 145, and 161 km downstream of MCN (Figure 9.3). Route specific survival rates were also found to be higher in the tailrace downstream of MCN than other MCN tailwater reaches for all routes except for turbine passed fish (Table 9.2, Table 9.3, and Table 9.4).

OR

Figure 9.1. Reach between Fish Release Locations R_2 (red marker at right) and R_3 (red marker at left) that Includes the Blalock Island Area (white rectangle), which is Shallow and Wide

The VPR survival estimates for each run of fish met the BiOp standards for the respective seasons in this 2012 study, and the VPR model met all major assumptions. The VPR model provided estimates that comported well with potentially problematic single-release estimates for the 2-km reach from MCN (CR470) to the tailrace array at CR468 (see the first vertical bar in each plot in Figure 9.3). The use of the tailrace array as a primary array for a single release estimates has the potential to be biased high by detections of tagged fish that died during dam and tailrace passage, and that is why the VPR model is used. Even though none of the 80 dead tagged fish released in spill discharge during the 2012 study were detected on the tailrace array, but the probability of detecting a few of the tagged fish that happened to die during passage through the dam or tailrace likely is higher than zero when V_1 sample sizes are considered (1,360 CH1; 1,297 STH; 2,362 CH0).

Table 9.1. Single-release Reach Survival Rates. Significantly higher survival rates are highlighted in gray.

River Reach	River Reach km	V_1 $\hat{S}^{(a,b)}$	1/2 95% CI	V_1 Regroup at R_2 $\hat{S}^{(a,b)}$	1/2 95% CI	R_2 $\hat{S}$	1/2 95% CI	R_3 $\hat{S}$	1/2 95% CI
				CH1					
CR470-468	2	0.9835	0.0069						
CR468-422(c,g)	46	0.9328	0.0137	0.9332	0.0135	0.9288	0.0155		
CR422-349(d)	73	0.9502	0.0125	0.9505	0.0123	0.9743	0.0100	0.9485	0.0131
CR349-325(e)	21	0.9710	0.0096	0.9712	0.0096	0.9568	0.0123	0.9582	0.0118
CR325-309(f)	16	0.9910	0.0057	0.9911	0.0057	0.9908	0.0061	0.9894	0.0063
				STH					
CR470-468	2	0.9784	0.0078						
CR468-422(c,g)	46	0.9338	0.0137	0.9341	0.0135	0.9149	0.0159		
CR422-349(d)	73	0.9486	0.0125	0.9489	0.0125	0.9335	0.0147	0.9381	0.0137
CR349-325(e)	21	0.9740	0.0094	0.9733	0.0094	0.9783	0.0090	0.9685	0.0102
CR325-309(f)	16	0.9984	0.0025	0.9984	0.0025	0.9950	0.0043	0.9926	0.0051
				CH0					
CR470-468	2	0.9782	0.0057						
CR468-422(c,g)	46	0.9351	0.0100	0.9351	0.0098	0.9274	0.0118		
CR422-349(d)	73	0.9555	0.0086	0.9556	0.0086	0.9558	0.0096	0.9434	0.0104
CR349-325(e)	21	0.9367	0.0104	0.9367	0.0104	0.9437	0.0108	0.9408	0.0108
CR325-309(f)	16	0.9917	0.0041	0.9917	0.0041	0.9894	0.0051	0.9905	0.0047

(a) Using CR468 as a primary array or to regroup V_1 fish in the tailrace could include tagged fish that did not survive dam and tailrace passage, and this could lead to overestimation of survival rates.
(b) Out of 80 tagged dead fish released into MCN spill in 2012, none were detected on the MCN tailrace array 2 km downstream of the dam.
(c) MCN tailrace egress array to Crow Butte State Park, WA.
(d) Crow Butte State Park to JDA.
(e) JDA to Celilo, OR.
(f) Celilo, OR to TDA.
(g) Number of fish not detected on CR468 that were later detected on at least one downstream array: CH1 = 2; STH = 1; CH0 = 1.

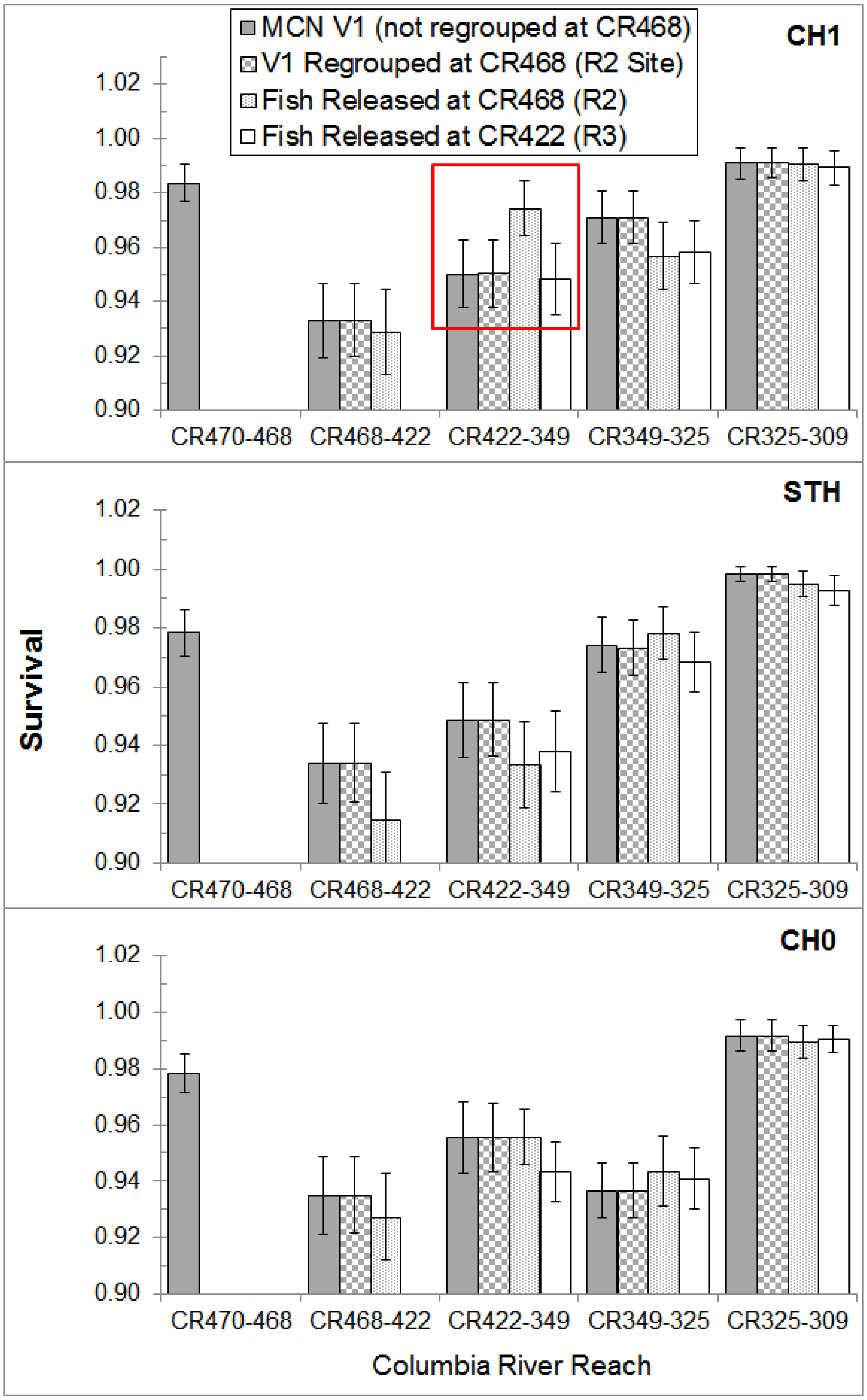


Figure 9.2. Plots of Single-release Reach Survival Estimates for CH1, STH, and CH0 in Four Release Groups (see legend in top plot). CR470 is at the MCN dam face, CR468 is at the tailrace node array and R_2 fish-release site, CR422 is at Crow Butte State Park, CR349 is at the JDA dam face, CR325 is at Celilo, Oregon, and CR309 is at the TDA dam face. The red box highlights the only significant differences observed among estimates for the four release groups, where CH1 R_2 survival was significantly higher than estimates for all three groups in the reach between CR422 and CR349.

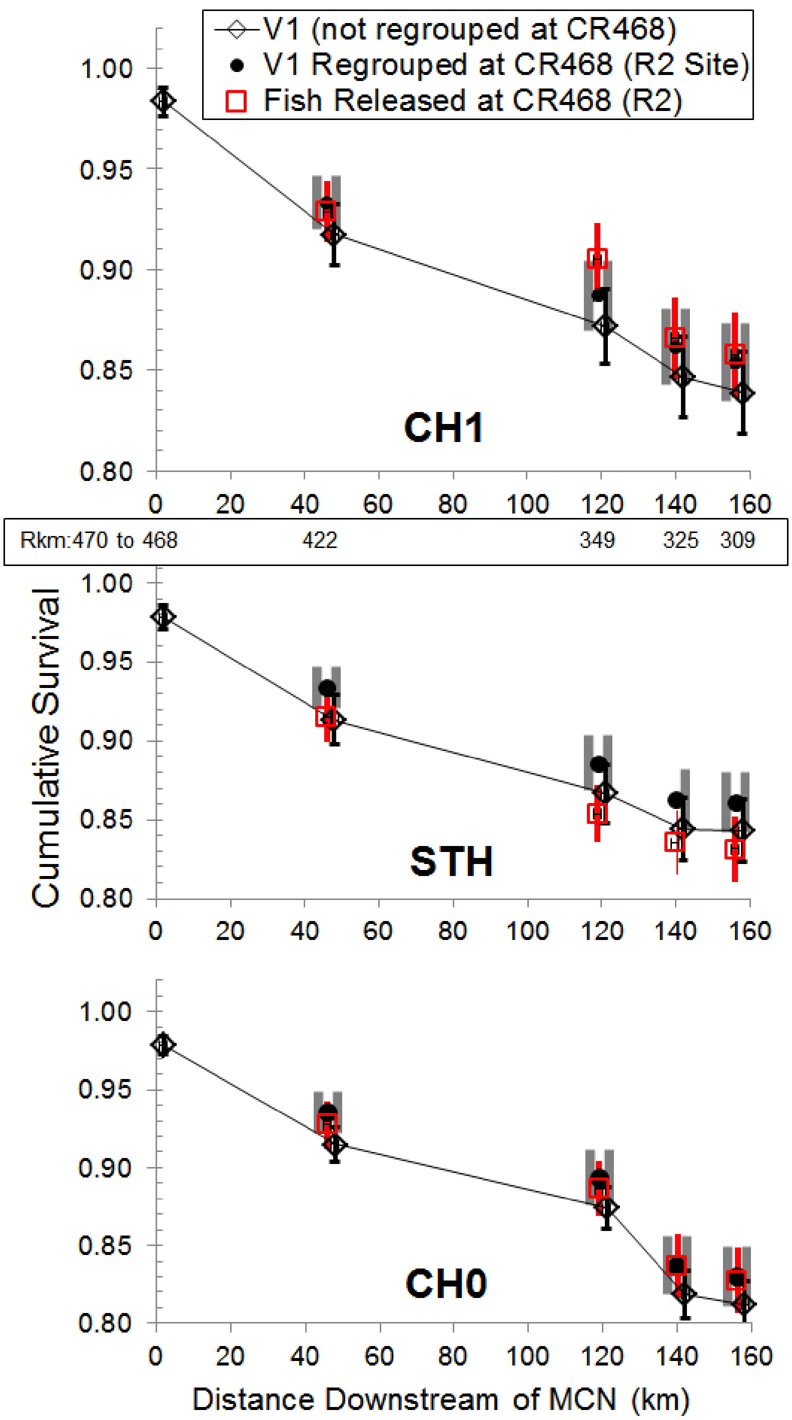


Figure 9.3. Plot of Cumulative Survival Estimates for CH1, STH, and CH0 in Three Release Groups (see legend in top plot). The bar above the center plot for STH shows the rkm that corresponds with distances listed on the x-axis of each plot. Rkm 470 is at the MCN dam face, 468 is at the tailrace node array and R_2 fish release site, CR422 is at Crow Butte State Park, CR349 is at the JDA dam face, CR325 is at Celilo, Oregon, and CR309 is at the TDA dam face. Vertical bars are 95% confidence intervals.

Table 9.2. Route Specific Single-release Reach Survival Rates for CH1

River Reach	River Reach km	V_1 $\hat{S}^{(a,b)}$	95% CI	V_1 Regroup at R_2 $\hat{S}^{(a,b)}$	95% CI	R_2 $\hat{S}$	95% CI	R_3 $\hat{S}$	95% CI
JBS					**CH1**				
CR470-468	2	0.9848	0.0131						
CR468-422[c,g]	46	0.9040	0.0321	0.9049	0.0318	0.9240	0.0151	`	
CR422-349[d]	73	0.9384	0.0276	0.9390	0.0272	0.9720	0.0098	0.9458	0.0127
CR349-325[e]	21	0.9781	0.0172	0.9783	0.0171	0.9562	0.0122	0.9575	0.0118
CR325-309[f]	16	0.9816	0.0163	0.9819	0.0161	0.9903	0.0061	0.9890	0.0063
TSW									
CR470-468	2	0.9917	0.0172						
CR468-422[c,g]	46	0.9462	0.0421	0.9459	0.0421	0.9240	0.0151		
CR422-349[d]	73	0.9716	0.0319	0.9714	0.0319	0.9720	0.0098	0.9458	0.0127
CR349-325[e]	21	0.9804	0.0269	0.9804	0.0269	0.9562	0.0122	0.9575	0.0118
CR325-309[f]	16	1.0000	0.0000	1.0000	0.0000	0.9903	0.0061	0.9890	0.0063
non-TSW									
CR470-468	2	0.9852	0.0080						
CR468-422[c,g]	46	0.9382	0.0161	0.9384	0.0161	0.9240	0.0151		
CR422-349[d]	73	0.9479	0.0153	0.9480	0.0153	0.9720	0.0098	0.9458	0.0127
CR349-325[e]	21	0.9671	0.0127	0.9672	0.0125	0.9562	0.0122	0.9575	0.0118
CR325-309[f]	16	0.9919	0.0065	0.9920	0.0065	0.9903	0.0061	0.9890	0.0063
Turbine									
CR470-468	2	0.9318	0.0745						
CR468-422[c,g]	46	0.9756	0.0472	0.9524	0.0645	0.9240	0.0151		
CR422-349[d]	73	0.9750	0.0484	0.9750	0.0484	0.9720	0.0098	0.9458	0.0127
CR349-325[e]	21	0.9487	0.0692	0.9487	0.0692	0.9562	0.0122	0.9575	0.0118
CR325-309[f]	16	1.0000	0.0000	1.0000	0.0000	0.9903	0.0061	0.9890	0.0063

(a) Using CR468 as a primary array or to regroup V_1 fish in the tailrace could include tagged fish that did not survive dam and tailrace passage, and this could lead to overestimation of survival rates.
(b) Out of 80 tagged dead fish released into MCN spill in 2012, none were detected on the MCN tailrace array 2 km downstream of the dam.
(c) MCN tailrace egress array to Crow Butte State Park, WA.
(d) Crow Butte State Park to JDA.
(e) JDA to Celilo, OR.
(f) Celilo, OR to TDA.
(g) Number of fish not detected on CR468 that were later detected on at least one downstream array: CH1 = 2.

Table 9.3. Route Specific Single-release Reach Survival Rates for STH

River Reach	River Reach km	V_1 $\hat{S}^{(a,b)}$	95% CI	V_1 Regroup at R_2 $\hat{S}^{(a,b)}$	95% CI	R_2 $\hat{S}$	95% CI	R_3 $\hat{S}$	95% CI
JBS					**STH**				
CR470-468	2	0.9840	0.0180						
CR468-422[c,g]	46	0.9511	0.0312	0.9511	0.0312	0.9149	0.0159		
CR422-349[d]	73	0.9143	0.0416	0.9143	0.0416	0.9335	0.0147	0.9381	0.0137
CR349-325[e]	21	0.9938	0.0122	0.9938	0.0122	0.9783	0.0090	0.9685	0.0102
CR325-309[f]	16	1.0003	0.0008	1.0003	0.0008	0.9950	0.0043	0.9926	0.0051
TSW									
CR470-468	2	0.9867	0.0129						
CR468-422[c,g]	46	0.9125	0.0321	0.9125	0.0321	0.9149	0.0159		
CR422-349[d]	73	0.9742	0.0188	0.9742	0.0188	0.9335	0.0147	0.9381	0.0137
CR349-325[e]	21	0.9695	0.0208	0.9695	0.0208	0.9783	0.0090	0.9685	0.0102
CR325-309[f]	16	0.9961	0.0076	0.9961	0.0076	0.9950	0.0043	0.9926	0.0051
non-TSW									
CR470-468	2	0.9832	0.0090						
CR468-422[c,g]	46	0.9383	0.0171	0.9384	0.0171	0.9149	0.0159		
CR422-349[d]	73	0.9455	0.0167	0.9456	0.0167	0.9335	0.0147	0.9381	0.0137
CR349-325[e]	21	0.9716	0.0125	0.9717	0.0125	0.9783	0.0090	0.9685	0.0102
CR325-309[f]	16	0.9987	0.0029	0.9987	0.0029	0.9950	0.0043	0.9926	0.0051
Turbine									
CR470-468	2	0.8333	0.1333						
CR468-422[c,g]	46	0.9200	0.1064	0.9200	0.1064	0.9149	0.0159		
CR422-349[d]	73	1.0000	0.0000	1.0000	0.0000	0.9335	0.0147	0.9381	0.0137
CR349-325[e]	21	0.9565	0.0833	0.9565	0.0833	0.9783	0.0090	0.9685	0.0102
CR325-309[f]	16	1.0000	0.0000	1.0000	0.0000	0.9950	0.0043	0.9926	0.0051

(a) Using CR468 as a primary array or to regroup V_1 fish in the tailrace could include tagged fish that did not survive dam and tailrace passage, and this could lead to overestimation of survival rates.
(b) Out of 80 tagged dead fish released into MCN spill in 2012, none were detected on the MCN tailrace array 2 km downstream of the dam.
(c) MCN tailrace egress array to Crow Butte State Park, WA.
(d) Crow Butte State Park to JDA.
(e) JDA to Celilo, OR.
(f) Celilo, OR to TDA.
(g) Number of fish not detected on CR468 that were later detected on at least one downstream array: STH = 1.

Table 9.4. Route Specific Single-release Reach Survival Rates for CH0

River Reach	River Reach km	V_1 $\hat{S}^{(a,b)}$	95% CI	V_1 Regroup at R_2 $\hat{S}^{(a,b)}$	95% CI	R_2 $\hat{S}$	95% CI	R_3 $\hat{S}$	95% CI
JBS					**CH0**				
CR470-468	2	0.9903	0.0110						
CR468-422[c,g]	46	0.9541	0.0235	0.9511	0.0241	0.9252	0.0116		
CR422-349[d]	73	0.9450	0.0263	0.9418	0.0269	0.9544	0.0096	0.9415	0.0104
CR349-325[e]	21	0.9489	0.0261	0.9489	0.0261	0.9434	0.0108	0.9410	0.0108
CR325-309[f]	16	0.9808	0.0167	0.9808	0.0167	0.9892	0.0051	0.9903	0.0047
non-TSW									
CR470-468	2	0.9845	0.0055						
CR468-422[c,g]	46	0.9341	0.0112	0.9341	0.0112	0.9252	0.0116		
CR422-349[d]	73	0.9566	0.0094	0.9565	0.0094	0.9544	0.0096	0.9415	0.0104
CR349-325[e]	21	0.9337	0.0120	0.9337	0.0120	0.9434	0.0108	0.9410	0.0108
CR325-309[f]	16	0.9930	0.0041	0.9930	0.0041	0.9892	0.0051	0.9903	0.0047
Turbine									
CR470-468	2	0.9062	0.0382						
CR468-422[c,g]	46	0.9113	0.0392	0.9118	0.0390	0.9252	0.0116		
CR422-349[d]	73	0.9622	0.0274	0.9624	0.0274	0.9544	0.0096	0.9415	0.0104
CR349-325[e]	21	0.9489	0.0325	0.9435	0.0341	0.9434	0.0108	0.9410	0.0108
CR325-309[f]	16	0.9940	0.0118	0.9940	0.0118	0.9892	0.0051	0.9903	0.0047

(a) Using CR468 as a primary array or to regroup V_1 fish in the tailrace could include tagged fish that did not survive dam and tailrace passage, and this could lead to overestimation of survival rates.
(b) Out of 80 tagged dead fish released into MCN spill in 2012, none were detected on the MCN tailrace array 2 km downstream of the dam.
(c) MCN tailrace egress array to Crow Butte State Park, WA.
(d) Crow Butte State Park to JDA.
(e) JDA to Celilo, OR.
(f) Celilo, OR to TDA.
(g) Number of fish not detected on CR468 that were later detected on at least one downstream array: CH0 = 1.

After the 2012 study compliance report for McNary was published, the SRWG had several requests for additional analysis, and those requests and the results are listed below.

1. **Estimate survival from R_2 to R_3 for V_1 regrouped at R_2.**

   The estimates are presented in Table 9.1 and Figure 9.1.

2. **Statistically compare the estimated survival from R_2 to R_3 for V_1 regrouped at R_2 to the R_2 release.**

There was no significant difference between survival estimates for V_1, V_1 regrouped at R_2, or the R_2 release of fish in the reach between the tailrace array (R_2 release site) and Crow Butte State Park at CR422 where R_3 releases were made (Table 9.1 and Figure 9.2).

3. **What proportion and sample sizes of the dead fish are seen on the R_2 array that might bias the analysis in 1 and 2?**

None of the 80 tagged dead fish released into MCN spill discharge were detected on the tailrace egress array 2 km downstream of MCN. The 3-node array at R_2 regrouped nearly all V_1 fish. It was by far the most efficient tailrace egress array in the lower Columbia River. Single-release estimates of survival from the dam face to the tailrace array 2 km downstream all exceeded BiOp criteria, although those estimates are problematic because there always is the potential for dead tagged fish in V_1 to make it to the tailrace array and be counted as live fish in subsequent capture histories.

4. **Estimate survival of fish in V_1 and R_2 from Crow Butte State Park (CR422; R_3 release site) to the JDA dam face (CR349).**

The estimates are presented in Table 9.1 and Figure 9.2.

5. **Statistically compare estimated survival of fish in V_1, R_2, and R_3 releases from Crow Butte State Park (CR422; R_3 release site) to the JDA dam face (CR349).**

The only significant difference was for CH1, and in that case, R_2 survival was significantly higher than the survival of V_1 and R_3 fish passing through that reach.

9.4 Spatial and Temporal Consistency of Survival Estimates

An examination of survival estimates for reference releases of fish at R_2 and R_3 to JDA supports our contention that composite estimates of dam passage survival were not biased by the reference releases. Estimates of survival from release sites to JDA were spatially consistent among the five fish release locations across the river at R_2 and R_3 sites (Figure 9.4, Figure 9.5, and Figure 9.6). Estimates of R_2 and R_3 survival from release to JDA also were consistent through time by 2-d block (Figure 9.7, Figure 9.8, and Figure 9.9). A slight downward trend in both R_2 and R_3 survival to JDA was apparent for STH (Figure 9.8), but not for CH1 (Figure 9.7) and CH0 (Figure 9.9).

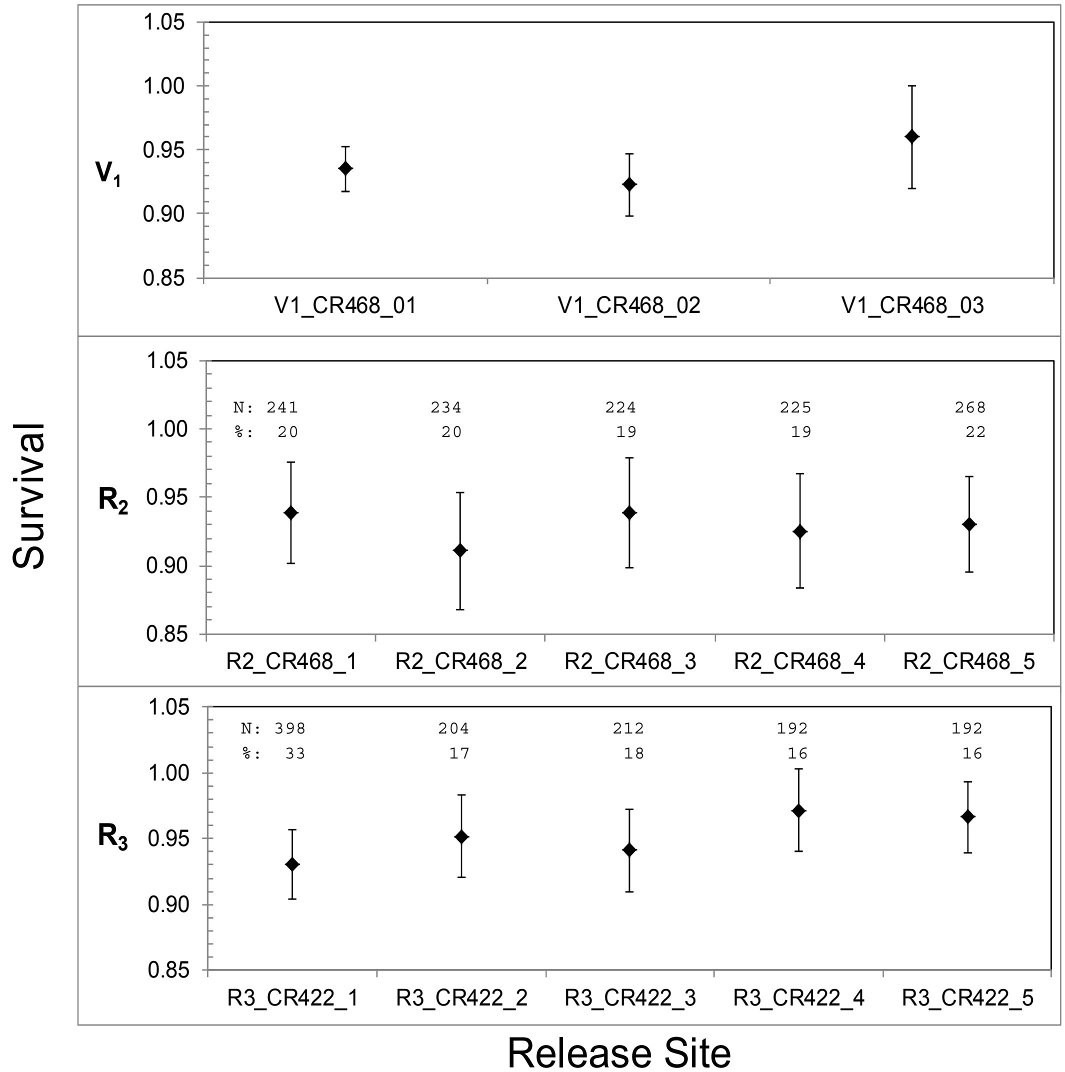


Figure 9.4. Single-release Estimates of Survival Probabilities (y-axis) for CH1 Released Across the Columbia River Downstream of MCN at Three or Five Locations from the Washington to the Oregon Side of the Channel (x-axis). The top plot shows survival probabilities for the reach from the tailrace (CR468) to Crow Butte (CR422) for three virtual releases of fish formed by regrouping dam-passed fish (V_1) on the tailrace autonomous node that received the most receptions of each AMT code. The middle plot shows reach survival probabilities of tailrace-released fish (R_2 at CR468) to JDA (CR349), and the bottom plot shows reach survivals of tailwater-released fish (Crow Butte, Washington at CR422) to JDA (CR349). Two lines of numbers above survival bars indicate the number of fish (N) and percent (%) of fish released at each site. Vertical error bars represent the extent of the 95% confidence intervals.

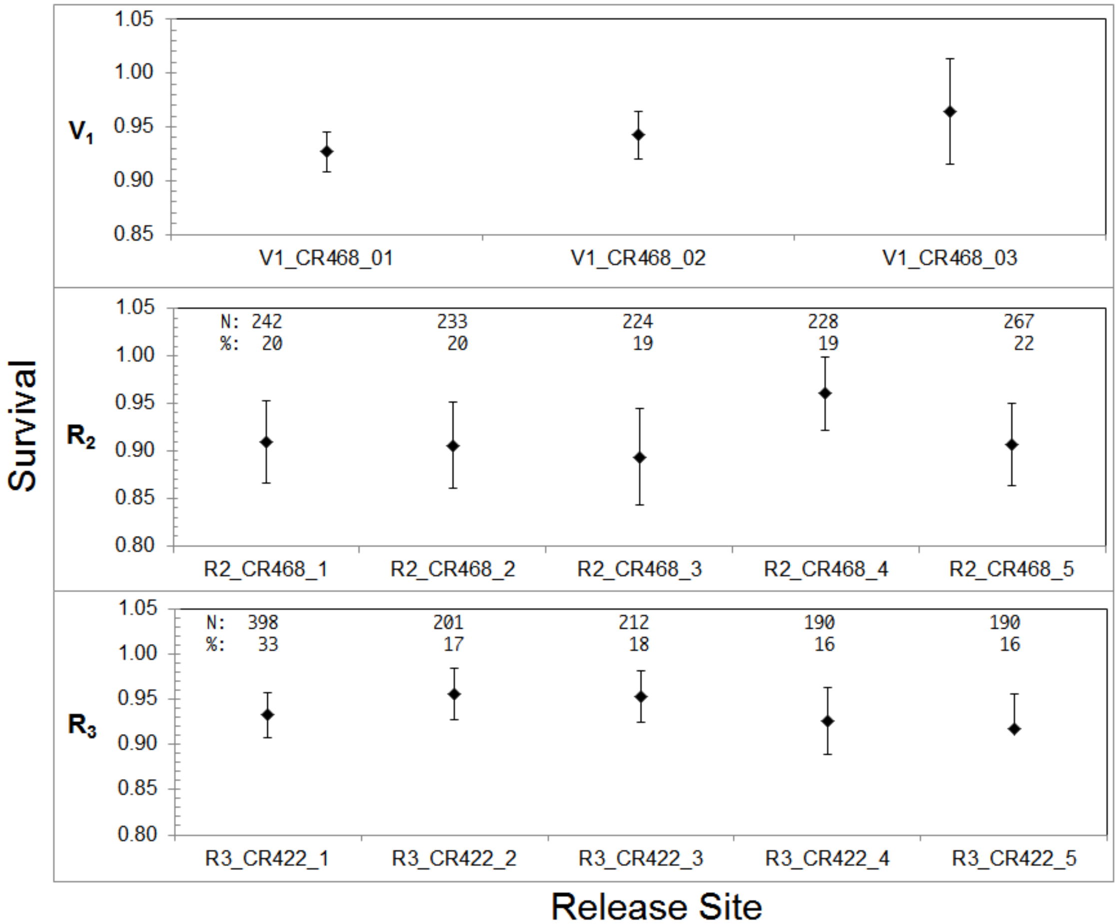


Figure 9.5. Single-release Estimates of Survival Probabilities (y-axis) for Juvenile STH Released Across the Columbia River Downstream of MCN at Three or Five Locations from the Washington to the Oregon Side of the Channel (x-axis). The top plot shows survival probabilities for the reach from CR468 to CR422 for three virtual releases of fish formed by regrouping dam-passed fish (V_1) on the tailrace autonomous node that received the most receptions of each AMT code. The middle plot shows reach survival probabilities of tailrace-released fish (R_2 at CR468) to Crow Butte, Washington (CR422), and the bottom plot shows reach survivals of tailwater-released fish (Crow Butte, Washington at CR422) to JDA (CR349). Two lines of numbers above survival bars indicate the number (N) and percent (%) of fish released at each site. Vertical error bars represent the extent of the 95% confidence interval.

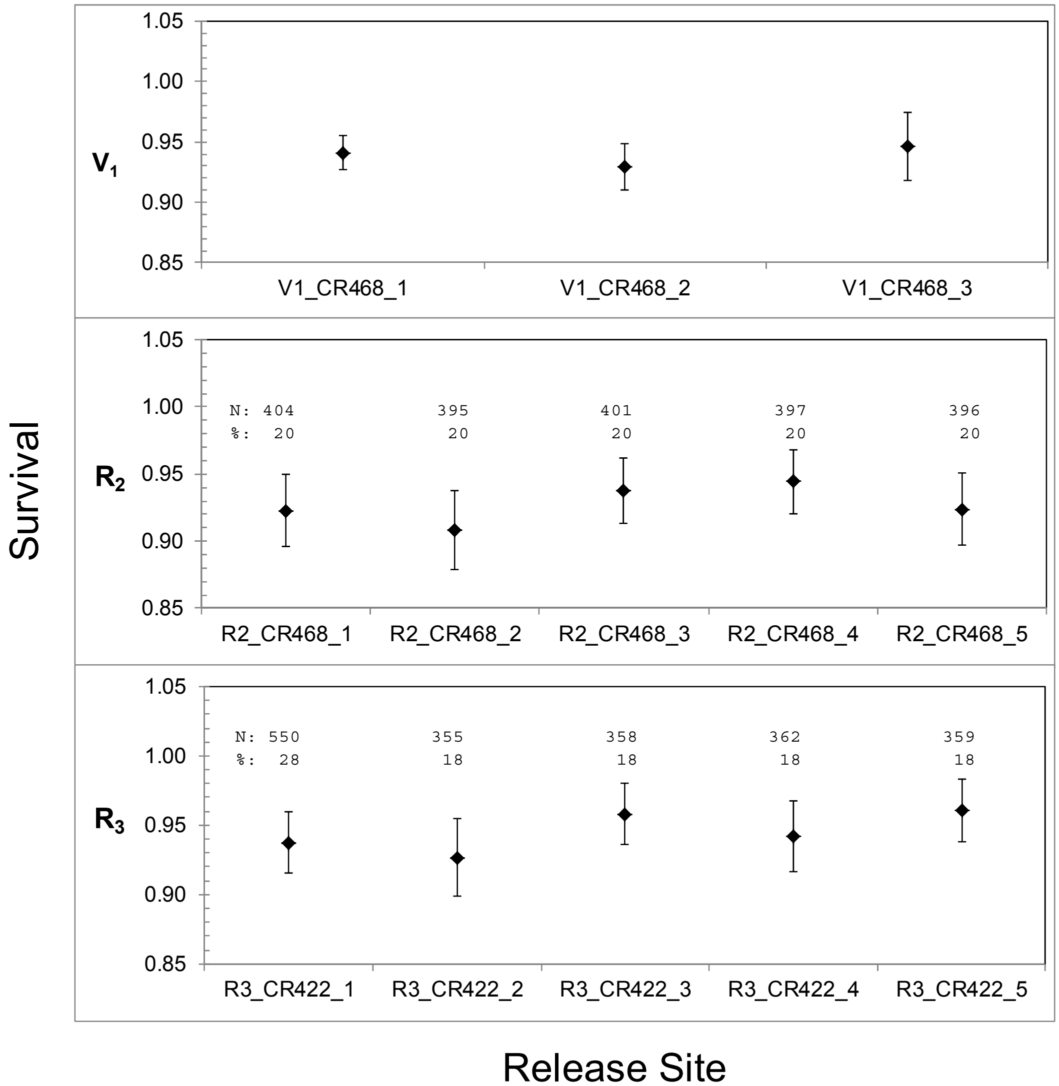


Figure 9.6. Single-release Estimates of Survival Probabilities (y-axis) for CH0 Released Across the Columbia River at Three or Five Locations from the Washington to the Oregon Side of the Channel (x-axis). The top plot shows survival probabilities for the reach from CR468 to CR422 for three virtual releases of fish formed by regrouping dam-passed fish on the tailrace autonomous node that received the most receptions of a AMT code. The middle plot shows survival probabilities of tailrace-released fish from the tailrace (CR468) to near Crow Butte, Washington (CR422), and the bottom chart shows the survival rates for tailwater- released fish (CR422) to JDA (CR349). Two lines of numbers above survival bars indicate the number (*N*) and percent (%) of fish released at each site. Vertical error bars represent the extent of the 95% confidence interval.

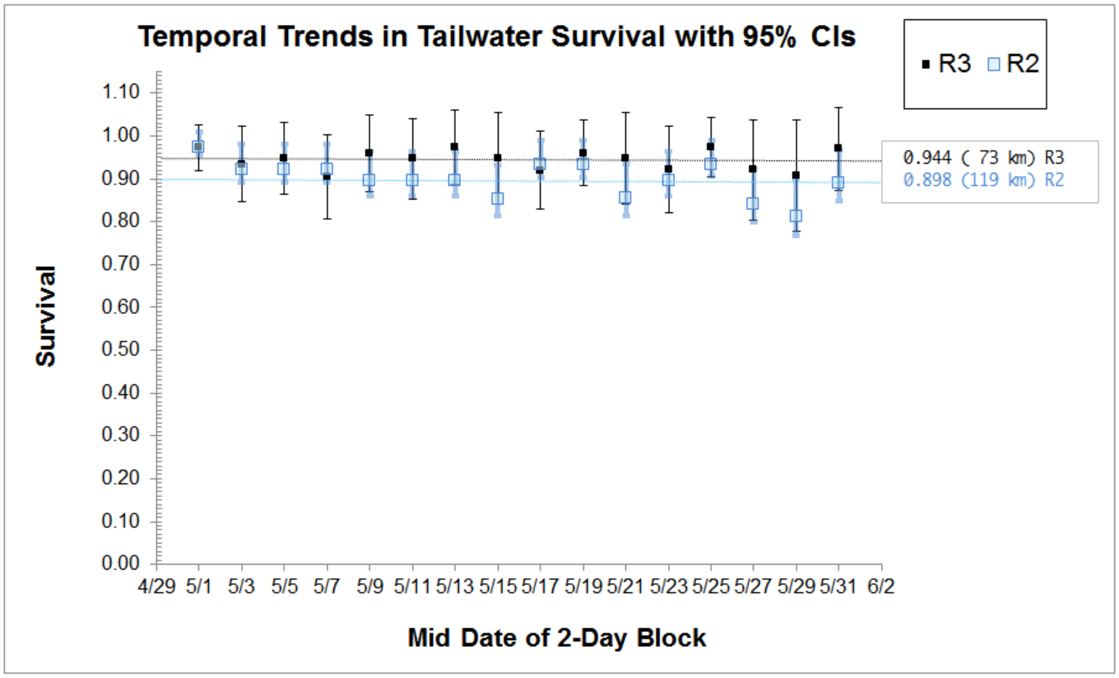


Figure 9.7. Temporal Trends in CH1 Survival from Release site R_2 or R_3 to JDA by 2-d Block. Horizontal lines indicate the composite estimate for the study, which is listed in the text box along with the length of the river reach evaluated.

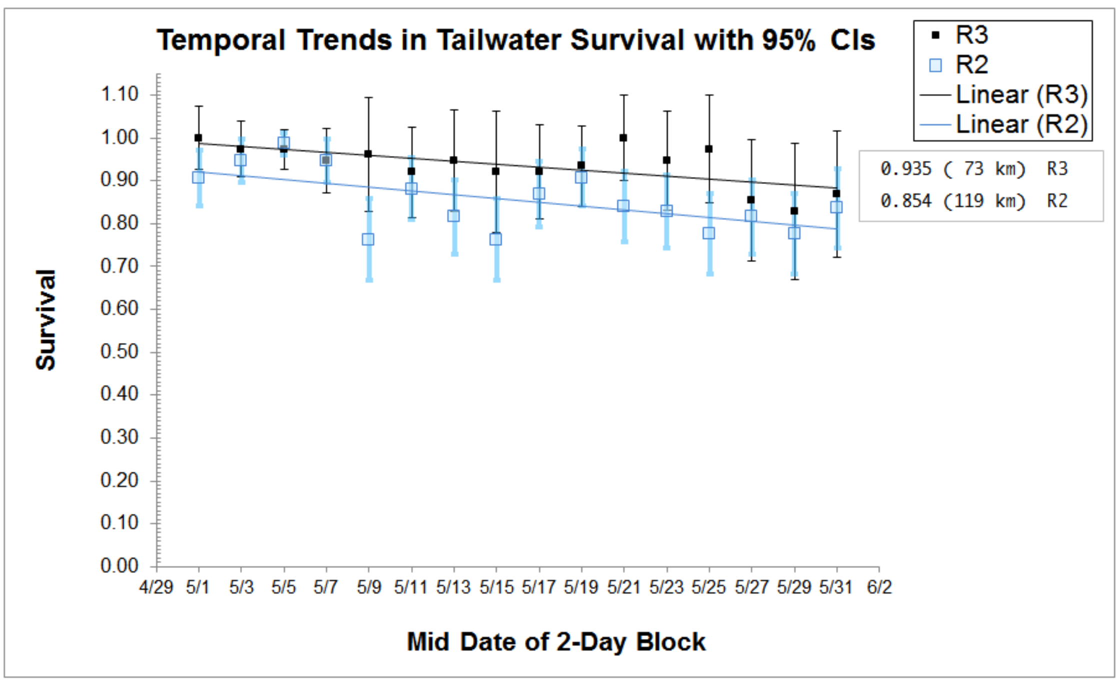


Figure 9.8. Temporal Trends in STH Survival from Release Site R_2 or R_3 to JDA by 2-d Block. Fitted lines suggest a slight downward trend in survival for both releases of fish. Composite estimate for the study are listed in the text box along with the length of the river reach evaluated.

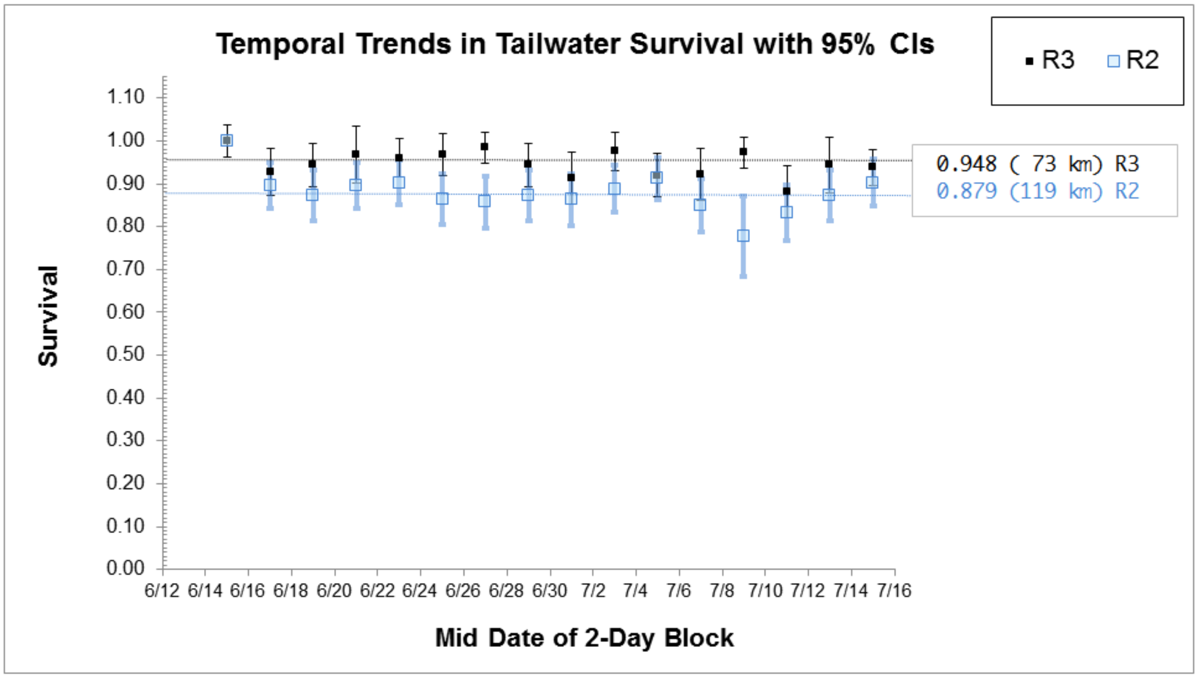


Figure 9.9. Temporal Trends in CH0 Survival from Release Site R_2 or R_3 to JDA by 2-d Block. Horizontal lines indicate the composite estimate for the study, which is listed in the text box along with the length of the river reach evaluated.

9.5 Historical Context

Historically, both AT and RT studies have been used to estimate survival rates and passage efficiencies for CH1, STH, and CH0 at MCN. In the early 2000s, RT was the primary method for estimating survival rates throughout the lower Columbia River; in more recent years (2006–2009), AT has become the primary method for obtaining these estimates. In 2012, the JSATS technology was used at MCN to obtain these estimates.

Adams and Evans (2011) synthesized findings of AT survival studies for studies conducted in 2006 through 2009 at MCN. Fish implanted with AMTs were released upstream of MCN in the mid-Columbia and used for estimating paired- and single-release dam passage survival rates. Average fork lengths of CH1, STH, and CH0 used for the 2006–2009 studies were approximately 154 mm, 214 mm, and 119 mm, respectively. Average fork lengths for CH1, STH, and CH0 for the current study were 143.7 mm, 206.7 mm, and 112.9 mm, respectively.

Paired-release survival rates from 2006–2009 are presented in Figure 9.10, along with the results of this investigation (2012). Survival rates for CH1 and STH in 2012 were historically similar to paired-release survival rates. Paired-release survival for STH was not achieved in 2006 and 2007, because there were no associated control releases. For CH0, paired-release survival rates for 2012 were approximately 8% higher than the 2009 estimates.

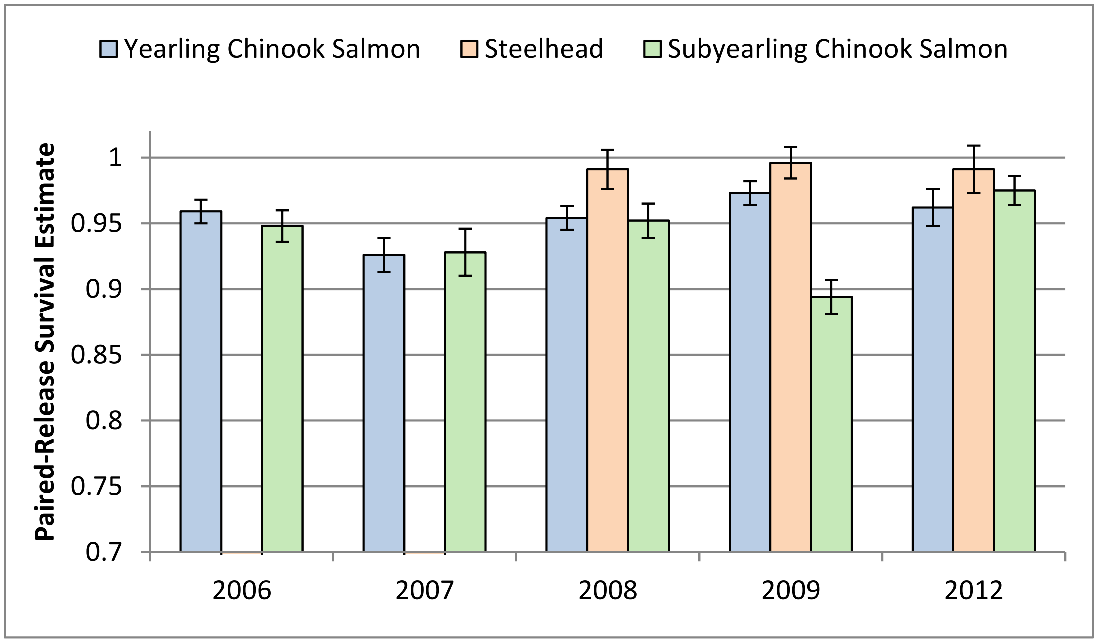


Figure 9.10. Paired-release Dam Passage Survival Rates of CH1, STH, and CH0 at MCN from 2006 to 2009, and 2012

Single-release survival estimates from the same study years are presented in Figure 9.11 for CH1, STH, and CH0. The single-release dam passage survival rate for CH0 in 2012 was approximately 3 to 9% above the historic range (2006 to 2009; Adams and Evans 2011). In contrast, CH1 and STH single-release survival estimates were at the low end of the 2006–2009 historic range.

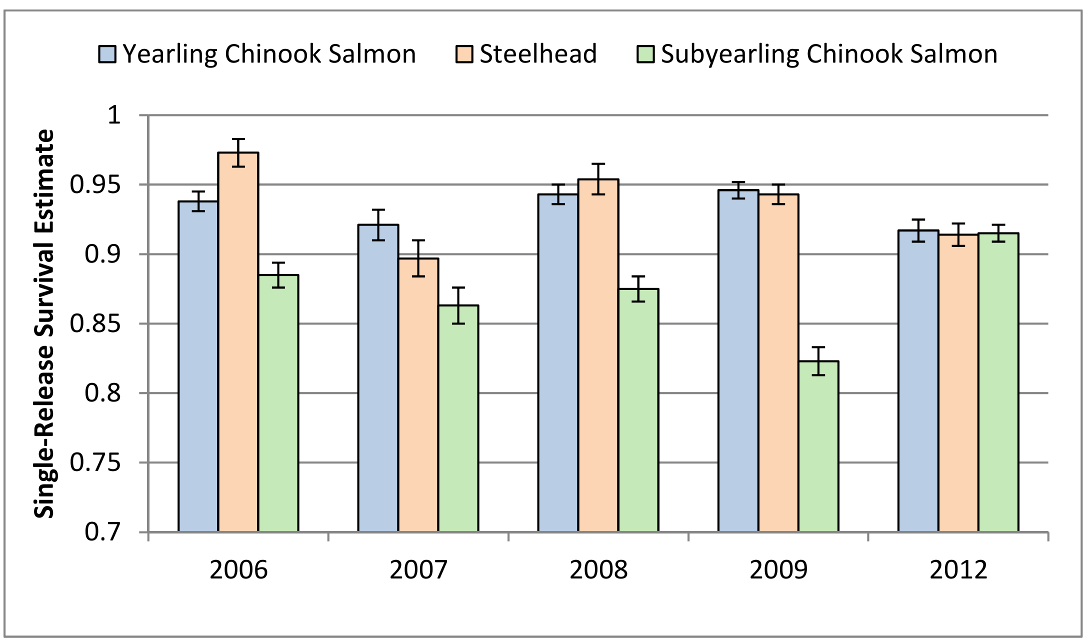


Figure 9.11. Single-release Dam Passage Survival Rates CH1, STH, and CH0 at MCN from 2006 to 2009, and 2012

At MCN, the estimated FPE has ranged widely since 2006. Figure 9.12 summarizes FPE for CH1, STH, and CH0 from 2006 through 2009 (Adams and Evans 2011) with the current study year also shown for comparison. In 2012, FPE was notably higher for all three salmonid stocks. For CH1 and CH0, FPE was approximately 0.10 higher than noted historically, and the estimate for STH was approximately 0.05 higher than previous study years.

SPE estimates from studies conducted in 2006–2009 (Adams and Evans 2011) and the current study year are presented in Figure 9.13. The SPE for all three salmonid stocks tagged and released for the 2012 JSATS study were markedly higher than historically observed from the 2006–2009 studies. For CH1, the estimated SPE in 2012 was more than 0.06 higher than estimates from previous studies (differences ranging from 0.068 to 0.187). Similar estimates were observed for STH, with an estimated SPE of 0.832 in 2012; estimates for earlier studies were from 0.05 to 0.184 less. The SPE for CH0 in 2012 was 0.783, considerably higher than observed in previous study years; differences in SPE for the 2006−2009 estimates ranged from 0.114 to 0.243 less than that observed in 2012 (Table 9.5).

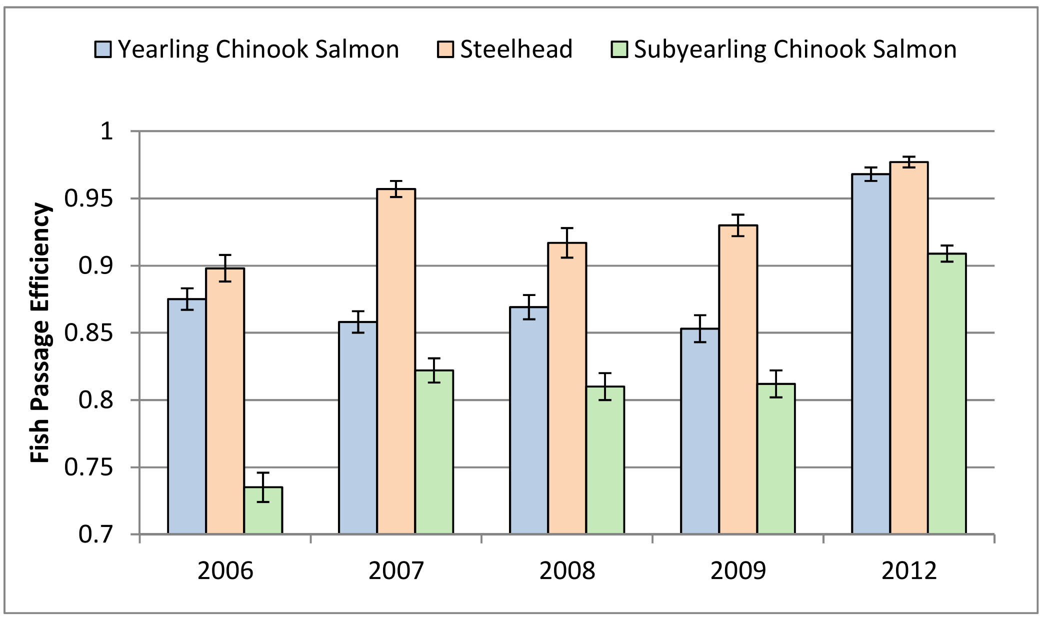


Figure 9.12. Estimates of FPE for CH1, STH, and CH0 at MCN from 2006 to 2009 (Adams and Evans 2011) and 2012. Standard errors are in parentheses.

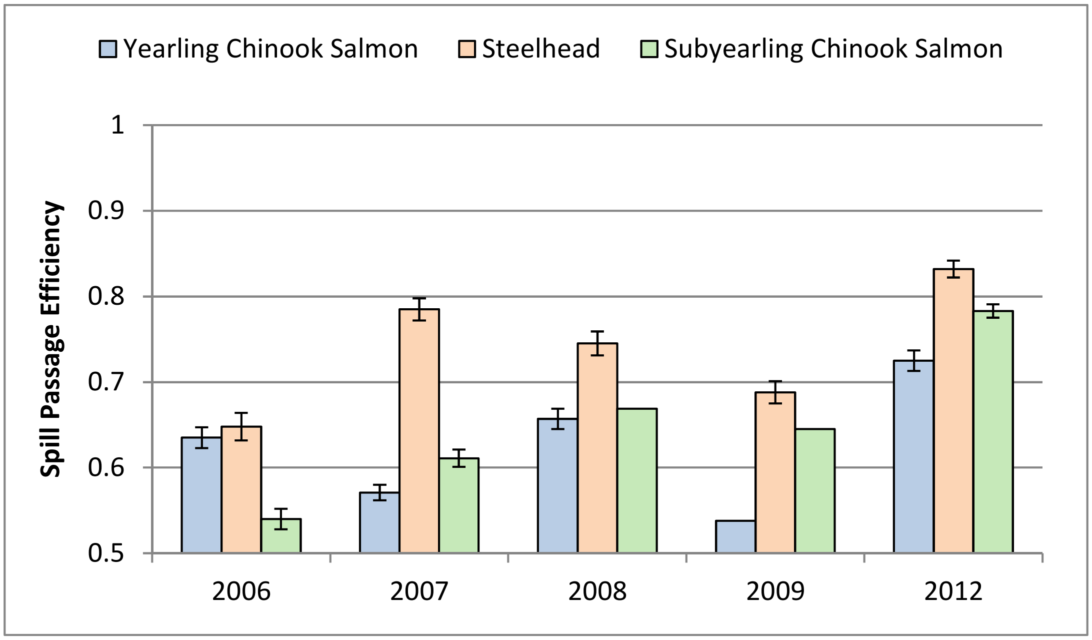


Figure 9.13. Estimates of SPE for CH1, STH, and CH0 at MCN from 2006 to 2009 (Adams and Evans 2011) and 2012. Standard errors are in parentheses.

9.5.1 TSW Performance

TSWs were first installed in Spill Bays 20 and 22 at MCN in 2007. The TSW in Spill Bay 20 (TSW1) has always been placed in Spill Bay 20 when in use (Figure 9.14). TSW2 has been placed in Spill Bay 22 (2007), Spill Bay 19 (2008, summer 2009), Spill Bay 4 (spring 2009), and in Spill Bay 19 for the current evaluation.

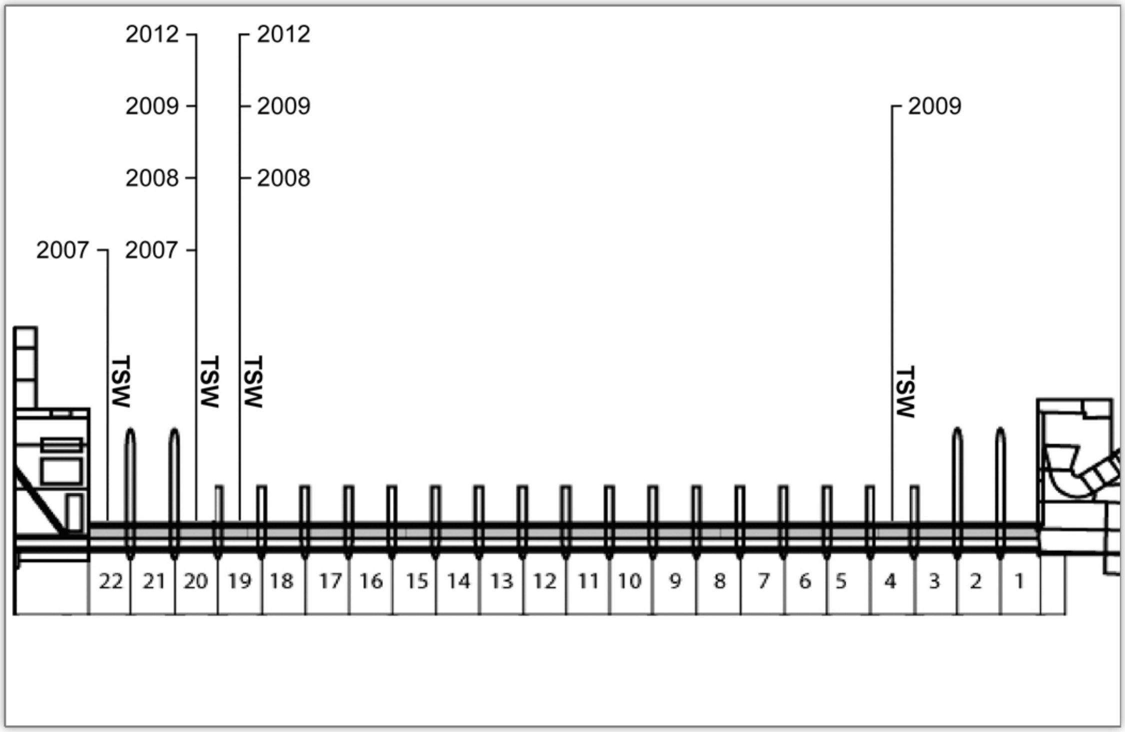


Figure 9.14. Spillway Plan View Displaying TSW Locations During 2007, 2008, 2009, and 2012

The single-release survival estimate for passage through the TSW spill bays for juvenile STH in 2012 was 0.900, 2.23% lower than passage through the remainder of the spillway (Table 9.5). Single-release survival estimates for TSW passage for previous studies were higher—ranging from 0.906 to 0.972 for individual TSW routes. Combining the individual estimates (TSW1 and TSW2) for each year produces considerably higher TSW passage survival estimates for STH—greater than 93% for 2007 and above 96% for 2008 and 2009. Further comparison indicates non-TSW spillway survival for STH was relatively low (0.9226) for the current study; the 2007 survival estimate was lower (0.891), and all other years exhibited higher spillway survival. Spillway passage efficiency for STH was significantly higher for the current study period (Table 9.5).

Single-release survival through the spillway for CH1 improved 0.52% using the TSW route. TSW passage survival and efficiency were comparable to estimates from previous studies (Table 9.5). Non-TSW spillway survival was somewhat lower than those observed during previous studies; however, spillway passage efficiency for CH1 was significantly higher for the current study period.

The TSW gates were removed during the summer study; therefore, TSW passage performance for CH0 could not be determined. The non-TSW spillway survival estimate for the current study was comparable to survival estimates observed for previous studies; however, spillway passage efficiency for CH0 was significantly higher for the current evaluation, trending similarly to that of CH1 and STH.

Table 9.5. Single-release Survival Estimates for STH, CH1, and CH0 Passing at TSW Spill Bays at MCN, 2006 through 2009, and 2012. Prior studies rated passage through the two TSW spill bays individually; 2012 results are for combined TSW passage. TSW gates were removed during the summer season; therefore, subyearling Chinook were subject to normal spill conditions. Standard errors are in parentheses.

Juvenile Steelhead	TSW1 Survival	TSW2 Survival	Spillway Survival (Non-TSW)	Spillway Passage Efficiency	TSW1 Efficiency Dam	TSW2 Efficiency Dam
2006	NA	NA	0.986 (0.011)	0.648 (0.016)	NA	NA
2007	0.906 (0.017)	0.967 (0.020)	0.891 (0.031)	0.785 (0.013)[a]	0.468 (0.015)	0.179 (0.012)
2008	0.972 (0.016)	0.967 (0.014)	0.987 (0.010)	0.745 (0.014)	0.166 (0.011)	0.237 (0.013)
2009	0.967 (0.017)	0.961 (0.012)	0.942 (0.012)	0.688 (0.013)	0.103 (0.009)	0.243 (0.013)
2012	0.9003 (0.0173)		0.9226 (0.0096)	0.832 (0.010)	0.233 (0.012)	

Yearling Chinook	TSW1	TSW2	Spillway Survival (Non-TSW)	Spillway Passage Efficiency	TSW1 Efficiency Dam	TSW2 Efficiency Dam
2006	NA	NA	0.954 (0.007)	0.635 (0.012)	NA	NA
2007	0.935 (0.022)	0.922 (0.033)	0.960 (0.016)	0.571 (0.009)[a]	0.168 (0.009)	0.076 (0.006)
2008	0.906 (0.026)	0.965 (0.020)	0.956 (0.009)	0.657 (0.012)	0.102 (0.008)	0.077 (0.007)
2009	0.984 (0.016)	0.961 (0.018)	0.954 (0.009)	0.538[b]	0.045 (0.006)	0.091 (0.008)
2012	0.9307 (0.0242)		0.9257 (0.0090)	0.725 (0.012)	0.083 (0.008)	

Subyearling Chinook	TSW1	TSW2	Spillway Survival (Non-TSW)	Spillway Passage Efficiency	TSW1 Efficiency Dam	TSW2 Efficiency Dam
2006	NA	NA	0.943 (0.009)	0.540 (0.012)	NA	NA
2007	0.881 (0.027)	0.828 (0.038)	0.921 (0.020)	0.611 (0.010)[a]	0.174 (0.009)	0.096 (0.007)
2008	0.889 (0.026)	0.912 (0.026)	0.918 (0.011)	0.669*	0.093 (0.007)	0.078 (0.007)
2009	0.822 (0.025)	0.847 (0.025)	0.875 (0.014)	0.645*	NA	0.131 (0.008)
2012	NA		0.9201 (0.0062)	0.783 (0.008)	NA	

(a) Adams and Counihan (2009).
(b) Standard error was not reported.

9.5.2 JBS Performance

Prior to the 2012 field season, the JBS outflow pipe was relocated from its original location about 250 ft downstream of the dam to a new location about 1,100 ft downstream of the dam, and extended to terminate in the tailrace approximately 1,200 ft from the shore to reduce predation on outmigrating juvenile salmonids. Single-release survival estimates from the current evaluation indicate there was no improvement in the survival of CH1, and no significant effect on STH survival that can be attributed to the JBS relocation; however, there was a noticeable increase in the survival estimate for CH0 (Table 9.6).

Table 9.6. Single-Release Survival Estimates Through the Juvenile Bypass System at MCN, from Acoustic Studies Conducted in 2006 through 2009 (Adams and Evans 2011) and 2012. Standard errors are in parentheses.

Species/Stock	2006	2007	2008	2009	2012
STH	0.976 (0.016)	0.859 (0.029)	0.992 (0.011)	0.957 (0.012)	0.9358 (0.0179)
CH1	0.945 (0.012)	0.916 (0.018)	0.946 (0.015)	0.955 (0.010)	0.8922 (0.0173)
CH0	0.921 (0.017)	0.869 (0.025)	0.845 (0.025)	0.855 (0.022)	0.9460 (0.0131)

9.6 Conclusions and Recommendations

Results compiled during the 2012 JSATS evaluation at MCN complied with BiOp performance standards (NOAA Fisheries 2008) for all three runs studied. The standard error of STH was higher than 0.015, but the point estimate was significantly higher than 0.9600, which is a more strenuous requirement. The greater standard error for STH likely was due the loss of 6.74% of STH between R_1 and MCN. Further studies to monitor predation are needed to help determine the cause of increased mortality in this reach. Installing additional detection arrays to the tailwater reach between the tailrace release site and Crow Butte State Park would help identify where most tailwater losses are occurring.

Percent spill during the spring and summer conditions exceeded target spill discharge levels of 40% for the spring (10 April through 19 June) and 50% for the summer (20 June through 31 August). Therefore, survival was estimated season-wide under prevailing conditions with no attempt to identify target conditions.

The relocation of the JBS outfall pipe had positive results for CH0 survival, but there was no noticeable increase in STH survival, and CH1 survival appeared to be significantly lower.

Increased mortality was observed between the tailrace array (CR468) and Crow Butte (CR422). The nesting season gull population of the Blalock Islands increased 550% between 2009 and 2012. Further research is needed to determine the impact this gull colony has on juvenile salmon.

10.0 References

3 Treaty Tribes-Action Agencies. 2008. *Memorandum of Agreement Among the Umatilla, Warm Springs and Yakama Tribes, Bonneville Power Administration, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation,* Portland, Oregon, April 4, 2008. Available online at http://www.salmonrecovery.gov/Files/BiologicalOpinions/3-tribe-AA-MOA-Final.pdf.

Absolon RF, MB Eppard, BP Sandford, GA Axel, EE Hockersmith, and JW Ferguson. 2003. *Effects of Turbines Operating at Two Different Discharge Levels on Survival and Condition of Yearling Chinook Salmon at McNary Dam, 2002*. National Marine Fisheries Service, Seattle, Washington.

Adams NS and SD Evans. 2011. *Summary of Juvenile Salmonid Passage and Survival at McNary Dam – Acoustic Telemetry Studies, 2006-09*. U.S. Geological Survey, Reston, Virginia.

Adams, NS, JM Plumb, TW Hatton, EC Jones, NM Swyers, MD Sholtis, RE Reagan, and KM Cash. 2008. *Survival and Migration Behavior of Juvenile Salmonids at McNary Dam, 2006*. Report No. 2006-W68SBV60478899, U. S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Adams NS, CE Walker, and RW Perry. 2011. *A Multi-Year Analysis of Passage and Survival at McNary Dam, 2004–09*. U.S. Geological Survey Open-File Report 2011-1230, Reston, Virginia.

Axel GA and DB Dey. 2001. *Evaluation of Subyearling Fall Chinook Salmon Passage in the McNary Dam Juvenile Fish Bypass Facility, 2000*. National Marine Fisheries Service, Seattle, Washington.

Axel GA, EE Hockersmith, MB Eppard, BP Sandford, SG Smith, and DB Dey. 2003 *Passage Behavior and Survival of Hatchery Yearling Chinook Salmon Passing Ice Harbor and McNary Dams During a Low Flow Year, 2001*. National Marine Fisheries Service, Seattle, Washington.

Axel G, J Beeman, R Brown, B Eppard, S Fielding, E Hockersmith, T Liedtke, P Christopher, and C Woodley. 2011. *Surgical Protocols for Implanting JSATS Transmitters into Juvenile Salmonids for Studies Conducted for the U. S. Army Corps of Engineers*. Version 1.0. USACE, Portland District, Portland, Oregon.

BRNW (Bird Research Northwest). 2013. *Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River: 2012 Draft Annual Report*. Real Time Research, Inc., Bend, Oregon. Available online at http://www.birdresearchnw.org.

Burnham KP, DR Anderson, GC White, C Brownie, and KH Pollock. 1987. "Design and analysis methods for fish survival experiments based on release-recapture." *American Fisheries Society Monograph* 5.

Deng Z, MA Weiland, TJ Carlson, and MB Eppard. 2010. "Design and Instrumentation of a Measurement and Calibration System for an Acoustic Telemetry System." *Sensors* 10(4):3090−3099. doi:10.3390/s100403090.

Deng ZD, MA Weiland, T Fu, TA Seim, BL Lamarche, EY Choi, TJ Carlson, and MB Eppard. 2011. "A Cabled Acoustic Telemetry System for Detecting and Tracking Juvenile Salmon: Part 2. Three-Dimensional Tracking and Passage Outcomes." *Sensors* 11(6):5661−5676. doi:10.3390/s110605661.

Elandt-Johnson RC and NL Johnson. 1980. *Survival Models and Data Analysis*. John Wiley & Sons, New York.

Evans SD, CE Walker, SJ Brewer, and NS Adams. 2010. *Assessing Survival of Mid-Columbia River released juvenile salmonids at McNary Dam, WA, 2008-09*. U.S. Geological Survey Open-File Report 2010-1237, Reston, Virginia.

Lady JM, P Westhagen, and JR Skalski. 2012. *Program ATLAS 1: Active Tag Life Adjusted Survival.* Columbia Basin Research, School of Aquatic and Fishery Sciences, University of Washington, Seattle, Washington.

Li T and JJ Anderson. 2009. "The vitality model: A way to understand population survival and demographic heterogeneity." *Theoretical Population Biology* 76:118–131.

Martinson RD, GM Kovalchuk, and D Ballinger. 2010. *Monitoring of Downstream Salmon and Steelhead at Federal Hydroelectric Facilities.* Annual Report. Project No. 87-127-01, Pacific States Marine Fisheries Commission, The Dalles, Oregon.

NOAA (National Oceanic and Atmospheric Administration). 2008. *Biological Opinion – Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program.* National Marine Fisheries Service (NOAA Fisheries) – Northwest Region, Seattle, Washington. Available at: http://www.salmonrecovery.gov/.

Roby DD, K Collis, DE Lyons, A Evans, JY Adkins, Y Suzuki, P Loschl, T Lawes, K Bixler, B Cramer, A Peck-Richardson, M Hawbecker, N Hostetter, E Dykstra, J Harms, W Mashburn, J Tennyson, N Ventolini, RD Ledgerwood, and S Sebring. 2012. R*esearch, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River. Final 2011 Annual Report*. Bonneville Power Administration and U.S. Army Corps of Engineers, Portland, Oregon.

Seber GAF. 1982. *The Estimation of Animal Abundance*. MacMillan, New York.

Skalski JR, RA Buchanan, RL Townsend, TW Steig, and S Hemstrom. 2009. "A multiple-release model to estimate route-specific and dam passage survival at a hydroelectric project." *North American Journal of Fisheries Management* 29:670–679.

Skalski JR, RL Townsend, TW Steig, and S Hemstrom. 2010. "Comparison of two alternative approaches for estimating dam passage survival of salmon smolts." *North American Journal of Fisheries Management* 30:831–839.

Titzler PS, GA McMichael, and JA Carter. 2010. "Autonomous acoustic receiver deployment and mooring techniques for use in larger rivers and estuaries." *North American Journal of Fisheries Management* 30:853−859.

Townsend RL, JR Skalski, P Dillingham, and TW Steig. 2006. "Correcting bias in survival estimation resulting from tag failure in acoustic and radiotelemetry studies." *Journal of Agricultural Biology and Environmental Statistics* 11(2):183–196.

USACE (U.S. Army Corps of Engineers). 2012a. *Federal Columbia River Power System Juvenile Dam Passage Performance Standard and Metrics*. Northwestern Division, Portland, Oregon.

USACE (U.S. Army Corps of Engineers). 2012b. *Fish Passage Plan: Corps of Engineers Projects*. Northwestern Division, Portland, Oregon.

Watkins WA and WE Schevill. 1972. "Sound source location by arrival-times on a non-rigid three-dimensional hydrophone array." *Deep-Sea Research* 19:691−706.

Weiland MA, ZD Deng, TA Seim, BL Lamarche, EY Choi, T Fu, TJ Carlson, AI Thronas, and MB Eppard. 2011. "A cabled acoustic telemetry system for detecting and tracking juvenile salmon: Part 1. Engineering design and instrumentation." *Sensors* 11(6):5645–5660. doi:10.3390/s110605645.

Appendix A

Review of Fish Condition Associated with Juvenile Salmon Collected and Tagged for the Lower River Survival Study, 2012

Appendix A

Review of Fish Condition Associated with Juvenile Salmon Collected and Tagged for the Lower River Survival Study, 2012

Prepared by CM Woodley and KA Wagner

In 2012, 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, 2012 (herein referred to as the Lower Columbia River [LCR] Survival Study) 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 FCRPS Biological Opinion (BiOp; NOAA Fisheries 2008) and the Columbia Basin Fish Accords (Fish Accords; Three Treaty Tribes-Action Agencies 2008).

To evaluate fish condition throughout various stages of the tagging process, gross necropsy observations were investigated in yearling Chinook salmon (CH1) and juvenile steelhead (STH) in the spring and subyearling Chinook salmon (CH0) in the summer of 2012. 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 BON SMF using the sort-by-code (SBC) system as an assessment of the 2012 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 an essential technology for observing 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. 2001; 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). This assumption was first investigated using gross necropsy and physiological markers in the 2010 LCR survival study. Prior to this, tag and/or tagging effects were 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 minimal 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 that transmitter presence and/or the tagging process result in negative effects, 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 often 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 exiting 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 determined, corrections for transmitter loss can be calculated into survival models. To account for transmitter loss and/or expulsion, a surgeon feedback task was included in the 2011 LCR survival study. More specifically, a subsample of tagged fish was examined 24 h after tagging and then 7 d later to assess the quality of surgery and the likelihood of tag expulsion or drop. This effective mechanism allowed for feedback to the surgeon by 24 h and 7 d post-surgery of the weekly subsampling of tagged fish. This added task, provided information to the surgeons without having to conduct a classic tag expulsion study. Though tag expulsion studies are useful, retaining out-migrating juvenile salmon tends to result in additional stress on the fish and subsequently accelerated disease rates and mortality (Woodley et al. 2010).

The 2012 LCR survival study examined the survival model assumption 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 at the John Day Dam (JDA) SMF with those of tagged fish 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, which were not examined in previous survival studies, can critically affect the results and conclusions of research and monitoring programs. In 2010, we introduced fish condition metrics as a way to better evaluate this assumption (Weiland et al. 2013). In both 2010 and 2011, this approach indicated that external observations were not necessarily good indicators of internal condition or 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. In addition, internal damage was more extensive in the tagged fish and fish collected in the SBC system, which was hypothesized to cause increased physiological costs, delayed mortality, decreased performance, and altered behavior (Jepsen et al. 2002, Lacroix et al. 2004; Welch et al. 2007). In 2011, given the abbreviated season and high flows, fish condition monitoring effort was not conducted in the summer.

Besides affecting the condition of the fish, surgical outcomes can affect fish performance and survival. 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). And thus, surgeon performance can cause behavioral or physiological differences between tagged fish and run-of-river populations. Therefore, our experimental design in 2012 allowed surgeons to assess fish condition and/or surgeries as a predictor of survival.

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 (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; however, the techniques are lethal and limited in the ability to assess nutrition, immune, and trauma conditions (Carlson et al. 2011; Woodley et al. 2011). Understanding stressor effects on fish encountering hydroelectric systems or other underwater hazards and how the stressors affect individual condition, performance, and behavior will help 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 with AMTs and PITs 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 changes in physiological state as a result of handling, the effects of the tags, and the tagging process. The goal of the fish condition research was to further define measures used for population viability analyses that assess the vulnerability of a population to the FCRPS and assist with the ranking of management priorities based on the condition of fish moving through the FCRPS.

A.2 Methods and Materials

This study was conducted during a 5-wk sampling period in spring 2012 and a 6-wk sampling period in summer 2012. It 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 spring 2012, CH1 and STH were collected, tagged, and sampled from late April to early June. In summer 2012, CH0 were collected, tagged, and sampled from mid-June through late-July. Only fish with a fork length between 84 and 288 mm were used for this study. All study fish were collected at the JDA (rkm 349) SMF and sorted into one of the following four treatment groups:

- 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 accepted into the concurrent LCR survival study, 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 >5%, >20% scale loss, etc. Fish with these conditions may not be capable of outmigration or may have high stress levels, and the potential for delayed mortality; however, they are still representative of a small percentage of juvenile out-migrating salmon.
- 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 were selected for tag implantation, implanted with a JSATS AMT and PIT, allowed to recover for at least 24 h, transported and released in the river near Roosevelt, Washington, and recaptured downriver at BON (travel time 4–10 d) using the SBC system. Fish may have been held up to 24 h at BON before sampling.

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

Table A.1. Sample sizes for Fish Condition Assessment by species and week.

Species	Treatment Group	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Total**
CH1	ROR	20	20	20	20	20		**100**
	PRT	20	20	20	20	20		**100**
	TGD	20	12	25	19	20		**96**
	SBC	8	24	6	5	11		**54**
STH	ROR	20	20	20	20	20		**100**
	PRT	20	20	20	20	20		**100**
	TGD	20	28	15	21	20		**104**
	SBC	1	3	0	5	3		**12**
CH0	ROR	20	20	20	20	20	20	**120**
	PRT	20	20	20	20	20	20	**120**
	TGD	20	20	20	20	20	20	**120**
	SBC	0	22	9	12	20	15	**78**

A.2.2 Surgical Implantation of Transmitters

For the fish in the TGD and SBC treatment groups, each was surgically implanted with a PIT and AMT. The weights of the tags varied with species. CH0 and CH1 were implanted with a single-battery JSATS AMT weighing 0.30 g in air and 0.19 g in water, which combined with the PIT (0.085 g in air) weighed 0.31 g in air. STH were implanted with a single-battery JSATS AMT weighing 0.43 g in air and a PIT weighing 0.085 g in air (combined weight of 0.52 g). 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 5- to 7-mm incision was made along the *linea alba*, between the pectoral fins and pelvic girdle. A PIT and AMT were inserted into the coelomic cavity through the incision. The incision was closed with two, simple interrupted sutures using a 1×1×1×1 wrap knot with 5-0 Monocryl™ sutures. Post-surgery, fish were placed into 5-gal 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 SMFs, dissolved oxygen levels, signs of disease, and general health. Water temperatures (Figure A.1) and dissolved gas percent increased (Figure A.2) at the JDA SMF and BON SMF over the study period.

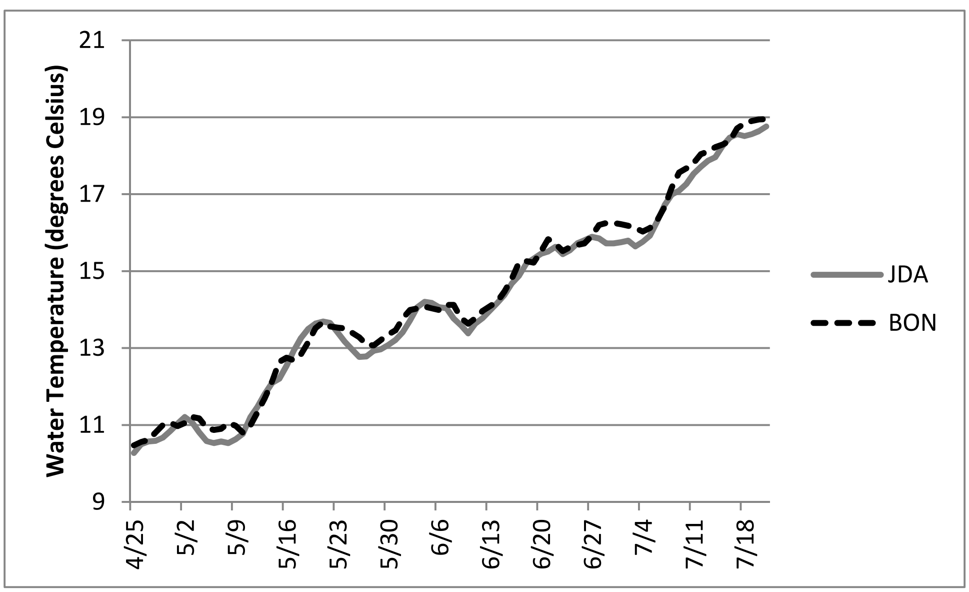


Figure A.1. Water Temperature from 25 April through 21 July, 2013 at the JDA SMF and the BON SMF

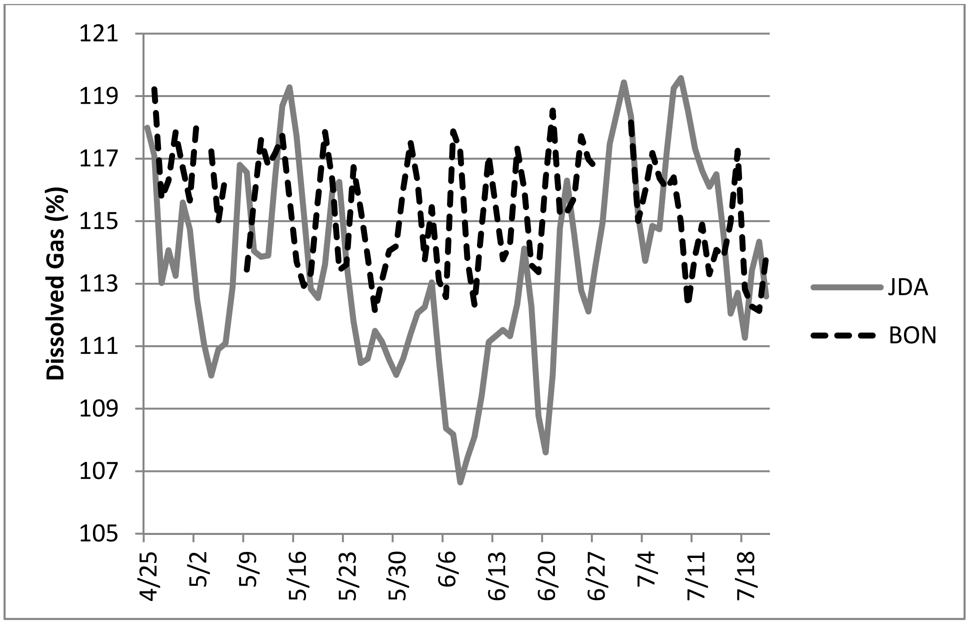


Figure A.2. Total Dissolved Gas Percent from 25 April through 21 July, 2013 at the JDA SMF and BON SMF

A.2.3 Fish Transportation and Release

For transportation of TGD and SBC fish, 5-gal perforated recovery buckets were placed in insulated transportation totes containing 200 gal 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. The SBC fish (the same fish tagged for the survival studies) were transported to Roosevelt, Washington, and upon arrival, water temperature and dissolved oxygen levels were noted. If needed, 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. The PIT codes from the released fish were logged into the PIT Tag Information System (PTAGIS) fish database program. The 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 100-gal 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 1.5-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 for their presence/absence (Table A.2).

After necropsy, brain tissue, liver, spleen, and epaxial white muscle posterior the dorsal fin were harvested from each fish, placed in individual cryovials, and frozen at –80°C for archiving condition via biochemistry analyses.

Table A.2. An abbreviated list of observations made on 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

A.2.5 Statistical Analysis

To evaluate the effects of tagging and to determine if tagged fish are representative of in-river fish, necropsy observations of the ROR, PRT, and TGD treatment groups were compared. To determine 24-h and in-river effects of tagging, necropsy observations and physiological metrics of the PRT, TGD, and SBC treatment groups were compared. Necropsy observations for these analyses were totaled per fish and analyzed with analyses of variance (ANOVAs), followed by Tukey's honestly significant difference (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. Between-species comparisons were not made. All analyses were performed using JMP® (Version 10) and the level of significance was tested at $P < 0.05$.

A.3 Results

A.3.1 Data Adjustments

No data adjustments were made.

A.3.2 Size Variability

At the time of sampling for ROR and PRT fish and at the time of tagging for TGD and SBC fish, fork lengths (FLs) and wet weights (WWs) ranged from 99 to 256 mm and 9.5 to 143.4 g for CH1; from 115 to 280 mm and 14.0 to 165.0 g for STH; 84 to 152 mm and 9.5 g to 35.9 g for CH0 (Table A.3). Fish size (FL and WW) significantly varied by treatment for CH1 (both $F(3, 358) < 5.41$; $P < 0.002$), and for STH (both $F(3, 302) < 6.12$; $P = 0.0005$; Table A.6). CH0 size (FL and WW) did not significantly vary by treatment (both $F(3, 430) < 0.50$, $P < 0.091$; Table A.6). Wet weight for CH1, STH, and CH0 significantly predicted FL (all $P < 0.0001$; Table A.4). Weekly FL and WW significantly varied over the study period for CH1 and CH0 (all $P < 0.0002$), but was similar across all weeks for STH (all $P > 0.46$; Table A.5; Table A.6). For CH1, FL and WW were significantly greater in the third and fourth sampling weeks compared to the first sampling week ($P < 0.009$). For the CH0, FL and WW were significantly greater in the first and second sampling weeks compared to all other weeks (all $P < 0.0014$)

Table A.3. Average (standard deviation) fork Length and Wet Weight of CH1, STH, and CH0 by Treatment and Sampling Week

Species	Treatment Group	Week 1 (mm; g)	Week 2 (mm; g)	Week 3 (mm; g)	Week 4 (mm; g)	Week 5 (mm; g)	Week 6 (mm; g)
CH1	ROR	137.3 (18.0) 24.4 (10.9)	149.0 (24.4) 34.3 (17.3)	148.3 (19.0) 33.4 (15.9)	170.1 (35.5) 49.6 (31.3)	150.5 (16.3) 33.9 (11.5)	-
	PRT	131.6 (17.0) 22.2 (8.8)	139.4 (16.1) 27.0 (9.1)	145.7 (21.3) 30.4 (14.0)	139.9 (14.3) 25.9 (7.0)	139.0 (11.0) 25.9 (5.8)	-
	TGD	147.1 (20.3) 30.4 (13.2)	141.7 (19.1) 26.1 (11.9)	162.0 (39.3) 43.7 (35.7)	156.4 (33.5) 38.8 (30.2)	143.0 (13.0) 27.7 (8.2)	-
	SBC	135.8 (14.2) 26.4 (10.2)	148.7 (24.9) 33.3 (20.8)	163.7 (36.1) 39.1 (25.3)	145.8 (11.4) 28.2 (8.4)	143.2 (12.7) 25.4 (6.7)	-
STH	ROR	209.8 (32.6) 82.6 (38.1)	215.2 (25.0) 91.3 (26.9)	219.3 (21.0) 88.5 (28.5)	218.3 (17.0) 86.1 (24.0)	204.1 (22.3) 72.6 (21.0)	-
	PRT	201.5 (21.7) 71.9 (23.6)	206.4 (25.3) 78.2 (3.5)	197.9 (27.6) 67.5 (26.9)	210.3 (28.4) 77.9 (29.7)	194.1 (28.1) 62.5 (27.0)	-
	TGD	208.7 (20.2) 76.5 (26.2)	184.1 (38.7) 58.6 (34.9)	202.6 (20.9) 70.4 (18.8)	184.9 (31.1) 56.0 (30.8)	203.4 (26.1) 75.1 (29.7)	-
	SBC	219.0 (0.0) 89.8 (0.0)	213.0 (29.5) 84.1 (41.6)	-	202.6 (18.3) 67.3 (23.3)	187.0 (64.6) 63.1 (48.5)	-
CH0	ROR	118.3 (5.3) 17.5 (3.0)	116.7 (8.5) 16.7 (3.5)	113.5 (7.7) 15.0 (3.3)	109.6 (5.0) 13.2 (1.7)	112.6 (11.3) 14.8 (5.8)	106.5 (5.1) 12.8 (2.2)
	PRT	114.1 (6.0) 14.5 (2.5)	119.1 (7.3) 17.3 (3.5)	108.4 (6.5) 13.0 (2.9)	111.9 (4.1) 13.4 (1.9)	106.6 (5.3) 12.3 (1.9)	109.4 (7.3) 13.3 (2.8)
	TGD	115.7 (5.8) 15.3 (3.0)	116.9 (7.3) 16.3 (3.1)	108.5 (4.1) 12.1 (1.6)	110.0 (4.1) 13.3 (1.5)	108.2 (8.2) 12.6 (3.9)	112.5 (9.6) 14.6 (4.1)
	SBC	-	117.5 (12.4) 16.6 (4.6)	114.9 (6.1) 14.8 (3.1)	113.0 (7.5) 13.7 (2.3)	107.5 (6.9) 12.5 (2.3)	109.2 (6.3) 13.1 (2.5)

Table A.4. Regression Data for Wet Weight to Fork Length Relationship by CH1, STH and CH0

Species	Intercept	Slope	r^2	N	F	P
CH1	-80.18	0.76	0.92	359	4393.9	<0.0001
STH	-129.82	1.00	0.93	303	3732.4	<0.0001
CH0	-31.05	0.40	0.88	434	3237.3	<0.0001

Table A.5. 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 (mm)	SD (mm)	N	Significance
CH1	1	138.3	3.0	67	C
	2	145.2	2.8	76	B, C
	3	153.7	2.9	71	A, B
	4	156.8	2.8	74	A
	5	144.0	2.9	71	B, C
STH	1	206.9	3.7	60	A
	2	200.3	3.4	71	A
	3	206.7	3.9	54	A
	4	201.2	3.9	55	A
	5	199.9	3.6	63	A
CH0	1	116.0	0.9	60	A
	2	117.5	0.8	82	A
	3	110.7	0.9	69	B
	4	110.9	0.9	72	B
	5	108.7	0.8	78	B
	6	109.4	0.9	73	B

Table A.6. Results of Tukey-Kramer HSD Analyses for Wet Weight by Week and by CH1, STH and CH0. Treatment is not included in these relationships.

Species	Week	Mean (g)	SD (g)	N	Significance
CH1	1	25.8	2.4	67	C
	2	30.8	2.2	76	A, B, C
	3	36.7	2.3	71	A, B
	4	39.0	2.2	74	A
	5	28.6	2.3	71	B, C
STH	1	77.3	3.9	60	A
	2	74.4	3.6	71	A
	3	75.9	4.0	55	A
	4	69.9	4.0	55	A
	5	69.7	3.8	63	A
CH0	1	15.8	0.4	60	A
	2	16.7	0.4	82	A
	3	13.6	0.4	69	B
	4	13.3	0.4	72	B
	5	13.1	0.4	79	B
	6	13.5	0.4	73	B

A.3.3 Necropsy Observations

During necropsy, the number of external fish condition observations of the condition for fish in the TGD treatment group was significantly greater than those noted for fish in the ROR and PRT treatment groups for CH1 (both $P \leq 0.0001$), STH (both $P < 0.0007$) and for CH0 (both $P < 0.0001$; Table A.7; Table A.11). For CH1, STH and CH0, the ROR and PRT external observations were non-significant (all $P > 0.53$). This result was not the same for the internal observations where significantly more internal observations (e.g., trauma, tag damage, infection) were noted in the TGD group than in the ROR and PRT groups across the season for each species (CH1, STH, and CH0) (all $P < 0.0001$; Table A.10, Table A.8). 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 irritation included, hematomas, hemorrhaging, deflation, or impressions left on tissue and organs. The above analyses did not include external surgery quality.

Table A.7. ANOVA Results for ROR, PRT, and TGD Comparisons of External and Internal Observations Reported for each Species

	Observation	Means			ANOVA		
Species	Group	ROR	PRT	TDG	Df	*F*	*P*
CH1	External	9.5 ± 0.4	9.8 ± 0.5	16.0 ± 05	2, 304	61.9	<0.0001
	Internal	4.8 ± 0.3	3.8 ± 0.3	6.5 ± 0.3	2, 304	22.1	<0.0001
STH	External	14.4 ± 0.6	14.0 ± 0.5	17.4 ± 0.5	2, 290	11.4	<0.0001
	Internal	6.8 ± 0.3	6.1 ± 0.3	8.1 ± 0.3	2, 290	9.6	<0.0001
CH0	External	5.1 ± 0.3	6.1 ± 0.3	8.4 ± 0.3	2, 357	32.6	<0.0001
	Internal	5.0 ± 0.2	4.2 ± 0.3	9.6 ± 0.3	2, 357	175.4	<0.0001

* Indicate significant differences.

Table A.8. Tukey-Kramer HSD Results for ROR, PRT, and TGD Comparisons of Internal Observations Reported for each Species

Species	Treatment Group	External HSD P	Internal HSD P
CH1	ROR : PRT	0.903	0.027*
	PRT : TGD	<0.0001*	<0.0001*
	TGD : ROR	<0.0001*	0.0001*
STH	ROR : PRT	0.854	0.281
	PRT : TGD	<0.0001*	<0.0001*
	TGD : ROR	0.0007*	0.0224*
CH0	ROR : PRT	0.053	0.030*
	PRT : TGD	<0.0001*	<0.0001*
	TGD : ROR	<0.0001*	<0.0001*

* Indicate significant differences.

For STH and CH0, the external observations noted in the SBC treatment group were significantly greater than in the TGD or the PRT treatment groups (all $P < 0.0001$; Table A.9, Table A.10. For CH1, more external observations were noted in the TGD and SBC treatment groups than in the PRT groups (both P < 0.0001). The mean internal observations for CH1, STH, and CH0 were greatest for the SBC treatment groups followed by TGD and then PRT treatment groups (all $P < 0.0001$; Table A.10).

Table A.9. 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	9.8 ± 0.5	16.0 ± 0.5	15.3 ± 0.7	2, 247	45.76	< 0.0001*
	Internal	3.8 ± 0.4	6.5 ± 0.3	10.5 ± 0.5	2, 247	54.8	< 0.0001*
STH	External	14.0 ± 0.6	17.4 ± 0.5	23.0 ± 1.6	2, 213	19.44	< 0.0001*
	Internal	6.1 ± 0.3	8.1 ± 0.3	13.4 ± 1.0	2, 213	27.96	< 0.0001*
CH0	External	6.1 ± 0.3	8.4 ± 0.3	10.9 ± 0.4	2, 315	40.59	< 0.0001*
	Internal	4.2 ± 0.3	9.6 ± 0.3	12.8 ± 0.4	2, 315	137.87	< 0.0001*

* Indicate significant differences.

Table A.10. 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	< 0.0001*	< 0.0001*
	TGD : SBC	0.6922	< 0.0001*
	PRT : SBC	< 0.0001*	< 0.0001*
STH	PRT : TGD	< 0.0001*	0.0001*
	TGD : SBC	0.0026*	< 0.0001*
	PRT : SBC	< 0.0001*	< 0.0001*
CH0	PRT : TGD	< 0.0001*	< 0.0001*
	TGD : SBC	< 0.0001*	< 0.0001*
	PRT : SBC	< 0.0001*	< 0.0001*

* Indicate significant differences.

To further elucidate factors that may have influenced the frequency of observed responses for each treatment group within and among species, ANOVAs were conducted to examine observed responses over time. External and internal observations were pooled and assigned a week of collection (WK 1 through 6) based on the 5−6 wk for a tagging season (Table A.11). For CH1, WK 1 was significantly greater than WK 2−5 ($P \leq 0.0004$; Table A.12). The general trend for CH1 indicated a peak in external and internal observations in WK 3. This pattern was also detectable in the STH. For STH, though, WK 4 had significantly more observations noted than WKs 1 and 2 ($P \leq 0.0229$; Table A.12). For CH0, the trends were less discernible with a peak in WK 2, followed by WKs 5 and 6. The total observations observed in WK 2 were significantly greater than in WKs 1, 3 and 4 (all $P \leq 0.0236$).

Table A.11. ANOVA Results for Week Comparisons of External and Internal Observations Reported for Each Species

	Means						ANOVA		
Species	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	Df	*F*	*P*
CH1	12.1 ± 1.0	19.4 ± 0.9	20.7 ± 1.0	19.8 ± 0.9	17.8 ± 1.0	-	4, 356	12.6020	< 0.0001*
STH	17.9 ± 1.0	22.1 ± 0.9	24.6 ± 1.1	26.9 ± 1.1	23.6 ± 1.0	-	4, 300	10.5807	<0.0001*
CH0	12.4 ± 0.9	17.1 ± 0.8	13.3 ± 0.9	13.2 ± 0.9	15.3 ± 0.8	16.0 ± 0.9	5, 432	4.5788	0.0004*

Table A.12. Tukey-Kramer HSD Results for Week Comparisons of External and Internal Observations Reported for Each Species

Species	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6
CH1	B	A	A	A	A	-
STH	C	B	A, B	A	A, B	-
CH0	B	A	B	B	A, B	A, B

Fish size was examined to determine if damage or disease was related to the necropsy observations. After pooling all species, runs, and treatments, smaller fish (as measured by FL) had more trauma- and disease-related external and internal observations than larger fish. The analysis yielded a two-factor solution, which accounted for 98.9% of the variance (all $P < 0.0001$; Figure A.3). The first factor naturally focused on the length and weight relationship explaining 76.8% of the variation. The second factor focused on the relationship between necropsy observations and adipose fin clipping, shown below as internal and external combined, explaining 22.1% of the data variation.

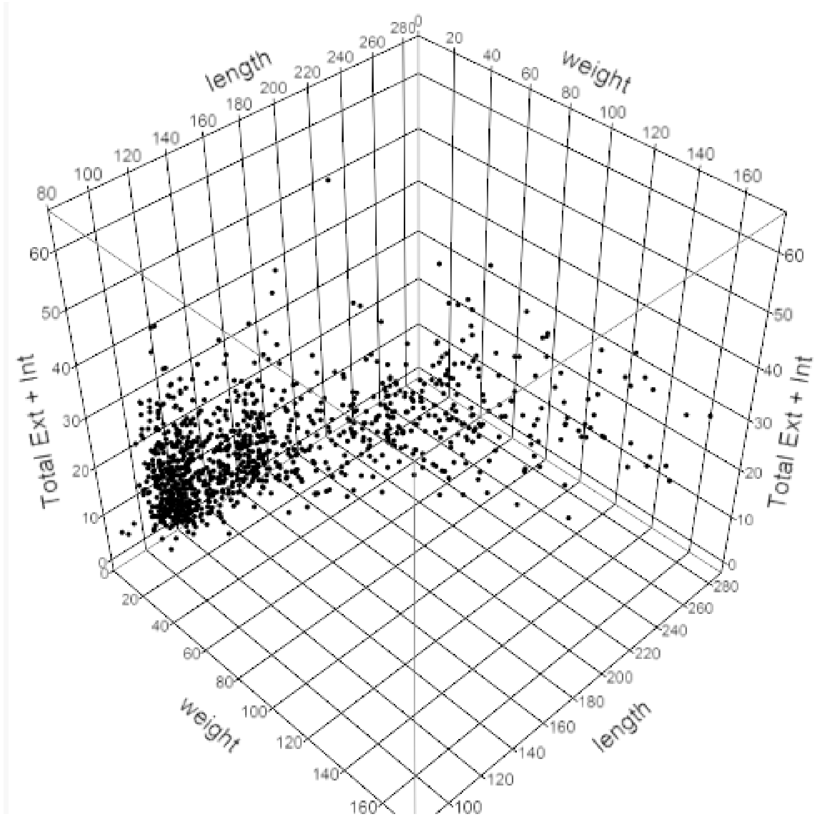


Figure A.3. The Frequency of External and Internal Observations made per Fish Compared to the Fork Length and Wet Weight of all Species and Treatments Combined

A.4 Discussion

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 at each phase of the tagging process. Fish were randomly sampled 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 examination of their conditions. External observations, when summed for total observations made per fish, for each species, indicated that there was no difference between the ROR and PRT fish. From this we inferred that the selection process during collection, which excluded moribund or physically deformed fish, was a preventative mechanism for selection of fish healthy enough to undergo surgical implantation, while still representing the majority of in-river migrants. The TGD group for each species had significantly more external condition observations than the ROR and PRT treatments. This indicates that handling, surgery, and transportation increased the external trauma or disease observations noted compared to the ROR and PRT fish selected for surgery. In general, the internal observations of trauma and disease were present in each treatment group with a greater prevalence in the TGD fish followed by the ROR fish and then the PRT fish. Trauma associated with damage from the tagger, incised tissue or tag, and infection were observed most frequently as the causes of damage. For example, the internal examinations of fish in the TGD treatment group noted that the spleen, swim bladder, and fat were most often damaged or irritated by tag presence and pressure, which deflated or left impressions in tissues and organs and caused hematomas and hemorrhaging. The effects of tags and tagging within the first 24 h were quite pronounced in the TGD sample fish, though not further examined, these effects are likely indicative of altered performance after release and perhaps even survival.

The study design allowed for the comparison of the PRT fish, TGD fish, and fish released in river that were later retrieved using the SBC system at BON. Fish collected at BON were from the uppermost release point, McNary, taking 4−10 d to travel to BON. More observations of external disease and trauma were noted for the acoustic-tagged CH1, STH, and CH0 recollected in the BON SBC system than for the TGD and PRT treatment groups, with the exception of external observations of STH. Internally, more disease and trauma were observed in the SBC treatment group than in the PRT or TGD treatment groups for CH1, STH, and CH0. Similar to observations noted above, tag and surgeon damage was a major factor causing internal trauma.

The fish condition necropsies also indicated that the overall condition of each species changed over time. The general trend of condition for CH1, STH, and CH0 indicated that at the beginning of each tagging session (WK 1), the juvenile salmon, regardless of species, were in better condition than the fish toward the end of the tagging session (WK 5 or WK 6). 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.

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 health or physiological state. The internal physical damage, which 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) that would not be detected using traditional external observations. 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 from the development of 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 biochemistry analyses further elaborate on fish condition for each treatment and warrant additional investigations into non-lethal fish condition assessments that do not underestimate condition.

A.6 References

3 Treaty Tribes-Action Agencies. 2008. *Memorandum of Agreement Among the Umatilla, Warm Springs and Yakama Tribes, Bonneville Power Administration, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation*, Portland, Oregon, April 4, 2008. Available at: http://www.salmonrecovery.gov/Files/BiologicalOpinions/3-tribe-AA-MOA-Final.pdf.

Baras E and L Westerloppe. 1999. "Transitional expulsion of surgically implanted tags by African *catfish Heterobranchus longifilis of variable size and age." Transactions of the American Fisheries Society* 128(4):737–746.

Brown RS, SJ Cooke, WG Anderson, and RS Scott. 1999. "Evidence to challenge the "2% rule" for biotelemetry." *North American Journal of Fisheries Management* 19:867–871.

Brown RS, RA Harnish, KM Carter, JW Boyd, KA Deters, and MB Eppard. 2010. "An evaluation of the maximum tag burden for implantation of acoustic transmitters in juvenile Chinook salmon." *The American Journal of Fisheries Management* 30:499–505.

Carlson TJ, GE Johnson, CM Woodley, and JR Skalski. 2011. *Compliance Monitoring of Underwater Blasting for Rock Removal at Warrior Point – Columbia River Channel Improvement Project, 2009/2010*. PNNL-20388, prepared for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, by Pacific Northwest National Laboratory, Richland, Washington.

CBSPSC (Columbia Basin Surgical Protocol Steering Committee). 2011. "Surgical Protocols for Implanting JSATS Transmitters into Juvenile Salmonids for Studies Conducted for the U.S. Army Corps of Engineers." Volume 1, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Chittenden CM, KG Butterworth, KF Cubitt, MC Jacobs, A Ladouceur, DW Welch, and RS McKinley. 2009. "Maximum tag to body size ratios for an endangered coho salmon (*O. kisutch*) stock based on physiology and performance." *Environmental Biology of Fishes* 84(1):129–140.

Clemens BJ, SP Clements, MD Karnowski, DB Jepsen, AI Gitelman, and CB Schreck. 2009. "Effects of transportation and other factors on survival estimates of juvenile salmonids in the unimpounded lower Columbia River." *Transactions of the American Fisheries Society* 138(1):169–188.

Deriso RB, MN Maunder, and JR Skalski. 2007. "Variance estimation in integrated assessment models and its importance for hypothesis testing." *Canadian Journal of Fisheries and Aquatic Sciences* 64(2):187–197.

Faber DM, MA Weiland, R Moursund, TJ Carlson, N Adams, and D Rhondorf. 2001. *Evaluation of the Fish Passage Effectiveness of the Bonneville I Prototype Surface Collector Using Three-Dimensional Ultrasonic Fish Tracking*. PNNL-13526, prepared for the U.S. Army Corps of Engineers, Portland, Oregon, Portland, Oregon, by Pacific Northwest National Laboratory, Richland, Washington.

Folmar LC and WW Dickhoff. 1980. "The parr-smolt transformation (smoltification) and seawater adaptation in salmonids: A review of selected literature." *Aquaculture* 21:1–37.

Fontenot DK and DL Neiffer. 2004. "Wound management in teleost fish: Biology of the healing process, evaluation, and treatment." *The Veterinary Clinics: Exotic Animal Practice* 7(1):57–86.

Greenburg JA and RM Clark. 2009. "Advances in suture material for obstetric and gynecologic surgery." *Reviews in Obstetrics and Gynecology* 2(3):146–158.

Halvorsen MB, BM Casper, CM Woodley, TJ Carlson, and AN Popper AN. 2011. *Predicting and mitigating hydroacoustic impacts on fish from pile installations.* NCHRP Research Results Digest 363, Project 25-28, National Cooperative Highway Research Program, Transportation Research Board, National Academy of Sciences, Washington, D.C. Available at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=763.

Harms CA. 2005. "Surgery in fish research: Common procedures and postoperative care." *Lab Animal* 34(1):28–34.

Jepsen N, A Koed, EB Thorstad, and E Baras. 2002. "Surgical implantation of telemetry transmitters in fish: How much have we learned?" *Hydrobiologia* 483(1–3):239–248.

Lacroix GL, D Knox, and P McCurdy. 2004. "Effects of implanted dummy acoustic transmitters on juvenile Atlantic salmon." *Transactions of the American Fisheries Society* 133(1):211–220.

Lucas MC. 1989. "Effects of implanted dummy transmitters on mortality, growth and tissue reaction in rainbow trout, *Salmo gairdneri* Richardson." *Journal of Fish Biology* 35:577–587.

Markus HC. 1933. "The effects of tags upon fresh water fishes." *American Fisheries Society* 63(1):319–325.

Martinelli TL, HC Hansel, and RS Sively. 1998. "Growth and physiological responses to surgical and gastric radio transmitter implantation techniques in subyearling Chinook salmon (*Oncorhynchus tshawytscha*)." *Hydrobiologia* 371/372:79–87.

Marty GD and RC Summerfelt. 1986. "Pathways and mechanisms for expulsion of surgically implanted dummy transmitters from channel catfish." *Transactions of the American Fisheries Society* 115:577–589.

Moore A, IC Russell, and ECE Potter. 1990. "The effects of intraperitoneally implanted dummy acoustic transmitters on the behavior and physiology of juvenile Atlantic salmon, *Salmo salar* L." *Journal of Fish Biology* 37:713–721.

Mulcahy DM. 2003. "Surgical implantation of transmitters into fish." *ILAR Journal* 44(4):295–306.

NOAA Fisheries. 2008. *Biological Opinion (BiOp) on the operation of the Federal Columbia River Power System (FCRPS)*. U.S. Department of Commerce, National Marine Fisheries Service, Northwest Regional Office, Seattle, Washington.

Petering RW and DL Johnson. 1991. "Suitability of a cyanoacrylate adhesive to close incisions in black crappies used in telemetry studies." *Transactions of the American Fisheries Society* 120:535–537.

Ploskey GR, MA Weiland, JS Hughes, SR Zimmerman, RE Durham, ES Fischer, J Kim, RL Townsend, JR Skalski, and RL McComas. 2007. *Acoustic Telemetry Studies of Juvenile Chinook Salmon Survival at the Lower Columbia Projects in 2006*. PNNL-16560, prepared for U.S. Army Corps of Engineers District, Portland, Oregon, by Pacific Northwest National Laboratory, Richland, Washington.

Ploskey GR, MA Weiland, JS Hughes, SR Zimmerman, RE Durham, ES Fischer, J Kim, RL Townsend, JR Skalski, RA Buchanan, and RL McComas. 2008. *Survival of Juvenile Chinook Salmon Passing the Bonneville Dam Spillway in 2007*. PNNL-18113, prepared for U.S. Army Corps of Engineers, Portland District, Portland, Oregon, by Pacific Northwest National Laboratory, Richland, Washington.

Scruton DA, CJ Pennell, CE Bourgeois, RF Goosney, TR Porter, and KD Clarke. 2007. "Assessment of a retrofitted downstream fish bypass system for wild Atlantic salmon (*Salmo salar*) smolts and kelts at a hydroelectric facility on the Exploits River, Newfoundland, Canada." *Hydrobiologia* 582(1):155–169.

Skalski JR. 1998. "Estimating season-wide survival rates of outmigrating salmon smolt in the Snake River, Washington." *Canadian Journal of Fisheries and Aquatic Sciences* 55(3):761–769.

Skalski JR, J Lady, R Townsend, AE Giorgi, JR Stevenson, CM Peven, and RD McDonald. 2001. "Estimating in-river survival of migrating salmonids smolts using radiotelemetry." *Canadian Journal of Fisheries and Aquatic Sciences* 58:1987–1997.

Stephenson JR, AJ Gingerich, RS Brown, BD Pflugrath, Z Deng, TJ Carlson, MJ Langeslay, ML Ahmann, RL Johnson, and AG Seaburg. 2010. "Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory." *Fisheries Research* 106(3):271–278.

Summerfelt RC and LS Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213–263 in CB Schreck and PB Moyle (eds). *Methods for Fish Biology*. American Fisheries Society, Bethesda, Maryland.

van Rijssel EJ, R Brand, C Admiraal, I Smit, and JB Trimbos. 1989. "Tissue reaction and surgical knots: The effect of suture size, knot configuration, and knot volume." *Obstetrics and Gynecology* 74(1):64–68.

Weiland, MA, CM Woodley, GR Ploskey and twenty-three coauthors. 2013. *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival at John Day Dam, 2010*. PNNL-22177, Pacific Northwest National Laboratory, Richland, Washington.

Welch DW, SD Batten, and BR Ward. 2007. "Growth, survival, and tag retention of steelhead trout (*O. mykiss*) surgically implanted with dummy acoustic tags." *Hydrobiologia* 582:289–299.

Winans GA and RS Nishioka. 1987. "A multivariate description of change in body shape of coho salmon (*Oncorhynchus kisutch*) during smoltification." *Aquaculture* 66:235–245.

Woodley CM, KM Knox, SM Carpenter, KM Carter, JA Kim, KA Wagner, IM Royer and RS Brown. 2011. *The Effects of Surgically Implanted JSATS Acoustic Micro-Transmitter on Expulsion and Survival of Juvenile Chinook and Steelhead, 2010*. PNNL-20570, Pacific Northwest National Laboratory, Richland, Washington.

Woodley CM, KA Wagner, KM Knox. 2012. *Determine the Influence of Time Held in "Knockdown" Anesthesia on Survival and Stress of Surgically Implanted Juvenile Salmonids*. PNNL-21096, Pacific Northwest National Laboratory, Richland, Washington.

Zale AV, C Brooke, and WC Fraser. 2005. "Effects of surgically implanted transmitter weights on growth and survival stamina of small adult Westslope cutthroat trout." *Transactions of the American Fisheries Society* 134:653–660.

A.7 Acknowledgments

We thank the project staff and individuals that helped us develop our approach. From PNNL, we thank Susan Ennor, Danielle Saunders, Jina Kim, Guri Roesijadi, Charlie Brandt, Gary Gill, Gayle Dirkes, Eric Fischer, Gary Johnson, Brian LaMarche, Jayson Martinez, Gene Ploskey, Jeni Smith, and Nathan Trimble. From PSMFC, we thank Greg Kovalchuk and staff at John Day Dam Juvenile Smolt Facility, Dean Ballinger and staff at Bonneville Dam Juvenile Smolt Facility, Rick Martinson and Nicole Tancreto for providing technical support and advice.

Appendix B

Assessment of Survival Model Assumptions

Appendix B

Assessment of Survival Model Assumptions

Survival model assumptions are assessed here to ensure that assumptions of the virtual/paired-release survival model design are not violated, drawing question to the validity of the model results. The assessment of assumptions cover in this section includes surgeon effects/handling mortality and tag shedding, fish size distribution, tag-life corrections, arrival distributions, and downstream mixing.

B.1 Surgeon Effects

B.1.1 Surgeon Effects – Spring Study

A total of eight different surgeons assisted in tagging all yearling Chinook salmon and steelhead smolts associated with the Juvenile Salmon Acoustic Telemetry System (JSATS) survival studies at McNary Dam in 2012. Surgeon effort was found to be balanced across the five release locations regardless of whether the data were pooled across species $\left(P\left(\chi^2_{28} \geq 7.8016\right) = 0.9999\right)$, or analyzed separately for yearling Chinook salmon $\left(P\left(\chi^2_{28} \geq 4.3024\right) \approx 1\right)$ or steelhead $\left(P\left(\chi^2_{28} \geq 5.1934\right) \approx 1\right)$ (Table B.1).

Surgeon effort was examined within each of the 32 replicate releases conducted over the course of the spring study (Table B.2, Table B.3). Surgeon effort was found to be balanced within replicates 1, 5, 9, 13, 17, 21, 25, and 29 $(P \approx 1)$. To accommodate staff time off during the month-long study, surgeon effort was conditionally balanced within the individual project releases (i.e., R_1–R_3, R_4–R_5) (Table B.2, Table B.3) for the remainder of the replicate release groups. This conditional and unconditional balance within replicates is the reason for the overall balance observed in Table B.1.

To test for surgeon effects, reach survivals and cumulative survivals were calculated for fish tagged by different staff members based on release location (i.e., R_1, …, R_5) and species (Table B.4). Of the 38 tests of homogeneous reach survivals, 6 were found to be significant at α = 0.10 (i.e., 15.8%). By chance alone, one might expect 10% of the 38 tests (i.e., 4) to be significant at α = 0.10 when no effect exists. Similarly, we found 11 of 38 tests of homogeneous cumulative survival to be significant at α = 0.10 (i.e., 28.9%). The percentages of rejections are higher than one might expect to see, but detailed examination of the data indicates no particular pattern in the results. No particular surgeon had fish with consistently lower survival rates. All surgeons had fish releases with the highest and lowest reach survival rates. For some unknown reason, there is more heterogeneity among the survival estimates across surgeons than expected by binomial change alone, but no identifiable below-average surgeons were observed. For this reason, all fish tagged by all surgeons were included in the subsequent survival analyses.

Table B.1. Numbers of Yearling Chinook Salmon and Steelhead Tagged by Each Staff Member by Release Location (i.e., R_1, R_2, ...) During the Study in Spring 2012. Chi-square tests of homogeneity were not significant for (a) yearling Chinook salmon or (b) steelhead smolts.

a. Combined yearling Chinook salmon and steelhead

Release	A	B	C	D	E	F	G	H	*P*-value
R1_CR503	457	297	348	358	288	286	293	472	
R2_CR468	361	257	309	309	248	258	249	406	
R3_CR422	357	258	311	310	235	262	253	412	
R4_CR346	310	222	247	258	190	227	209	334	
R5_CR325	306	223	238	259	199	231	207	332	
Chi-square = 7.8016				df = 28					0.9999

b. Yearling Chinook salmon

Release	A	B	C	D	E	F	G	H	*P*-value
R1_CR503	225	152	172	179	141	145	145	240	
R2_CR468	182	129	155	155	122	127	121	207	
R3_CR422	180	131	157	154	116	131	126	205	
R4_CR346	153	112	124	129	94	113	102	170	
R5_CR325	146	115	115	131	101	115	102	170	
Chi-square = 4.3024				df = 28					1

c. Steelhead

Release	A	B	C	D	E	F	G	H	*P*-value
R1_CR503	232	145	176	179	147	141	148	232	
R2_CR468	179	128	154	154	126	131	128	199	
R3_CR422	177	127	154	156	119	131	127	207	
R4_CR346	157	110	123	129	96	114	107	164	
R5_CR325	160	108	123	128	98	116	105	162	
Chi-square = 5.1934				df = 28					1

Table B.2. Contingency Tables with Numbers of Yearling Chinook Salmon Tagged by Each Staff Member per Release Location within a Replicate Release. A total of 32 replicate day or night releases were performed over the course of the spring 2012 study. Results of chi-square tests of homogeneity presented in the form of *P*-values.

a. Replicate 1

Release	C	G	E	H	*P*-value
R1_CR503	10	9	9	16	0.9983
R2_CR468	10	7	8	12	
R3_CR422	10	8	7	12	
R4_CR346	9	6	6	11	0.9463
R5_CR325	7	7	6	12	
Chi-square = 0.9358		df = 12			1

b. Replicate 2

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	10	9	9	15	0	0	0	0	
R2_CR468	11	6	8	13	0	0	0	0	0.9864
R3_CR422	12	7	7	12	0	0	0	0	
R4_CR346	0	0	0	0	10	6	9	7	0.9416
R5_CR325	0	0	0	0	10	7	7	8	
Chi-square = 185.6299				df = 28					<0.0001

c. Replicate 3

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	10	10	12	0	0	0	0	
R2_CR468	10	7	8	13	0	0	0	0	0.9939
R3_CR422	10	7	8	13	0	0	0	0	
R4_CR346	0	0	0	0	10	6	9	7	0.9819
R5_CR325	0	0	0	0	9	7	8	7	
Chi-square = 83.6099				df = 28					<0.0001

d. Replicate 4

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	8	9	16	0	0	0	0	
R2_CR468	10	7	7	14	0	0	0	0	0.9983
R3_CR422	9	8	6	15	0	0	0	0	
R4_CR346	0	0	0	0	11	7	8	6	0.9827
R5_CR325	0	0	0	0	10	6	9	6	
Chi-square = 184.1847				df = 28					<0.0001

Table B.2. (contd)

e. Replicate 5

Release	A	B	D	F	*P*-value
R1_CR503	14	9	11	9	
R2_CR468	12	8	11	7	0.9999
R3_CR422	12	8	10	8	
R4_CR346	10	7	8	7	0.8918
R5_CR325	9	9	8	5	
Chi-square = 1.2926		df = 12			1

f. Replicate 6

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	9	13	7	
R2_CR468	0	0	0	0	13	8	10	7	0.9983
R3_CR422	0	0	0	0	12	8	10	8	
R4_CR346	8	6	7	10	0	0	0	0	0.9799
R5_CR325	8	7	6	11	0	0	0	0	
Chi-square = 184.2352				df = 28					<0.0001

g. Replicate 7

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	10	12	6	
R2_CR468	0	0	0	0	11	8	10	9	0.9103
R3_CR422	0	0	0	0	12	6	10	9	
R4_CR346	7	6	7	12	0	0	0	0	1
R5_CR325	7	6	7	12	0	0	0	0	
Chi-square = 185.2379				df = 28					<0.0001

h. Replicate 8

Release	C	G	E	H	A	B	D	F	P-value
R1_CR503	0	0	0	0	15	9	11	9	
R2_CR468	0	0	0	0	13	8	10	7	0.9999
R3_CR422	0	0	0	0	12	8	9	8	
R4_CR346	7	8	5	11	0	0	0	0	0.8848
R5_CR325	7	6	7	10	0	0	0	0	
Chi-square = 182.1678				df = 28					<0.0001

i. Replicate 9

Release	C	G	E	H	*P*-value
R1_CR503	11	9	8	16	
R2_CR468	10	8	7	13	1
R3_CR422	10	8	7	13	
R4_CR346	8	6	6	12	0.9667
R5_CR325	7	7	7	11	
Chi-square = 0.5237		df = 12			1

Table B.2. (contd)

j. Replicate 10

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	9	14	0	0	0	0	
R2_CR468	10	6	8	14	0	0	0	0	0.9986
R3_CR422	9	7	8	13	0	0	0	0	
R4_CR346	0	0	0	0	11	6	8	7	0.9532
R5_CR325	0	0	0	0	9	7	9	7	
Chi-square = 183.6209				df = 28					<0.0001

k. Replicate 11

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	10	8	10	16	0	0	0	0	
R2_CR468	11	9	6	12	0	0	0	0	0.9633
R3_CR422	9	7	8	14	0	0	0	0	
R4_CR346	0	0	0	0	9	7	9	7	0.9861
R5_CR325	0	0	0	0	9	6	9	8	
Chi-square = 186.6222				df = 28					<0.0001

l. Replicate 12

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	10	9	7	17	0	0	0	0	
R2_CR468	9	9	8	12	0	0	0	0	0.9903
R3_CR422	8	9	8	13	0	0	0	0	
R4_CR346	0	0	0	0	10	7	7	8	0.8837
R5_CR325	0	0	0	0	9	8	9	6	
Chi-square = 186.2008				df = 28					<0.0001

m. Replicate 13

Release	A	B	D	F	*P*-value
R1_CR503	15	9	10	9	
R2_CR468	13	7	10	8	0.9966
R3_CR422	11	8	11	8	
R4_CR346	9	8	8	7	0.9970
R5_CR325	9	8	7	7	
Chi-square = 1.5055		df = 12			0.9999

n. Replicate 14

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	14	9	11	9	
R2_CR468	0	0	0	0	12	8	10	8	1
R3_CR422	0	0	0	0	12	8	10	8	
R4_CR346	8	7	6	11	0	0	0	0	0.9861
R5_CR325	7	7	7	11	0	0	0	0	
Chi-square = 183.4326				df = 28					<0.0001

Table B.2. (contd)

o. Replicate 15

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	9	10	9	
R2_CR468	0	0	0	0	11	8	10	9	0.9918
R3_CR422	0	0	0	0	11	10	9	8	
R4_CR346	9	7	7	9	0	0	0	0	0.9532
R5_CR325	8	7	6	11	0	0	0	0	
Chi-square = 185.2049				df = 28					<0.0001

p. Replicate 16

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	16	9	11	8	
R2_CR468	0	0	0	0	10	9	10	8	0.9881
R3_CR422	0	0	0	0	12	9	9	8	
R4_CR346	8	6	6	12	0	0	0	0	0.9532
R5_CR325	8	7	7	10	0	0	0	0	
Chi-square = 185.3927				df = 28					<0.0001

q. Replicate 17

Release	C	G	E	H	*P*-value
R1_CR503	11	9	9	15	
R2_CR468	9	8	9	11	0.9957
R3_CR422	10	9	7	11	
R4_CR346	9	6	6	11	0.9872
R5_CR325	8	6	7	11	
Chi-square = 1.1469		df = 12			1

r. Replicate 18

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	10	7	15	0	0	0	0	
R2_CR468	10	8	8	12	0	0	0	0	0.9945
R3_CR422	11	8	8	11	0	0	0	0	
R4_CR346	0	0	0	0	10	7	8	7	0.9493
R5_CR325	0	0	0	0	8	8	8	8	
Chi-square = 185.0954				df = 28					<0.0001

s. Replicate 19

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	9	14	0	0	0	0	
R2_CR468	10	6	8	13	0	0	0	0	0.9985
R3_CR422	9	7	8	14	0	0	0	0	
R4_CR346	0	0	0	0	8	9	7	7	0.8110
R5_CR325	0	0	0	0	9	6	9	8	
Chi-square = 184.4256				df = 28					<0.0001

Table B.2. (contd)

t. Replicate 20

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	12	9	9	14	0	0	0	0	
R2_CR468	9	8	8	13	0	0	0	0	0.9998
R3_CR422	10	8	7	12	0	0	0	0	
R4_CR346	0	0	0	0	9	7	9	7	0.9437
R5_CR325	0	0	0	0	9	8	7	8	
Chi-square = 184.4286				df = 28					<0.0001

u. Replicate 21

Release	A	B	D	F	*P*-value
R1_CR503	14	9	11	9	
R2_CR468	12	8	9	9	0.9998
R3_CR422	12	9	9	8	
R4_CR346	10	7	7	7	0.9625
R5_CR325	9	7	9	7	
Chi-square = 0.5728		df = 12			1

v. Replicate 22

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	13	10	11	10	
R2_CR468	0	0	0	0	12	8	10	8	0.9994
R3_CR422	0	0	0	0	10	9	10	9	
R4_CR346	8	7	6	11	0	0	0	0	0.9847
R5_CR325	8	6	7	11	0	0	0	0	
Chi-square = 184.9371				df = 28					<0.0001

w. Replicate 23

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	14	8	11	11	
R2_CR468	0	0	0	0	11	8	10	9	0.9884
R3_CR422	0	0	0	0	11	9	11	7	
R4_CR346	7	7	7	11	0	0	0	0	0.9861
R5_CR325	8	7	6	11	0	0	0	0	
Chi-square = 185.8277				df = 28					<0.0001

x. Replicate 24

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	13	10	11	10	
R2_CR468	0	0	0	0	11	9	9	9	1
R3_CR422	0	0	0	0	11	9	10	8	
R4_CR346	8	7	6	11	0	0	0	0	0.9847
R5_CR325	8	6	7	11	0	0	0	0	
Chi-square = 184.6371				df = 28					<0.0001

Table B.2. (contd)

y. Replicate 25

Release	C	G	E	H	*P*-value
R1_CR503	11	10	10	13	
R2_CR468	9	8	7	14	0.9948
R3_CR422	10	8	7	13	
R4_CR346	8	7	6	11	1
R5_CR325	8	7	6	11	
Chi-square = 0.7352		df = 12			1

z. Replicate 26

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	9	15	0	0	0	0	
R2_CR468	8	8	8	14	0	0	0	0	0.9937
R3_CR422	10	9	6	13	0	0	0	0	
R4_CR346	0	0	0	0	8	7	8	7	0.9977
R5_CR325	0	0	0	0	9	7	8	7	
Chi-square = 182.2335				df = 28					<0.0001

aa. Replicate 27

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	9	15	0	0	0	0	
R2_CR468	9	8	7	14	0	0	0	0	0.9999
R3_CR422	10	8	7	13	0	0	0	0	
R4_CR346	0	0	0	0	9	6	8	8	0.9807
R5_CR325	0	0	0	0	10	7	8	7	
Chi-square = 183.7856				df = 28					<0.0001

bb. Replicate 28

Release	C	G	E	H	A	B	D	F	P-value
R1_CR503	10	9	8	17	0	0	0	0	
R2_CR468	10	8	7	13	0	0	0	0	0.9995
R3_CR422	10	8	7	13	0	0	0	0	
R4_CR346	0	0	0	0	10	8	8	6	0.9392
R5_CR325	0	0	0	0	9	7	8	8	
Chi-square = 185.6268				df = 28					<0.0001

cc. Replicate 29

Release	A	B	D	F	*P*-value
R1_CR503	13	10	11	10	
R2_CR468	11	9	10	7	0.9992
R3_CR422	11	8	10	9	
R4_CR346	9	7	8	8	1
R5_CR325	9	7	8	8	
Chi-square = 0.5707		df = 12			1

Table B.2. (contd)

dd. Replicate 30

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	13	10	12	9	
R2_CR468	0	0	0	0	11	8	10	9	0.9999
R3_CR422	0	0	0	0	11	8	10	9	
R4_CR346	9	7	4	12	0	0	0	0	0.7768
R5_CR325	6	6	6	13	0	0	0	0	
Chi-square = 186.4709				df = 28					<0.0001

ee. Replicate 31

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	14	11	12	10	
R2_CR468	0	0	0	0	9	8	8	7	0.9998
R3_CR422	0	0	0	0	10	7	8	8	
R4_CR346	6	4	5	8	0	0	0	0	0.9460
R5_CR325	5	5	4	9	0	0	0	0	
Chi-square = 159.5936				df = 28					<0.0001

ff. Replicate 32

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	12	11	11	10	
R2_CR468	0	0	0	0	10	7	8	6	0.9981
R3_CR422	0	0	0	0	10	7	8	8	
R4_CR346	5	5	4	7	0	0	0	0	0.9360
R5_CR325	5	5	5	5	0	0	0	0	
Chi-square = 151.1879				df = 28					<0.0001

Table B.3. Contingency Tables with Numbers of Steelhead Tagged by Each Staff Member per Release Location Within a Replicate Release. A total of 32 replicate day or nighttime releases were performed over the course of the spring 2012 study. Results of chi-square tests of homogeneity are presented in the form of *P*-values.

a. Replicate 1

Release	C	G	E	H	*P*-value
R1_CR503	11	8	10	15	
R2_CR468	10	7	8	12	0.9993
R3_CR422	10	8	7	13	
R4_CR346	8	6	7	11	1
R5_CR325	8	6	7	11	
Chi-square = 0.3823		df = 12			1

b. Replicate 2

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	10	8	10	16	0	0	0	0	
R2_CR468	9	7	8	14	0	0	0	0	1
R3_CR422	9	7	8	14	0	0	0	0	
R4_CR346	0	0	0	0	11	7	8	6	0.9872
R5_CR325	0	0	0	0	11	6	9	6	
Chi-square = 184.4663				df = 28					<0.0001

c. Replicate 3

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	12	9	11	12	0	0	0	0	
R2_CR468	9	8	7	14	0	0	0	0	0.9600
R3_CR422	9	8	7	14	0	0	0	0	
R4_CR346	0	0	0	0	11	7	8	6	0.9667
R5_CR325	0	0	0	0	12	6	7	7	
Chi-square = 187.048				df = 28					<0.0001

d. Replicate 4

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	10	14	0	0	0	0	
R2_CR468	9	8	8	13	0	0	0	0	1
R3_CR422	9	8	8	13	0	0	0	0	
R4_CR346	0	0	0	0	11	6	7	7	0.9970
R5_CR325	0	0	0	0	11	6	8	7	
Chi-square = 183.3133				df = 28					<0.0001

Table B.3. (contd)

e. Replicate 5

Release	A	B	D	F	*P*-value
R1_CR503	15	8	12	9	
R2_CR468	12	9	10	7	0.9985
R3_CR422	12	8	10	8	
R4_CR346	11	6	8	6	0.9768
R5_CR325	11	7	7	7	
Chi-square = 0.8446			df = 12		1

f. Replicate 6

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	8	11	9	
R2_CR468	0	0	0	0	13	8	9	8	0.9998
R3_CR422	0	0	0	0	13	7	10	7	
R4_CR346	9	6	6	11	0	0	0	0	0.9419
R5_CR325	8	6	8	10	0	0	0	0	
Chi-square = 183.4433				df = 28					<0.0001

g. Replicate 7

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	14	10	11	9	
R2_CR468	0	0	0	0	12	7	10	9	0.9980
R3_CR422	0	0	0	0	12	7	11	8	
R4_CR346	7	7	6	12	0	0	0	0	0.9906
R5_CR325	8	7	6	11	0	0	0	0	
Chi-square = 185.0656				df = 28					<0.0001

h. Replicate 8

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	14	9	12	9	
R2_CR468	0	0	0	0	12	7	11	8	0.9999
R3_CR422	0	0	0	0	13	7	10	8	
R4_CR346	8	7	6	11	0	0	0	0	0.9847
R5_CR325	8	6	7	11	0	0	0	0	
Chi-square = 184.6945				df = 28					<0.0001

Table B.3. (contd)

i. Replicate 9

Release	C	G	E	H	*P*-value
R1_CR503	11	9	9	15	
R2_CR468	9	9	8	12	0.9974
R3_CR422	10	7	7	14	
R4_CR346	7	7	6	11	0.9970
R5_CR325	8	7	6	11	
Chi-square = 0.6691		df = 12			1

j. Replicate 10

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	10	9	14	0	0	0	0	
R2_CR468	11	8	8	11	0	0	0	0	0.9986
R3_CR422	9	8	8	13	0	0	0	0	
R4_CR346	0	0	0	0	10	7	8	7	1
R5_CR325	0	0	0	0	10	7	8	7	
Chi-square = 184.6593				df = 28					<0.0001

k. Replicate 11

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	9	15	0	0	0	0	
R2_CR468	10	8	8	12	0	0	0	0	0.9974
R3_CR422	9	9	6	13	0	0	0	0	
R4_CR346	0	0	0	0	11	6	8	7	0.9516
R5_CR325	0	0	0	0	9	7	8	8	
Chi-square = 184.8016				df = 28					<0.0001

l. Replicate 12

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	10	10	9	14	0	0	0	0	
R2_CR468	10	7	8	13	0	0	0	0	0.9976
R3_CR422	9	7	8	14	0	0	0	0	
R4_CR346	0	0	0	0	11	6	8	7	0.9887
R5_CR325	0	0	0	0	10	7	8	7	
Chi-square = 184.1484				df = 28					<0.0001

Table B.3. (contd)

m. Replicate 13

Release	A	B	D	F	*P*-value
R1_CR503	15	10	10	9	
R2_CR468	12	8	10	8	0.9976
R3_CR422	11	8	11	8	
R4_CR346	9	7	9	7	0.9904
R5_CR325	10	7	8	7	
Chi-square = 0.7161		df = 12			1

n. Replicate 14

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	9	11	9	
R2_CR468	0	0	0	0	12	8	10	8	0.9999
R3_CR422	0	0	0	0	11	8	10	8	
R4_CR346	7	7	7	11	0	0	0	0	0.9861
R5_CR325	8	7	6	11	0	0	0	0	
Chi-square = 183.6893				df = 28					<0.0001

o. Replicate 15

Release	C	G	E	H	A	B	D	F	P-value
R1_CR503	0	0	0	0	15	9	12	8	
R2_CR468	0	0	0	0	11	8	10	9	0.9691
R3_CR422	0	0	0	0	11	10	8	9	
R4_CR346	7	8	7	9	0	0	0	0	0.9027
R5_CR325	9	6	7	10	0	0	0	0	
Chi-square = 186.7155				df = 28					<0.0001

p. Replicate 16

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	14	9	12	9	
R2_CR468	0	0	0	0	8	10	11	9	0.9361
R3_CR422	0	0	0	0	12	7	10	9	
R4_CR346	9	7	6	10	0	0	0	0	0.9886
R5_CR325	8	8	6	10	0	0	0	0	
Chi-square = 187.1404				df = 28					<0.0001

Table B.3. (contd)

q. Replicate 17

Release	C	G	E	H	*P*-value
R1_CR503	12	9	8	15	
R2_CR468	10	9	9	10	0.9882
R3_CR422	10	9	7	12	
R4_CR346	8	7	6	11	0.9911
R5_CR325	9	7	6	10	
Chi-square = 1.1282		df = 12			1

r. Replicate 18

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	10	14	0	0	0	0	
R2_CR468	10	7	8	13	0	0	0	0	0.9994
R3_CR422	10	8	7	13	0	0	0	0	
R4_CR346	0	0	0	0	9	7	8	8	0.9894
R5_CR325	0	0	0	0	10	7	8	7	
Chi-square = 184.8371				df = 28					<0.0001

s. Replicate 19

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	9	15	0	0	0	0	
R2_CR468	9	9	8	12	0	0	0	0	0.9998
R3_CR422	10	8	8	12	0	0	0	0	
R4_CR346	0	0	0	0	9	9	7	7	0.9465
R5_CR325	0	0	0	0	10	7	7	8	
Chi-square = 185.3981				df = 28					<0.0001

t. Replicate 20

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	10	9	14	0	0	0	0	
R2_CR468	9	8	7	14	0	0	0	0	0.9941
R3_CR422	11	9	7	11	0	0	0	0	
R4_CR346	0	0	0	0	8	7	9	8	0.9508
R5_CR325	0	0	0	0	10	7	8	7	
Chi-square = 186.0989				df = 28					<0.0001

Table B.3. (contd)

u. Replicate 21

Release	A	B	D	F	*P*-value
R1_CR503	16	9	11	8	
R2_CR468	11	8	10	8	0.9925
R3_CR422	11	8	10	9	
R4_CR346	10	7	8	7	1
R5_CR325	10	7	8	7	
Chi-square = 0.8351		df = 12			1

v. Replicate 22

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	10	10	9	
R2_CR468	0	0	0	0	11	8	10	9	0.9972
R3_CR422	0	0	0	0	11	8	10	9	
R4_CR346	9	7	6	10	0	0	0	0	0.9872
R5_CR325	8	7	7	10	0	0	0	0	
Chi-square = 185.2304				df = 28					<0.0001

w. Replicate 23

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	9	11	9	
R2_CR468	0	0	0	0	11	8	9	10	0.9804
R3_CR422	0	0	0	0	10	9	11	8	
R4_CR346	8	7	6	11	0	0	0	0	0.9901
R5_CR325	8	8	6	10	0	0	0	0	
Chi-square = 186.0532				df = 28					<0.0001

x. Replicate 24

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	15	9	11	9	
R2_CR468	0	0	0	0	11	9	10	8	0.9948
R3_CR422	0	0	0	0	10	9	10	9	
R4_CR346	8	7	7	10	0	0	0	0	0.9887
R5_CR325	8	7	6	11	0	0	0	0	
Chi-square = 185.4116				df = 28					<0.0001

Table B.3. (contd)

y. Replicate 25

Release	C	G	E	H	*P*-value
R1_CR503	12	10	8	14	
R2_CR468	10	8	8	12	0.9992
R3_CR422	10	7	8	13	
R4_CR346	8	7	6	11	0.9876
R5_CR325	7	8	6	11	
Chi-square = 0.8632		df = 12			1

z. Replicate 26

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	9	9	15	0	0	0	0	
R2_CR468	8	9	8	13	0	0	0	0	0.9987
R3_CR422	10	8	7	13	0	0	0	0	
R4_CR346	0	0	0	0	8	7	9	8	0.9488
R5_CR325	0	0	0	0	10	6	8	8	
Chi-square = 185.6711				df = 28					<0.0001

aa. Replicate 27

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	10	9	9	16	0	0	0	0	
R2_CR468	10	8	7	13	0	0	0	0	0.9994
R3_CR422	10	7	8	13	0	0	0	0	
R4_CR346	0	0	0	0	9	7	8	8	0.9886
R5_CR325	0	0	0	0	9	7	9	7	
Chi-square = 184.8612				df = 28					<0.0001

bb. Replicate 28

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	11	11	8	14	0	0	0	0	
R2_CR468	11	8	8	11	0	0	0	0	0.9973
R3_CR422	9	9	8	12	0	0	0	0	
R4_CR346	0	0	0	0	9	7	8	8	1
R5_CR325	0	0	0	0	9	7	8	8	
Chi-square = 184.8293				df = 28					<0.0001

Table B.3. (contd)

cc. Replicate 29

Release	A	B	D	F	*P*-value
R1_CR503	14	9	11	10	
R2_CR468	12	8	10	8	0.9998
R3_CR422	11	9	10	8	
R4_CR346	10	7	8	7	0.9508
R5_CR325	8	7	9	8	
Chi-square = 0.7372		df = 12			1

dd. Replicate 30

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	14	9	12	9	
R2_CR468	0	0	0	0	12	9	9	8	0.9984
R3_CR422	0	0	0	0	11	9	9	9	
R4_CR346	9	7	5	11	0	0	0	0	0.9853
R5_CR325	8	7	6	11	0	0	0	0	
Chi-square = 185.113				df = 28					<0.0001

ee. Replicate 31

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	13	9	10	8	
R2_CR468	0	0	0	0	10	6	8	7	0.9997
R3_CR422	0	0	0	0	9	7	8	7	
R4_CR346	6	5	5	7	0	0	0	0	0.9594
R5_CR325	4	5	4	7	0	0	0	0	
Chi-square = 146.3932				df = 28					<0.0001

ff. Replicate 32

Release	C	G	E	H	A	B	D	F	*P*-value
R1_CR503	0	0	0	0	13	9	12	8	
R2_CR468	0	0	0	0	9	7	7	7	0.9981
R3_CR422	0	0	0	0	9	6	8	7	
R4_CR346	5	5	4	7	0	0	0	0	0.9040
R5_CR325	6	3	4	7	0	0	0	0	
Chi-square = 145.6468				df = 28					<0.0001

Table B.4. Estimates of reach survival and cumulative survival for a) yearling Chinook salmon and b) steelhead smolts, along with P-values associated with the F-tests of homogeneous survival across fish tagged during spring 2012 by different staff members

a. Yearling Chinook salmon smolts

1) Release 1 (CR503) – Reach survival

	Release to CR422.0		CR422.0 to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9111	0.0190	0.9317	0.0176	0.9686	0.0126	0.9784	0.0107	0.9344	0.0185
B	0.8947	0.0249	0.9268	0.0224	0.9600	0.0175	1.0000	0.0000	0.9179	0.0251
C	0.9012	0.0228	0.9484	0.0178	0.9660	0.0150	0.9937	0.0071	0.9098	0.0247
D	0.8994	0.0225	0.9503	0.0171	0.9605	0.0158	1.0000	0.0000	0.9394	0.0199
E	0.8571	0.0296	0.9667	0.0164	0.9828	0.0121	0.9831	0.0123	0.9316	0.0247
F	0.8968	0.0253	0.9615	0.0170	0.9678	0.0159	0.9917	0.0083	0.9510	0.0199
G	0.9241	0.0220	0.9403	0.0205	0.9762	0.0136	0.9919	0.0081	0.9365	0.0225
H	0.9042	0.0190	0.9631	0.0128	0.9809	0.0095	0.9902	0.0069	0.9416	0.0166
P-value	0.6922		0.6846		0.9160		0.6937		0.9199	

2) Release 1 (CR503) – Cumulative survival

	Release to CR422.0		Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9111	0.0190	0.8489	0.0239	0.8222	0.0255	0.8044	0.0264	0.7517	0.0289
B	0.8947	0.0249	0.8292	0.0306	0.7961	0.0327	0.7961	0.0327	0.7307	0.0360
C	0.9012	0.0228	0.8547	0.0269	0.8256	0.0289	0.8204	0.0293	0.7464	0.0334
D	0.8994	0.0225	0.8547	0.0263	0.8210	0.0287	0.8210	0.0287	0.7712	0.0315
E	0.8571	0.0296	0.8286	0.0319	0.8143	0.0329	0.8006	0.0338	0.7458	0.0371
F	0.8968	0.0253	0.8623	0.0286	0.8345	0.0309	0.8276	0.0314	0.7871	0.0341
G	0.9241	0.0220	0.8690	0.0280	0.8483	0.0298	0.8414	0.0303	0.7880	0.0342
H	0.9042	0.0190	0.8708	0.0216	0.8542	0.0228	0.8458	0.0233	0.7964	0.0260
P-value	0.6922		0.9309		0.8989		0.9116		0.8012	

Table B.4. (contd)

3) Release 2 (CR468) – Reach survival

	Release to CR422.0		CR422.0 to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9066	0.0216	0.9879	0.0085	0.9691	0.0136	0.9809	0.0109	0.9420	0.0189
B	0.9147	0.0246	0.9407	0.0217	0.9369	0.0231	0.9904	0.0096	0.9728	0.0167
C	0.9161	0.0223	0.9718	0.0139	0.9639	0.0159	0.9848	0.0106	0.9425	0.0211
D	0.9484	0.0178	0.9456	0.0187	0.9565	0.0174	0.9924	0.0075	0.9084	0.0252
E	0.9262	0.0237	0.9912	0.0088	0.9821	0.0125	1.0000	0.0000	0.9733	0.0155
F	0.9055	0.0260	0.9478	0.0207	0.9266	0.0250	0.9901	0.0099	0.9504	0.0218
G	0.9587	0.0181	0.9914	0.0086	0.9826	0.0122	1.0000	0.0000	0.9395	0.0227
H	0.9227	0.0186	0.9895	0.0074	0.9365	0.0177	0.9892	0.0080	0.9257	0.0199
P-value	0.6034		0.0208		0.1745		0.8435		0.3297	

4) Release 2 (CR468) –Cumulative survival

	Release to CR422.0		Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9066	0.0216	0.8956	0.0227	0.8680	0.0251	0.8514	0.0264	0.8020	0.0296
B	0.9147	0.0246	0.8605	0.0305	0.8062	0.0348	0.7985	0.0353	0.7768	0.0369
C	0.9161	0.0223	0.8903	0.0251	0.8582	0.0280	0.8452	0.0291	0.7965	0.0327
D	0.9484	0.0178	0.8968	0.0244	0.8578	0.0281	0.8513	0.0286	0.7733	0.0337
E	0.9262	0.0237	0.9180	0.0248	0.9016	0.0270	0.9016	0.0270	0.8775	0.0298
F	0.9055	0.0260	0.8583	0.0309	0.7953	0.0358	0.7874	0.0363	0.7484	0.0385
G	0.9587	0.0181	0.9504	0.0197	0.9339	0.0226	0.9339	0.0226	0.8774	0.0300
H	0.9227	0.0186	0.9130	0.0196	0.8551	0.0245	0.8458	0.0251	0.7830	0.0287
P-value	0.6034		0.1751		0.0140		0.0077		0.0353	

Table B.4. (contd)

5) Release 3 (CR422) – Reach survival

	Release to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9389	0.0179	0.9527	0.0163	1.0000	0.0000	0.9516	0.0172
B	0.9389	0.0209	0.9098	0.0259	0.9910	0.0090	0.9455	0.0217
C	0.9745	0.0126	0.9542	0.0169	1.0000	0.0000	0.9272	0.0220
D	0.9482	0.0179	0.9723	0.0137	0.9929	0.0071	0.9357	0.0207
E	0.9397	0.0221	0.9817	0.0129	1.0006	0.0006	0.9443	0.0225
F	0.9313	0.0221	0.9672	0.0161	0.9746	0.0145	0.9056	0.0275
G	0.9524	0.0190	0.9667	0.0164	0.9569	0.0189	0.9662	0.0178
H	0.9317	0.0176	0.9581	0.0145	0.9891	0.0077	0.9415	0.0178
P-value	0.7931		0.1229		0.0752		0.6593	

6) Release 3 (CR422) – Cumulative survival

	Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9389	0.0179	0.8944	0.0229	0.8944	0.0229	0.8512	0.0267
B	0.9389	0.0209	0.8543	0.0309	0.8466	0.0316	0.8004	0.0350
C	0.9745	0.0126	0.9299	0.0204	0.9299	0.0204	0.8622	0.0278
D	0.9482	0.0179	0.9219	0.0217	0.9154	0.0225	0.8565	0.0283
E	0.9397	0.0221	0.9224	0.0248	0.9229	0.0249	0.8715	0.0312
F	0.9313	0.0221	0.9008	0.0261	0.8779	0.0286	0.7950	0.0354
G	0.9524	0.0190	0.9206	0.0241	0.8810	0.0289	0.8512	0.0320
H	0.9317	0.0176	0.8927	0.0216	0.8829	0.0225	0.8313	0.0264
P-value	0.7931		0.3975		0.3121		0.5294	

Table B.4. (contd)

7) Release 4 (CR346) – Reach survival

	Release to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE
A	0.9935	0.0065	0.9737	0.0130	0.9126	0.0233
B	1.0002	0.0002	0.9820	0.0126	0.9560	0.0199
C	0.9919	0.0080	0.9919	0.0081	0.9705	0.0163
D	1.0000	0.0000	0.9767	0.0133	0.9534	0.0190
E	1.0000	0.0000	0.9574	0.0208	0.9558	0.0217
F	0.9912	0.0088	1.0000	0.0000	0.9291	0.0244
G	1.0000	0.0000	0.9902	0.0098	0.9406	0.0235
H	1.0000	0.0000	0.9941	0.0059	0.9529	0.0163
P-value	0.9217		0.3168		0.6115	

8) Release 4 (CR346) – Cumulative survival

	Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE
A	0.9935	0.0065	0.9673	0.0144	0.8828	0.0261
B	1.0002	0.0002	0.9821	0.0125	0.9390	0.0229
C	0.9919	0.0080	0.9839	0.0113	0.9548	0.0194
D	1.0000	0.0000	0.9767	0.0133	0.9312	0.0225
E	1.0000	0.0000	0.9574	0.0208	0.9152	0.0288
F	0.9912	0.0088	0.9912	0.0088	0.9209	0.0255
G	1.0000	0.0000	0.9902	0.0098	0.9314	0.0250
H	1.0000	0.0000	0.9941	0.0059	0.9473	0.0172
P-value	0.9217		0.4389		0.5142	

Table B.4. (contd)

9) Release 5 (CR325) – Reach survival

	Release to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE
A	0.9932	0.0068	0.9385	0.0201
B	0.9826	0.0122	0.9217	0.0255
C	0.9913	0.0087	0.9744	0.0150
D	0.9771	0.0131	0.9551	0.0188
E	0.9802	0.0139	0.9192	0.0274
F	0.9826	0.0122	0.9207	0.0255
G	0.9804	0.0137	0.8909	0.0313
H	0.9941	0.0059	0.9121	0.0219
P-value	0.9313		0.2886	

10) Release 5 (CR325) – Cumulative survival

	Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE
A	0.9932	0.0068	0.9321	0.0209
B	0.9826	0.0122	0.9057	0.0275
C	0.9913	0.0087	0.9659	0.0171
D	0.9771	0.0131	0.9332	0.0222
E	0.9802	0.0139	0.9010	0.0297
F	0.9826	0.0122	0.9047	0.0274
G	0.9804	0.0137	0.8734	0.0331
H	0.9941	0.0059	0.9067	0.0224
P-value	0.9313		0.3072	

Table B.4. (contd)

b. Steelhead smolts

1) Release 1 (CR503) – Reach survival

	Release to CR422.0		CR422.0 to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.8796	0.0214	0.9310	0.0178	0.9474	0.0162	1.0000	0.0000	0.9722	0.0122
B	0.7986	0.0334	0.9652	0.0171	0.9369	0.0231	1.0000	0.0000	0.9245	0.0262
C	0.8239	0.0287	0.9448	0.0190	1.0000	0.0000	1.0000	0.0000	0.9726	0.0145
D	0.7933	0.0303	0.9577	0.0169	0.9779	0.0126	0.9925	0.0075	0.9404	0.0208
E	0.8844	0.0264	0.9692	0.0151	0.9920	0.0080	1.0005	0.0005	0.9709	0.0163
F	0.8298	0.0317	0.9231	0.0246	0.9811	0.0132	0.9904	0.0096	0.9417	0.0231
G	0.8851	0.0262	0.9389	0.0209	0.9752	0.0141	1.0000	0.0000	0.9792	0.0148
H	0.8966	0.0200	0.9618	0.0133	0.9746	0.0112	1.0006	0.0005	0.9482	0.0170
P-value	0.0229		0.5406		0.0428		0.8714		0.3292	

2) Release 1 (CR503) – Cumulative survival

	Release to CR422.0		Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.8796	0.0214	0.8190	0.0253	0.7759	0.0274	0.7759	0.0274	0.7543	0.0283
B	0.7986	0.0334	0.7708	0.0350	0.7222	0.0373	0.7222	0.0373	0.6677	0.0394
C	0.8239	0.0287	0.7784	0.0313	0.7784	0.0313	0.7784	0.0313	0.7571	0.0325
D	0.7933	0.0303	0.7598	0.0319	0.7430	0.0327	0.7374	0.0329	0.6935	0.0345
E	0.8844	0.0264	0.8571	0.0289	0.8503	0.0294	0.8508	0.0295	0.8260	0.0317
F	0.8298	0.0317	0.7660	0.0357	0.7515	0.0364	0.7443	0.0368	0.7009	0.0387
G	0.8851	0.0262	0.8311	0.0308	0.8105	0.0323	0.8105	0.0323	0.7937	0.0338
H	0.8966	0.0200	0.8623	0.0226	0.8404	0.0241	0.8409	0.0241	0.7973	0.0269
P-value	0.0229		0.0661		0.0370		0.0256		0.0057	

Table B.4. (contd)

3) Release 2 (CR468) – Reach survival

	Release to CR422.0		CR422.0 to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9162	0.0207	0.9451	0.0178	0.9739	0.0129	0.9933	0.0067	0.9688	0.0150
B	0.8828	0.0284	0.9115	0.0267	0.9902	0.0098	1.0000	0.0000	0.9219	0.0269
C	0.9351	0.0199	0.9375	0.0202	0.9704	0.0146	1.0000	0.0000	0.9589	0.0185
D	0.9286	0.0208	0.9231	0.0223	0.9847	0.0107	1.0000	0.0000	0.9690	0.0153
E	0.8810	0.0289	0.9640	0.0177	0.9810	0.0133	0.9908	0.0097	0.9536	0.0218
F	0.9160	0.0242	0.9417	0.0214	0.9643	0.0175	1.0000	0.0000	0.9820	0.0130
G	0.9297	0.0226	0.9160	0.0254	1.0002	0.0002	0.9811	0.0132	0.9161	0.0274
H	0.9196	0.0193	0.9290	0.0190	0.9706	0.0130	0.9939	0.0060	0.9417	0.0188
P-value	0.5984		0.7263		0.4919		0.8238		0.2294	

4) Release 2 (CR468) – Cumulative survival

	Release to CR422.0		Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9162	0.0207	0.8659	0.0255	0.8433	0.0272	0.8376	0.0276	0.8115	0.0295
B	0.8828	0.0284	0.8047	0.0350	0.7968	0.0356	0.7968	0.0356	0.7345	0.0392
C	0.9351	0.0199	0.8766	0.0265	0.8506	0.0287	0.8506	0.0287	0.8156	0.0317
D	0.9286	0.0208	0.8571	0.0282	0.8441	0.0292	0.8441	0.0292	0.8179	0.0311
E	0.8810	0.0289	0.8492	0.0319	0.8330	0.0333	0.8254	0.0339	0.7871	0.0369
F	0.9160	0.0242	0.8626	0.0301	0.8318	0.0327	0.8318	0.0327	0.8169	0.0339
G	0.9297	0.0226	0.8516	0.0314	0.8517	0.0314	0.8356	0.0328	0.7655	0.0378
H	0.9196	0.0193	0.8543	0.0250	0.8291	0.0267	0.8241	0.0270	0.7761	0.0298
P-value	0.5984		0.8151		0.9408		0.9634		0.5815	

Table B.4. (contd)

5) Release 3 (CR422) – Reach survival

	Release to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9266	0.0196	0.9695	0.0134	0.9937	0.0063	0.9624	0.0152
B	0.9291	0.0228	0.9487	0.0204	1.0000	0.0000	0.9647	0.0177
C	0.9805	0.0111	0.9868	0.0093	0.9866	0.0094	0.9497	0.0189
D	0.9359	0.0196	0.9583	0.0167	0.9928	0.0072	0.9799	0.0126
E	0.9496	0.0201	0.9732	0.0153	0.9908	0.0091	0.9630	0.0182
F	0.9313	0.0221	0.9664	0.0165	1.0000	0.0000	0.9489	0.0208
G	0.9055	0.0260	0.9561	0.0192	1.0000	0.0000	0.9770	0.0159
H	0.9324	0.0175	0.9789	0.0104	0.9839	0.0092	0.9704	0.0133
P-value	0.3370		0.7138		0.7856		0.8674	

6) Release 3 (CR422) – Reach survival

	Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9266	0.0196	0.8983	0.0227	0.8927	0.0233	0.8591	0.0262
B	0.9291	0.0228	0.8815	0.0287	0.8815	0.0287	0.8504	0.0318
C	0.9805	0.0111	0.9675	0.0143	0.9545	0.0168	0.9065	0.0241
D	0.9359	0.0196	0.8969	0.0244	0.8904	0.0251	0.8725	0.0270
E	0.9496	0.0201	0.9241	0.0243	0.9157	0.0255	0.8818	0.0297
F	0.9313	0.0221	0.9000	0.0263	0.9000	0.0263	0.8540	0.0312
G	0.9055	0.0260	0.8658	0.0303	0.8658	0.0303	0.8459	0.0327
H	0.9324	0.0175	0.9127	0.0197	0.8980	0.0211	0.8715	0.0237
P-value	0.3370		0.1350		0.3479		0.8434	

Table B.4. (contd)

7) Release 4 (CR346) – Reach survival

	Release to CR325.0		CR325.0 to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE	Est	SE
A	0.9936	0.0063	0.9936	0.0064	0.9742	0.0127
B	1.0000	0.0000	1.0000	0.0000	0.9639	0.0179
C	0.9919	0.0081	1.0005	0.0005	0.9446	0.0213
D	0.9535	0.0185	0.9919	0.0081	0.9597	0.0180
E	1.0000	0.0000	1.0009	0.0008	0.9589	0.0209
F	0.9825	0.0123	0.9911	0.0089	0.9657	0.0178
G	0.9720	0.0160	1.0000	0.0000	0.9327	0.0246
H	0.9939	0.0061	0.9816	0.0105	0.9693	0.0138
P-value	0.0947		0.4834		0.8119	

8) Release 4 (CR346) – Cumulative survival

	Release to CR325.0		Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE	Est	SE
A	0.9936	0.0063	0.9873	0.0090	0.9618	0.0153
B	1.0000	0.0000	1.0000	0.0000	0.9639	0.0179
C	0.9919	0.0081	0.9924	0.0081	0.9374	0.0223
D	0.9535	0.0185	0.9457	0.0199	0.9076	0.0256
E	1.0000	0.0000	1.0009	0.0008	0.9598	0.0205
F	0.9825	0.0123	0.9737	0.0150	0.9402	0.0226
G	0.9720	0.0160	0.9720	0.0160	0.9065	0.0281
H	0.9939	0.0061	0.9756	0.0120	0.9456	0.0178
P-value	0.0947		0.0512		0.3512	

Table B.4. (contd)

9) Release 5 (CR325) – Reach survival

	Release to CR309.0		CR309.0 to CR234.0	
	Est	SE	Est	SE
A	0.9879	0.0088	0.9471	0.0188
B	1.0000	0.0000	0.9458	0.0221
C	0.9593	0.0178	0.9492	0.0202
D	0.9688	0.0154	0.9362	0.0221
E	1.0000	0.0000	0.9204	0.0278
F	0.9655	0.0169	0.9470	0.0213
G	0.9905	0.0095	0.9622	0.0189
H	0.9447	0.0180	0.9555	0.0171
P-value	0.0688		0.9297	

10) Release 5 (CR325) – Cumulative survival

	Release to CR309.0		Release to CR234.0	
	Est	SE	Est	SE
A	0.9879	0.0088	0.9357	0.0202
B	1.0000	0.0000	0.9458	0.0221
C	0.9594	0.0178	0.9106	0.0257
D	0.9688	0.0154	0.9070	0.0258
E	1.0000	0.0000	0.9204	0.0278
F	0.9655	0.0169	0.9143	0.0261
G	0.9905	0.0095	0.9530	0.0208
H	0.9447	0.0180	0.9027	0.0235
P-value	0.0688		0.7495	

B.1.2. Surgeon Effects – Summer Study

Data from all nine release locations in the four-dam study were examined for surgeon effects. This was again done to maximize the statistical power to detect surgeon effects that might have influenced any of the lower Columbia River survival studies in summer 2012.

Surgeon effort was balanced across the nine release locations and eight surgeons (Table B.5) $\left(P\left(\chi^2_{56} \geq 4.8194\right)=1\right)$. Surgeon effort was also examined within each of the 32 replicate releases (Table B.6). Surgeon effort was found to be balanced within the individual project releases (i.e., R_1–R_3, R_4–R_5, R_6–R_7, and R_8–R_9) within each of the replicate releases (Table B.7). These conditionally balanced designs within the individual replicate and the balance of surgeons across projects resulted in the overall balanced design.

Tests of surgeon effects were examined across the nine release locations based on both reach survivals and cumulative reach survivals (Table B.7). Five of the 45 tests of homogeneous reach survival across surgeons were significant at α = 0.10 (i.e., 11.11%). Two of the 44 tests of homogeneous cumulative reach survival across surgeons were significant at α = 0.10 (i.e., 4.55%). The rate of rejection in both cases is below that expected by chance alone, suggesting no evidence of surgeon effects.

Based on the balanced release design (Table B.5 and Table B.6) and tests of homogeneity (Table B.7), all fish tagged by all staff members were used in the subsequent survival analyses for summer 2012.

Table B.5. Numbers of Subyearling Chinook Salmon Tagged by Each Staff Member by Release Location (i.e., R_1, R_2, . . .) in Summer 2012. Chi-square test of homogeneity was not significant $\left(P\left(\chi^2_{56} \geq 4.8194\right)=1\right)$.

	Surgeon							
Release location	E	C	H	G	B	D	F	A
R1_CR503	255	327	397	287	309	304	287	358
R2_CR468	201	246	316	224	239	248	235	284
R3_CR422	192	255	314	218	239	241	236	289
R4_CR346	98	126	153	111	119	119	116	144
R5_CR325	93	123	157	114	119	122	111	144
R6_CR307	81	105	124	90	91	94	89	114
R7_CR275	78	103	127	90	88	101	90	109
R8_CR233	203	260	315	225	235	241	227	288
R9_CR156	199	263	312	232	229	242	233	285
Chi-square = 4.8194				df = 56				P-value = 1

Table B.6. Contingency Tables with Numbers of Subyearling Chinook Salmon Tagged by Each Staff Member per Release Location Within a Replicate Release. A total of 32 replicate day or night releases were performed over the course of the summer 2012 study. Results of chi-square tests of homogeneity presented in the form of *P*-values.

a. Replicate 1

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	20	25	17	0	0	0	0	
R2_CR468	13	16	21	13	0	0	0	0	0.9992
R3_CR422	12	15	23	13	0	0	0	0	
R4_CR346	0	0	0	0	8	7	8	8	0.9876
R5_CR325	0	0	0	0	8	8	7	8	
R6_CR307	0	0	0	0	6	5	6	8	0.9841
R7_CR275	0	0	0	0	6	6	6	7	
R8_CR233	0	0	0	0	15	14	15	19	0.9824
R9_CR156	0	0	0	0	13	15	15	19	
Chi-square = 443.68				df = 56					<0.0001

b. Replicate 2

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	19	27	17	0	0	0	0	
R2_CR468	13	15	21	14	0	0	0	0	1
R3_CR422	12	16	21	14	0	0	0	0	
R4_CR346	0	0	0	0	9	7	9	10	0.9886
R5_CR325	0	0	0	0	8	8	9	10	
R6_CR307	0	0	0	0	6	5	6	8	0.9841
R7_CR275	0	0	0	0	6	6	6	7	
R8_CR233	12	16	21	14	0	0	0	0	0.9967
R9_CR156	12	17	20	14	0	0	0	0	
Chi-square = 452.75				df = 56					<0.0001

c. Replicate 3

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	17	19	23	
R2_CR468	0	0	0	0	15	15	16	17	0.9998
R3_CR422	0	0	0	0	15	15	15	18	
R4_CR346	0	0	0	0	8	8	8	11	0.9911
R5_CR325	0	0	0	0	8	9	8	10	
R6_CR307	5	6	9	5	0	0	0	0	0.9773
R7_CR275	4	6	9	6	0	0	0	0	
R8_CR233	13	16	19	14	0	0	0	0	0.9994
R9_CR156	13	16	20	14	0	0	0	0	
Chi-square = 451.42				df = 56					<0.0001

Table B.6. (contd)

d. Replicate 4

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	21	18	19	21	
R2_CR468	0	0	0	0	13	16	16	18	0.9884
R3_CR422	0	0	0	0	15	13	16	18	
R4_CR346	6	8	10	7	0	0	0	0	0.9929
R5_CR325	5	7	10	7	0	0	0	0	
R6_CR307	5	6	8	6	0	0	0	0	1
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	12	15	22	14	0	0	0	0	0.8004
R9_CR156	13	16	17	17	0	0	0	0	
Chi-square = 444.32				df = 56					<0.0001

e. Replicate 5

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	20	19	18	22	
R2_CR468	0	0	0	0	15	15	15	18	1
R3_CR422	0	0	0	0	15	15	15	18	
R4_CR346	6	9	9	7	0	0	0	0	0.9904
R5_CR325	6	8	10	7	0	0	0	0	
R6_CR307	5	6	9	5	0	0	0	0	0.9853
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	13	17	19	14	0	0	0	0	0.9701
R9_CR156	13	17	17	16	0	0	0	0	
Chi-square = 445.23				df = 56					<0.0001

f. Replicate 6

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	20	18	21	
R2_CR468	0	0	0	0	15	14	15	19	0.9990
R3_CR422	0	0	0	0	15	15	14	19	
R4_CR346	6	7	10	8	0	0	0	0	0.9901
R5_CR325	6	7	11	7	0	0	0	0	
R6_CR307	5	6	8	6	0	0	0	0	1
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	0	0	0	0	15	15	15	18	0.9961
R9_CR156	0	0	0	0	16	15	15	17	
Chi-square = 443.39				df = 56					<0.0001

Table B.6. (contd)

g. Replicate 7

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	15	18	26	16	0	0	0	0	
R2_CR468	13	14	22	14	0	0	0	0	1
R3_CR422	13	14	22	14	0	0	0	0	
R4_CR346	6	8	10	7	0	0	0	0	0.9416
R5_CR325	5	8	9	9	0	0	0	0	
R6_CR307	0	0	0	0	6	6	6	7	1
R7_CR275	0	0	0	0	6	6	6	7	
R8_CR233	0	0	0	0	15	15	14	18	0.9932
R9_CR156	0	0	0	0	15	14	15	19	
Chi-square = 440.69				df = 56					<0.0001

h. Replicate 8

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	19	27	17	0	0	0	0	
R2_CR468	11	15	21	14	0	0	0	0	1
R3_CR422	12	15	22	14	0	0	0	0	
R4_CR346	0	0	0	0	7	8	7	9	1
R5_CR325	0	0	0	0	7	8	7	9	
R6_CR307	0	0	0	0	5	6	6	8	0.9841
R7_CR275	0	0	0	0	6	6	6	7	
R8_CR233	0	0	0	0	16	15	15	17	0.9701
R9_CR156	0	0	0	0	14	15	15	19	
Chi-square = 442.39				df = 56					<0.0001

i. Replicate 9

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	15	19	27	17	0	0	0	0	
R2_CR468	12	14	22	14	0	0	0	0	0.9890
R3_CR422	13	17	18	15	0	0	0	0	
R4_CR346	0	0	0	0	7	7	8	9	0.9876
R5_CR325	0	0	0	0	8	7	7	9	
R6_CR307	0	0	0	0	6	6	5	8	0.9290
R7_CR275	0	0	0	0	6	7	6	6	
R8_CR233	0	0	0	0	16	14	14	19	0.9882
R9_CR156	0	0	0	0	15	15	15	18	
Chi-square = 444.76				df = 56					<0.0001

Table B.6. (contd)

j. Replicate 10

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	19	26	18	0	0	0	0	
R2_CR468	12	16	21	12	0	0	0	0	0.9893
R3_CR422	13	16	18	16	0	0	0	0	
R4_CR346	0	0	0	0	7	7	7	10	0.9894
R5_CR325	0	0	0	0	8	7	7	9	
R6_CR307	0	0	0	0	6	7	5	7	0.9826
R7_CR275	0	0	0	0	6	6	6	7	
R8_CR233	13	16	18	15	0	0	0	0	0.9288
R9_CR156	11	17	21	14	0	0	0	0	
Chi-square = 443.9105				df = 56					<0.0001

k. Replicate 11

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	18	18	23	
R2_CR468	0	0	0	0	14	16	15	18	0.9980
R3_CR422	0	0	0	0	15	13	16	19	
R4_CR346	0	0	0	0	8	7	7	9	0.9886
R5_CR325	0	0	0	0	8	7	8	8	
R6_CR307	6	7	7	5	0	0	0	0	0.9552
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	13	16	19	14	0	0	0	0	0.9936
R9_CR156	13	15	20	15	0	0	0	0	
Chi-square = 443.5449				df = 56					<0.0001

l. Replicate 12

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	19	17	23	
R2_CR468	0	0	0	0	13	15	15	19	0.9994
R3_CR422	0	0	0	0	14	15	15	18	
R4_CR346	6	8	10	7	0	0	0	0	0.9881
R5_CR325	7	8	9	7	0	0	0	0	
R6_CR307	5	7	8	5	0	0	0	0	1
R7_CR275	5	7	8	5	0	0	0	0	
R8_CR233	13	15	20	14	0	0	0	0	0.9548
R9_CR156	13	18	19	13	0	0	0	0	
Chi-square = 440.8645				df = 56					<0.0001

Table B.6. (contd)

m. Replicate 13

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	20	18	18	23	
R2_CR468	0	0	0	0	16	15	14	18	1
R3_CR422	0	0	0	0	16	14	15	18	
R4_CR346	6	8	10	7	0	0	0	0	1
R5_CR325	6	8	10	7	0	0	0	0	
R6_CR307	5	7	7	6	0	0	0	0	0.9841
R7_CR275	5	7	8	5	0	0	0	0	
R8_CR233	13	18	19	13	0	0	0	0	0.9967
R9_CR156	13	19	18	13	0	0	0	0	
Chi-square = 444.348				df = 56					<0.0001

n. Replicate 14

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	18	19	23	
R2_CR468	0	0	0	0	16	15	14	18	0.9992
R3_CR422	0	0	0	0	15	16	13	19	
R4_CR346	6	8	10	7	0	0	0	0	1
R5_CR325	6	8	10	7	0	0	0	0	
R6_CR307	5	8	8	4	0	0	0	0	0.9974
R7_CR275	5	7	8	4	0	0	0	0	
R8_CR233	0	0	0	0	15	15	15	18	0.9955
R9_CR156	0	0	0	0	14	15	16	18	
Chi-square = 446.1753				df = 56					<0.0001

o. Replicate 15

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	21	23	19	0	0	0	0	
R2_CR468	13	17	17	16	0	0	0	0	0.9967
R3_CR422	13	17	20	13	0	0	0	0	
R4_CR346	6	8	10	7	0	0	0	0	0.9853
R5_CR325	5	9	10	7	0	0	0	0	
R6_CR307	0	0	0	0	6	6	6	7	0.9826
R7_CR275	0	0	0	0	6	7	5	7	
R8_CR233	0	0	0	0	15	15	15	18	1
R9_CR156	0	0	0	0	15	15	15	18	
Chi-square = 445.4965				df = 56					<0.0001

Table B.6. (contd)

p. Replicate 16

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	21	23	19	0	0	0	0	
R2_CR468	13	16	19	15	0	0	0	0	0.9946
R3_CR422	11	16	22	14	0	0	0	0	
R4_CR346	0	0	0	0	7	8	7	9	0.9876
R5_CR325	0	0	0	0	8	7	7	9	
R6_CR307	0	0	0	0	6	6	6	7	0.9826
R7_CR275	0	0	0	0	5	7	6	7	
R8_CR233	0	0	0	0	14	16	14	19	0.9960
R9_CR156	0	0	0	0	15	16	14	18	
Chi-square = 445.4888				df = 56					<0.0001

q. Replicate 17

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	22	20	20	0	0	0	0	
R2_CR468	13	16	17	15	0	0	0	0	0.9852
R3_CR422	12	18	20	13	0	0	0	0	
R4_CR346	0	0	0	0	8	8	7	8	0.9876
R5_CR325	0	0	0	0	7	8	8	8	
R6_CR307	0	0	0	0	6	6	6	7	0.9826
R7_CR275	0	0	0	0	6	7	5	7	
R8_CR233	0	0	0	0	15	16	13	19	0.9772
R9_CR156	0	0	0	0	15	15	15	18	
Chi-square = 443.7151				df = 56					<0.0001

r. Replicate 18

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	20	24	19	0	0	0	0	
R2_CR468	13	15	21	14	0	0	0	0	0.9962
R3_CR422	13	18	19	13	0	0	0	0	
R4_CR346	0	0	0	0	7	8	7	9	0.9894
R5_CR325	0	0	0	0	7	7	7	10	
R6_CR307	0	0	0	0	6	6	6	7	0.9841
R7_CR275	0	0	0	0	5	6	6	8	
R8_CR233	12	16	19	15	0	0	0	0	0.9725
R9_CR156	13	17	20	13	0	0	0	0	
Chi-square = 444.3609				df = 56					<0.0001

Table B.6. (contd)

s. Replicate 19

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	19	19	22	
R2_CR468	0	0	0	0	16	16	14	16	0.9997
R3_CR422	0	0	0	0	15	15	15	18	
R4_CR346	0	0	0	0	8	7	7	9	0.9669
R5_CR325	0	0	0	0	7	8	6	10	
R6_CR307	5	7	7	6	0	0	0	0	0.9861
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	13	16	21	13	0	0	0	0	0.9951
R9_CR156	12	17	21	13	0	0	0	0	
Chi-square = 444.6745				df = 56					<0.0001

t. Replicate 20

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	19	18	22	
R2_CR468	0	0	0	0	16	15	14	18	1
R3_CR422	0	0	0	0	15	15	15	18	
R4_CR346	6	8	10	7	0	0	0	0	1
R5_CR325	6	8	10	7	0	0	0	0	
R6_CR307	5	7	8	5	0	0	0	0	1
R7_CR275	5	7	8	5	0	0	0	0	
R8_CR233	13	16	20	14	0	0	0	0	0.9957
R9_CR156	12	16	21	14	0	0	0	0	
Chi-square = 442.6701				df = 56					<0.0001

u. Replicate 21

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	20	19	17	23	
R2_CR468	0	0	0	0	15	16	15	17	0.9993
R3_CR422	0	0	0	0	15	14	15	18	
R4_CR346	7	8	10	6	0	0	0	0	0.9887
R5_CR325	6	8	11	6	0	0	0	0	
R6_CR307	5	7	7	6	0	0	0	0	0.9861
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	13	17	18	15	0	0	0	0	0.9814
R9_CR156	12	16	20	15	0	0	0	0	
Chi-square = 444.7641				df = 56					<0.0001

Table B.6. (contd)

v. Replicate 22

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	19	18	23	
R2_CR468	0	0	0	0	15	15	15	18	1
R3_CR422	0	0	0	0	15	16	14	18	
R4_CR346	7	8	9	7	0	0	0	0	0.9881
R5_CR325	6	8	10	7	0	0	0	0	
R6_CR307	5	7	6	7	0	0	0	0	0.9423
R7_CR275	5	7	7	5	0	0	0	0	
R8_CR233	0	0	0	0	14	17	14	18	0.9850
R9_CR156	0	0	0	0	15	15	14	18	
Chi-square = 444.6288				df = 56					<0.0001

w. Replicate 23

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	21	24	18	0	0	0	0	
R2_CR468	13	16	19	15	0	0	0	0	0.9996
R3_CR422	13	18	19	13	0	0	0	0	
R4_CR346	5	9	9	8	0	0	0	0	0.9853
R5_CR325	6	8	9	8	0	0	0	0	
R6_CR307	0	0	0	0	6	6	5	8	0.9861
R7_CR275	0	0	0	0	6	7	5	7	
R8_CR233	0	0	0	0	15	16	15	17	0.9959
R9_CR156	0	0	0	0	14	16	15	18	
Chi-square = 445.7262				df = 56					<0.0001

x. Replicate 24

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	21	24	18	0	0	0	0	
R2_CR468	13	17	20	13	0	0	0	0	0.9999
R3_CR422	13	17	20	13	0	0	0	0	
R4_CR346	0	0	0	0	7	8	7	9	1
R5_CR325	0	0	0	0	7	8	7	9	
R6_CR307	0	0	0	0	5	7	6	7	1
R7_CR275	0	0	0	0	5	7	6	7	
R8_CR233	0	0	0	0	15	16	14	18	0.9953
R9_CR156	0	0	0	0	14	16	15	18	
Chi-square = 443.9546				df = 56					<0.0001

Table B.6. (contd)

y. Replicate 25

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	22	23	17	0	0	0	0	
R2_CR468	13	17	19	13	0	0	0	0	0.9999
R3_CR422	13	17	18	15	0	0	0	0	
R4_CR346	0	0	0	0	7	9	7	8	0.9886
R5_CR325	0	0	0	0	8	8	7	8	
R6_CR307	0	0	0	0	6	6	6	7	0.9826
R7_CR275	0	0	0	0	5	7	6	7	
R8_CR233	0	0	0	0	16	15	15	17	0.9847
R9_CR156	0	0	0	0	14	15	15	18	
Chi-square = 441.9847				df = 56					<0.0001

z. Replicate 26

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	16	21	26	16	0	0	0	0	
R2_CR468	13	15	19	16	0	0	0	0	0.9846
R3_CR422	11	18	19	15	0	0	0	0	
R4_CR346	0	0	0	0	8	7	7	9	0.9669
R5_CR325	0	0	0	0	7	8	6	10	
R6_CR307	0	0	0	0	6	6	6	7	1
R7_CR275	0	0	0	0	6	6	6	7	
R8_CR233	13	19	19	12	0	0	0	0	0.8913
R9_CR156	12	16	19	15	0	0	0	0	
Chi-square = 446.1691				df = 56					<0.0001

aa. Replicate 27

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	20	17	23	
R2_CR468	0	0	0	0	16	17	14	16	0.9996
R3_CR422	0	0	0	0	15	17	14	17	
R4_CR346	0	0	0	0	7	7	7	10	0.9436
R5_CR325	0	0	0	0	7	8	5	10	
R6_CR307	5	6	9	5	0	0	0	0	0.9853
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	12	16	22	13	0	0	0	0	0.9581
R9_CR156	13	15	20	15	0	0	0	0	
Chi-square = 445.4018				df = 56					<0.0001

Table B.6. (contd)

bb. Replicate 28

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	20	18	21	
R2_CR468	0	0	0	0	15	15	14	19	0.9998
R3_CR422	0	0	0	0	15	16	14	18	
R4_CR346	7	8	10	6	0	0	0	0	0.9847
R5_CR325	6	8	10	7	0	0	0	0	
R6_CR307	5	6	7	7	0	0	0	0	0.9861
R7_CR275	5	6	8	6	0	0	0	0	
R8_CR233	13	15	19	16	0	0	0	0	0.9819
R9_CR156	12	15	21	15	0	0	0	0	
Chi-square = 444.2154				df = 56					<0.0001

cc. Replicate 29

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	20	17	23	
R2_CR468	0	0	0	0	15	16	14	18	1
R3_CR422	0	0	0	0	15	15	15	18	
R4_CR346	7	7	10	7	0	0	0	0	0.9861
R5_CR325	6	8	10	7	0	0	0	0	
R6_CR307	5	6	8	6	0	0	0	0	0.9861
R7_CR275	5	7	7	6	0	0	0	0	
R8_CR233	12	16	20	15	0	0	0	0	0.9881
R9_CR156	12	16	18	16	0	0	0	0	
Chi-square = 443.5412				df = 56					<0.0001

dd. Replicate 30

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	0	0	0	0	19	21	17	22	
R2_CR468	0	0	0	0	14	17	15	17	0.9998
R3_CR422	0	0	0	0	14	17	15	17	
R4_CR346	6	8	9	7	0	0	0	0	0.9392
R5_CR325	6	6	10	8	0	0	0	0	
R6_CR307	5	6	8	6	0	0	0	0	0.9795
R7_CR275	4	7	8	6	0	0	0	0	
R8_CR233	0	0	0	0	14	16	14	19	0.9960
R9_CR156	0	0	0	0	15	16	14	18	
Chi-square = 444.5203				df = 56					<0.0001

Table B.6. (contd)

ee. Replicate 31

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	18	22	26	21	0	0	0	0	
R2_CR468	12	13	19	15	0	0	0	0	0.9994
R3_CR422	10	11	16	12	0	0	0	0	
R4_CR346	5	6	7	6	0	0	0	0	0.9974
R5_CR325	5	6	8	6	0	0	0	0	
R6_CR307	0	0	0	0	4	5	4	6	0.9773
R7_CR275	0	0	0	0	4	5	5	5	
R8_CR233	0	0	0	0	12	13	13	17	0.9754
R9_CR156	0	0	0	0	12	15	12	16	
Chi-square = 393.8158				df = 56					<0.0001

ff. Replicate 32

Release	E	C	H	G	B	D	F	A	P-value
R1_CR503	15	22	26	18	0	0	0	0	
R2_CR468	11	14	18	11	0	0	0	0	0.9986
R3_CR422	8	12	17	11	0	0	0	0	
R4_CR346	0	0	0	0	6	6	6	7	0.9951
R5_CR325	0	0	0	0	6	6	5	7	
R6_CR307	0	0	0	0	5	5	4	5	0.9773
R7_CR275	0	0	0	0	4	5	4	6	
R8_CR233	0	0	0	0	13	13	12	17	0.9773
R9_CR156	0	0	0	0	13	14	13	15	
Chi-square = 381.9773				df = 56					<0.0001

Table B.7. Estimates of Reach and Cumulative Survival for Subyearling Chinook Salmon and Associated *F*-test of Homogeneous Survival Across Fish Tagged by Different Staff Members in Summer 2012

a. Release 1 – Reach survival

	Release to CR470.0		CR470.0 to CR422.0		CR422.0 to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR275.0		CR275.0 to CR234.0		CR234.0 to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9777	0.0078	0.9229	0.0143	0.9505	0.0121	0.9375	0.0139	0.9860	0.0070	0.9395	0.0142	0.9889	0.0065	0.9468	0.0147	0.9768	0.0106
B	0.9841	0.0072	0.9175	0.0158	0.9465	0.0135	0.9198	0.0168	0.9962	0.0041	0.9167	0.0178	1.0002	0.0002	0.9531	0.0150	0.9887	0.0083
C	0.9908	0.0053	0.8920	0.0172	0.9412	0.0138	0.9449	0.0138	0.9961	0.0039	0.9570	0.0127	0.9926	0.0058	0.9399	0.0158	0.9954	0.0054
D	0.9803	0.0080	0.9161	0.0161	0.9560	0.0124	0.9387	0.0148	0.9878	0.0070	0.9504	0.0140	0.9957	0.0043	0.9550	0.0139	1.0012	0.0007
E	0.9647	0.0116	0.9228	0.0170	0.9604	0.0130	0.9447	0.0155	0.9951	0.0049	0.9559	0.0144	0.9694	0.0124	0.9730	0.0122	0.9941	0.0063
F	0.9759	0.0091	0.9247	0.0158	0.9537	0.0131	0.9271	0.0165	0.9913	0.0061	0.9427	0.0154	0.9953	0.0047	0.9476	0.0155	0.9949	0.0056
G	0.9721	0.0097	0.9104	0.0171	0.9724	0.0103	0.9224	0.0171	0.9779	0.0098	0.9910	0.0064	0.9822	0.0091	0.9480	0.0155	0.9893	0.0077
H	0.9748	0.0079	0.9093	0.0146	0.9573	0.0108	0.9521	0.0117	1.0000	0.0000	0.9497	0.0123	0.9967	0.0033	0.9493	0.0132	0.9803	0.0090
P-value	0.5443		0.8721		0.7766		0.7610		0.2749		0.0246		0.0307		0.8701		0.2653	

b. Release 1 – Cumulative survival

	Release to CR470.0		Release to CR422.0		Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR275.0		Release to CR234.0		Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A	0.9777	0.0078	0.9022	0.0157	0.8575	0.0185	0.8039	0.0210	0.7927	0.0215	0.7447	0.0231	0.7364	0.0234	0.6973	0.0246	0.6811	0.0249
B	0.9841	0.0072	0.9029	0.0168	0.8547	0.0201	0.7861	0.0233	0.7832	0.0235	0.7179	0.0256	0.7181	0.0256	0.6844	0.0267	0.6766	0.0268
C	0.9908	0.0053	0.8838	0.0177	0.8318	0.0207	0.7859	0.0227	0.7829	0.0228	0.7492	0.0240	0.7437	0.0242	0.6990	0.0255	0.6958	0.0256
D	0.9803	0.0080	0.8980	0.0174	0.8586	0.0200	0.8059	0.0227	0.7961	0.0231	0.7566	0.0246	0.7533	0.0247	0.7194	0.0258	0.7202	0.0259
E	0.9647	0.0116	0.8902	0.0196	0.8549	0.0221	0.8076	0.0247	0.8037	0.0249	0.7682	0.0265	0.7447	0.0273	0.7246	0.0281	0.7204	0.0282
F	0.9759	0.0091	0.9024	0.0175	0.8606	0.0204	0.7979	0.0237	0.7909	0.0240	0.7456	0.0257	0.7422	0.0258	0.7033	0.0270	0.6997	0.0271
G	0.9721	0.0097	0.8850	0.0188	0.8606	0.0204	0.7939	0.0239	0.7763	0.0246	0.7693	0.0249	0.7556	0.0254	0.7163	0.0268	0.7087	0.0270
H	0.9748	0.0079	0.8864	0.0159	0.8485	0.0180	0.8079	0.0198	0.8079	0.0198	0.7672	0.0213	0.7647	0.0213	0.7259	0.0226	0.7116	0.0230
P-value	0.5443		0.9784		0.9788		0.9923		0.9813		0.8396		0.9452		0.9396		0.8998	

Table B.7. (contd)

c. Release 2 – Reach survival

			Release to CR422.0		CR422.0 to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR275.0		CR275.0 to CR234.0		CR234.0 to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A			0.9296	0.0152	0.9394	0.0147	0.9673	0.0114	0.9876	0.0073	0.9442	0.0150	0.9864	0.0078	0.9367	0.0166	0.9896	0.0076
B			0.9205	0.0175	0.9636	0.0126	0.9426	0.0161	0.9848	0.0087	0.9433	0.0166	0.9891	0.0077	0.9826	0.0112	0.9671	0.0145
C			0.9228	0.0170	0.9648	0.0122	0.9401	0.0161	0.9904	0.0069	0.9602	0.0138	0.9848	0.0089	0.9586	0.0146	0.9940	0.0062
D			0.9194	0.0173	0.9430	0.0154	0.9206	0.0185	0.9848	0.0087	0.9381	0.0173	0.9835	0.0094	0.9835	0.0114	0.9616	0.0161
E			0.9353	0.0173	0.9468	0.0164	0.9326	0.0188	0.9880	0.0085	0.9329	0.0195	0.9804	0.0112	0.9617	0.0161	0.9844	0.0110
F			0.9277	0.0169	0.9404	0.0160	0.9513	0.0150	0.9897	0.0073	0.9430	0.0167	0.9949	0.0055	0.9399	0.0179	0.9876	0.0090
G			0.9330	0.0167	0.9713	0.0116	0.9307	0.0179	1.0004	0.0004	0.9305	0.0186	0.9945	0.0057	0.9607	0.0152	0.9862	0.0097
H			0.9177	0.0155	0.9655	0.0107	0.9534	0.0126	0.9887	0.0065	0.9354	0.0152	0.9837	0.0081	0.9550	0.0134	0.9951	0.0048
P-value			0.9932		0.5042		0.5409		0.8623		0.9499		0.8961		0.2245		0.2164	

d. Release 2 – Cumulative survival

			Release to CR422.0		Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR275.0		Release to CR234.0		Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A			0.9296	0.0152	0.8732	0.0197	0.8447	0.0215	0.8342	0.0221	0.7877	0.0243	0.7770	0.0248	0.7278	0.0266	0.7202	0.0268
B			0.9205	0.0175	0.8870	0.0205	0.8361	0.0240	0.8234	0.0247	0.7767	0.0270	0.7682	0.0274	0.7548	0.0283	0.7300	0.0289
C			0.9228	0.0170	0.8902	0.0199	0.8369	0.0236	0.8289	0.0241	0.7959	0.0258	0.7838	0.0263	0.7513	0.0277	0.7468	0.0278
D			0.9194	0.0173	0.8669	0.0216	0.7981	0.0255	0.7859	0.0261	0.7373	0.0280	0.7251	0.0284	0.7132	0.0291	0.6858	0.0296
E			0.9353	0.0173	0.8856	0.0225	0.8259	0.0267	0.8159	0.0273	0.7612	0.0301	0.7463	0.0307	0.7177	0.0319	0.7065	0.0321
F			0.9277	0.0169	0.8723	0.0218	0.8298	0.0245	0.8213	0.0250	0.7745	0.0273	0.7705	0.0275	0.7242	0.0292	0.7152	0.0295
G			0.9330	0.0167	0.9063	0.0195	0.8434	0.0243	0.8438	0.0243	0.7851	0.0275	0.7808	0.0277	0.7501	0.0291	0.7398	0.0294
H			0.9177	0.0155	0.8861	0.0179	0.8448	0.0204	0.8353	0.0209	0.7813	0.0233	0.7686	0.0238	0.7340	0.0249	0.7305	0.0250
P-value			0.9932		0.9183		0.8893		0.8190		0.8566		0.8114		0.9441		0.8622	

Table B.7. (contd)

e. Release 3 – Reach survival

					Release to CR349.0		CR349.0 to CR325.0		CR325.0 to CR309.0		CR309.0 to CR275.0		CR275.0 to CR234.0		CR234.0 to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A					0.9412	0.0138	0.9556	0.0125	0.9767	0.0094	0.9167	0.0174	0.9827	0.0086	0.9571	0.0137	0.9858	0.0086
B					0.9372	0.0157	0.9361	0.0165	0.9854	0.0084	0.9356	0.0173	0.9894	0.0074	0.9544	0.0158	0.9811	0.0112
C					0.9137	0.0176	0.9348	0.0163	0.9862	0.0080	0.9668	0.0123	0.9954	0.0049	0.9472	0.0159	0.9882	0.0083
D					0.9423	0.0151	0.9156	0.0185	1.0000	0.0000	0.8889	0.0218	0.9728	0.0120	0.9285	0.0194	0.9878	0.0093
E					0.9375	0.0175	0.9333	0.0186	1.0000	0.0000	0.9226	0.0206	0.9935	0.0064	0.9805	0.0111	1.0000	0.0000
F					0.9534	0.0137	0.9412	0.0158	1.0000	0.0000	0.9471	0.0155	0.9746	0.0112	0.9305	0.0189	0.9630	0.0149
G					0.9541	0.0142	0.9614	0.0134	0.9849	0.0086	0.9082	0.0206	0.9944	0.0056	0.9943	0.0057	1.0001	0.0001
H					0.9490	0.0124	0.9461	0.0131	0.9929	0.0050	0.9570	0.0121	0.9889	0.0065	0.9847	0.0076	1.0001	0.0001
P-value					0.6476		0.5717		0.2967		0.0291		0.3174		0.0040		0.0605	

f. Release 3 – Cumulative survival

					Release to CR349.0		Release to CR325.0		Release to CR309.0		Release to CR275.0		Release to CR234.0		Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A					0.9412	0.0138	0.8993	0.0177	0.8784	0.0193	0.8052	0.0234	0.7913	0.0240	0.7573	0.0254	0.7465	0.0257
B					0.9372	0.0157	0.8773	0.0213	0.8645	0.0223	0.8089	0.0256	0.8003	0.0261	0.7638	0.0279	0.7494	0.0283
C					0.9137	0.0176	0.8541	0.0222	0.8424	0.0229	0.8144	0.0244	0.8107	0.0246	0.7679	0.0267	0.7588	0.0269
D					0.9423	0.0151	0.8627	0.0222	0.8627	0.0222	0.7669	0.0273	0.7460	0.0281	0.6927	0.0298	0.6842	0.0301
E					0.9375	0.0175	0.8750	0.0239	0.8750	0.0239	0.8073	0.0285	0.8021	0.0288	0.7865	0.0296	0.7865	0.0296
F					0.9534	0.0137	0.8973	0.0199	0.8973	0.0199	0.8499	0.0234	0.8283	0.0247	0.7707	0.0278	0.7422	0.0287
G					0.9541	0.0142	0.9173	0.0187	0.9034	0.0200	0.8205	0.0260	0.8159	0.0263	0.8112	0.0266	0.8113	0.0266
H					0.9490	0.0124	0.8979	0.0171	0.8915	0.0176	0.8532	0.0200	0.8437	0.0205	0.8308	0.0212	0.8309	0.0212
P-value					0.6476		0.3731		0.4859		0.3012		0.2486		0.0235		0.0064	

Table B.7. (contd)

g. Release 4 – Reach survival

							Release to CR325.0		CR325.0 to CR309.0		CR309.0 to CR275.0		CR275.0 to CR234.0		CR234.0 to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A							1.0000	0.0000	1.0000	0.0000	0.9167	0.0230	0.9932	0.0076	0.9535	0.0185	1.0003	0.0003
B							1.0000	0.0000	0.9916	0.0084	0.9576	0.0185	0.9735	0.0151	0.9545	0.0199	1.0004	0.0004
C							1.0000	0.0000	0.9921	0.0079	0.9440	0.0206	0.9831	0.0119	0.9741	0.0147	1.0000	0.0000
D							1.0000	0.0000	1.0000	0.0000	0.8908	0.0286	1.0002	0.0002	0.9830	0.0135	0.9787	0.0149
E							1.0000	0.0000	0.9898	0.0102	0.9691	0.0176	0.9894	0.0106	0.9469	0.0234	0.9891	0.0121
F							1.0000	0.0000	1.0000	0.0000	0.9483	0.0206	1.0000	0.0000	0.9737	0.0156	0.9897	0.0103
G							1.0000	0.0000	1.0000	0.0000	0.9459	0.0215	0.9905	0.0095	0.9712	0.0164	1.0000	0.0000
H							0.9935	0.0065	0.9934	0.0066	0.9404	0.0193	0.9932	0.0070	0.9722	0.0141	0.9919	0.0080
P-value							0.9966		0.9572		0.2388		0.5865		0.8045		0.6814	

h. Release 4 – Cumulative survival

							Release to CR325.0		Release to CR309.0		Release to CR275.0		Release to CR234.0		Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A							1.0000	0.0000	1.0000	0.0000	0.9167	0.0230	0.9104	0.0239	0.8681	0.0282	0.8683	0.0282
B							1.0000	0.0000	0.9916	0.0084	0.9496	0.0201	0.9244	0.0242	0.8824	0.0295	0.8827	0.0295
C							1.0000	0.0000	0.9921	0.0079	0.9365	0.0217	0.9206	0.0241	0.8968	0.0271	0.8968	0.0271
D							1.0000	0.0000	1.0000	0.0000	0.8908	0.0286	0.8909	0.0286	0.8758	0.0305	0.8571	0.0321
E							1.0000	0.0000	0.9898	0.0102	0.9592	0.0200	0.9490	0.0222	0.8986	0.0306	0.8888	0.0319
F							1.0000	0.0000	1.0000	0.0000	0.9483	0.0206	0.9483	0.0206	0.9233	0.0249	0.9138	0.0261
G							1.0000	0.0000	1.0000	0.0000	0.9459	0.0215	0.9369	0.0231	0.9099	0.0272	0.9099	0.0272
H							0.9935	0.0065	0.9869	0.0092	0.9281	0.0209	0.9218	0.0217	0.8961	0.0248	0.8889	0.0254
P-value							0.9966		0.9159		0.4336		0.6888		0.8919		0.8673	

Table B.7. (contd)

i. Release 5 – Reach survival

									Release to CR309.0		CR309.0 to CR275.0		CR275.0 to CR234.0		CR234.0 to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A									0.9931	0.0069	0.9510	0.0180	1.0002	0.0002	0.9787	0.0127	0.9840	0.0112
B									0.9832	0.0118	0.9402	0.0219	1.0015	0.0012	0.9252	0.0254	1.0000	0.0000
C									1.0000	0.0000	0.9187	0.0246	1.0002	0.0003	0.9732	0.0153	1.0003	0.0003
D									0.9918	0.0082	0.9752	0.0141	1.0000	0.0000	0.9658	0.0168	1.0003	0.0004
E									0.9892	0.0107	0.9130	0.0294	0.9881	0.0118	0.9639	0.0205	1.0015	0.0012
F									0.9910	0.0090	0.9545	0.0199	1.0000	0.0000	0.9631	0.0187	0.9891	0.0111
G									1.0000	0.0000	0.9561	0.0192	1.0004	0.0004	0.9630	0.0182	1.0000	0.0000
H									0.9809	0.0109	0.9610	0.0156	1.0002	0.0003	0.9667	0.0150	0.9936	0.0077
P-value									0.8337		0.4055		0.5798		0.6072		0.5697	

j. Release 5 – Cumulative survival

									Release to CR309.0		Release to CR275.0		Release to CR234.0		Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A									0.9931	0.0069	0.9444	0.0191	0.9446	0.0191	0.9245	0.0222	0.9097	0.0239
B									0.9832	0.0118	0.9244	0.0242	0.9257	0.0243	0.8565	0.0322	0.8565	0.0322
C									1.0000	0.0000	0.9187	0.0246	0.9189	0.0247	0.8943	0.0277	0.8945	0.0277
D									0.9918	0.0082	0.9672	0.0161	0.9672	0.0161	0.9341	0.0225	0.9345	0.0225
E									0.9892	0.0107	0.9032	0.0307	0.8925	0.0321	0.8602	0.0360	0.8615	0.0360
F									0.9910	0.0090	0.9459	0.0215	0.9459	0.0215	0.9110	0.0272	0.9011	0.0284
G									1.0000	0.0000	0.9561	0.0192	0.9565	0.0192	0.9211	0.0253	0.9211	0.0253
H									0.9809	0.0109	0.9427	0.0186	0.9429	0.0186	0.9115	0.0228	0.9056	0.0235
P-value									0.8337		0.5108		0.3564		0.3386		0.4658	

Table B.7. (contd)

k. Release 6 – Reach survival

											Release to CR275.0		CR275.0 to CR234.0		CR234.0 to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A											1.0000	0.0000	1.0000	0.0000	0.9474	0.0209	1.0000	0.0000
B											1.0000	0.0000	1.0000	0.0000	0.9780	0.0154	1.0000	0.0000
C											0.9905	0.0095	0.9905	0.0096	0.9916	0.0099	0.9895	0.0112
D											0.9894	0.0106	1.0002	0.0003	0.9795	0.0153	0.9879	0.0121
E											1.0000	0.0000	0.9753	0.0172	0.9873	0.0126	1.0000	0.0000
F											0.9775	0.0157	0.9774	0.0161	0.9654	0.0203	0.9867	0.0132
G											0.9889	0.0110	1.0000	0.0000	0.9775	0.0157	1.0000	0.0000
H											1.0000	0.0000	0.9923	0.0080	0.9590	0.0179	1.0005	0.0005
P-value											0.8550		0.6237		0.5666		0.9283	

l. Release 6 – Cumulative survival

											Release to CR275.0		Release to CR234.0		Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A											1.0000	0.0000	1.0000	0.0000	0.9474	0.0209	0.9474	0.0209
B											1.0000	0.0000	1.0000	0.0000	0.9780	0.0154	0.9780	0.0154
C											0.9905	0.0095	0.9810	0.0133	0.9728	0.0163	0.9626	0.0187
D											0.9894	0.0106	0.9896	0.0106	0.9693	0.0182	0.9576	0.0208
E											1.0000	0.0000	0.9753	0.0172	0.9630	0.0210	0.9630	0.0210
F											0.9775	0.0157	0.9555	0.0220	0.9224	0.0286	0.9101	0.0303
G											0.9889	0.0110	0.9889	0.0110	0.9667	0.0189	0.9667	0.0189
H											1.0000	0.0000	0.9923	0.0080	0.9516	0.0193	0.9520	0.0193
P-value											0.8550		0.4015		0.5931		0.4837	

Table B.7. (contd)

m. Release 7 – Reach survival

													Release to CR234.0		CR234.0 to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A													1.0000	0.0000	0.9729	0.0157	0.9901	0.0099
B													0.9886	0.0113	0.9770	0.0161	1.0006	0.0007
C													1.0001	0.0001	0.9911	0.0099	0.9792	0.0146
D													0.9607	0.0194	0.9700	0.0178	0.9881	0.0118
E													1.0000	0.0000	0.9872	0.0127	1.0000	0.0000
F													0.9891	0.0111	0.9773	0.0159	1.0001	0.0002
G													1.0000	0.0000	0.9667	0.0189	1.0000	0.0000
H													1.0010	0.0007	0.9597	0.0177	1.0000	0.0000
P-value													0.1548		0.8860		0.6569	

n. Release 7 – Cumulative survival

													Release to CR234.0		Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A													1.0000	0.0000	0.9729	0.0157	0.9633	0.0180
B													0.9886	0.0113	0.9659	0.0193	0.9665	0.0194
C													1.0001	0.0001	0.9912	0.0098	0.9706	0.0167
D													0.9607	0.0194	0.9319	0.0253	0.9208	0.0269
E													1.0000	0.0000	0.9872	0.0127	0.9872	0.0127
F													0.9891	0.0111	0.9667	0.0189	0.9668	0.0189
G													1.0000	0.0000	0.9667	0.0189	0.9667	0.0189
H													1.0010	0.0007	0.9606	0.0173	0.9606	0.0173
P-value													0.1548		0.4022		0.4429	

Table B.7. (contd)

o. Release 8 – Reach survival

															Release to CR156.0		CR156.0 to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A															0.9938	0.0049	0.9889	0.0064
B															1.0004	0.0004	0.9954	0.0046
C															0.9885	0.0066	1.0000	0.0000
D															0.9967	0.0042	0.9867	0.0076
E															0.9901	0.0069	1.0002	0.0002
F															0.9912	0.0062	1.0001	0.0001
G															0.9959	0.0045	0.9952	0.0048
H															0.9908	0.0055	0.9966	0.0036
P-value															0.7721		0.3038	

p. Release 8 – Cumulative survival

															Release to CR156.0		Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A															0.9938	0.0049	0.9828	0.0077
B															1.0004	0.0004	0.9957	0.0042
C															0.9885	0.0066	0.9885	0.0066
D															0.9967	0.0042	0.9835	0.0082
E															0.9901	0.0069	0.9903	0.0069
F															0.9912	0.0062	0.9913	0.0062
G															0.9959	0.0045	0.9911	0.0063
H															0.9908	0.0055	0.9875	0.0063
P-value															0.7721		0.8956	

Table B.7. (contd)

q. Release 9 – Reach survival

																	Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A																	1.0000	0.0000
B																	1.0001	0.0001
C																	1.0003	0.0003
D																	1.0000	0.0000
E																	0.9900	0.0071
F																	0.9914	0.0060
G																	1.0000	0.0000
H																	1.0001	0.0001
P-value																	0.3604	

r. Release 9 – Cumulative survival

																	Release to CR113.0	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
A																	1.0000	0.0000
B																	1.0001	0.0001
C																	1.0003	0.0003
D																	1.0000	0.0000
E																	0.9900	0.0071
F																	0.9914	0.0060
G																	1.0000	0.0000
H																	1.0001	0.0001
P-value																	0.3604	

B.2 Fish Size Distributions

Comparison of fish implanted with AMTs and ROR fish sampled at McNary Dam through the Smolt Monitoring Program shows that the length frequency distributions were generally well matched for yearling Chinook salmon (Figure B.1) and steelhead (Figure B.2). The size of subyearling Chinook salmon was somewhat larger than the fish sampled by the Fish Passage Center (Figure B.3). Mean lengths for the tagged fish were 143.7 mm for yearling Chinook salmon, 206.7 mm for steelhead, and 112.9 mm for subyearling Chinook salmon. Mean lengths for yearling Chinook salmon, steelhead, and subyearling Chinook salmon sampled by the Fish Passage Center at the McNary Dam juvenile sampling facility were 140.6 mm, 204.1 mm, and 104.9 mm, respectively. The length frequency distributions for the three yearling Chinook salmon releases, the three steelhead releases (Figure B.2), and the three subyearling Chinook salmon releases (Figure B.3) also were quite similar. Fish size did not change over the course of the spring study (Figure B.4). During summer, the size of subyearling Chinook salmon declined slightly with time.

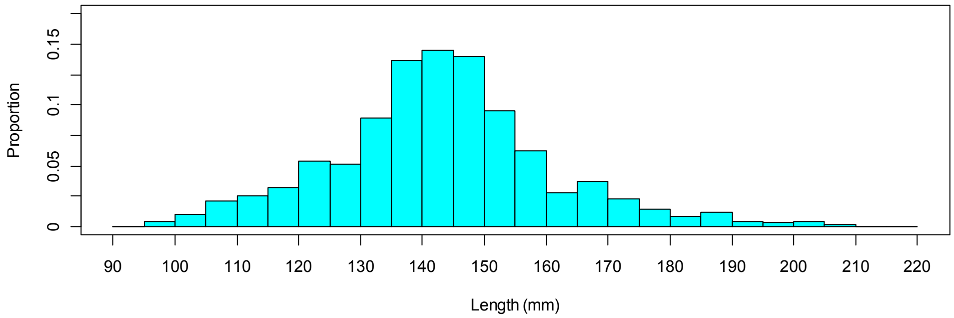
B.3 AMT-Life Corrections

During 2012, separate AMT lots were used for each species in the spring and the summer study. From each of these AMT lots, 98 to 100 tags were systematically sampled to conduct independent AMT-life studies. A three-parameter Weibull curve was used to fit the tags used in the steelhead study, and the vitality curve of Li and Anderson (2009) was used to fit the yearling and subyearling Chinook salmon data (Figure B.5). Average AMT lives were 32.2 d, 23.0 d, and 23.3 d for the steelhead, yearling, and subyearling Chinook salmon AMT lots, respectively.

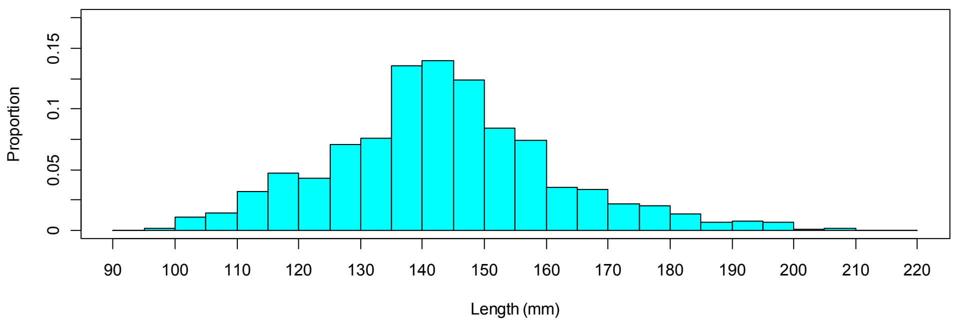
B.4 Arrival Distributions

The estimated probability that an AMT was active when fish arrived at a downstream detection array depends on the AMT-life curve and the distribution of observed travel times for yearling Chinook salmon, steelhead, and subyearling Chinook salmon (Figure B.6). Examination of the fish arrival distributions to the last detection array used in the survival analyses indicated all fish had passed through the study area before AMT failure became important. These probabilities were calculated by integrating the AMT survivorship curve over the observed distribution of fish arrival times (i.e., time from AMT activation to arrival; Figure B.6). The probabilities of a JSATS AMT being active at a downstream detection site were specific to release location, fish stock, and season (Table B.8). In all cases, the probability that an AMT was active at a downstream detection site as far as rkm 325 was 99.25% for yearling Chinook salmon smolts, 100% for steelhead smolts, and 99.63% for subyearling Chinook salmon smolts (Table B.8).

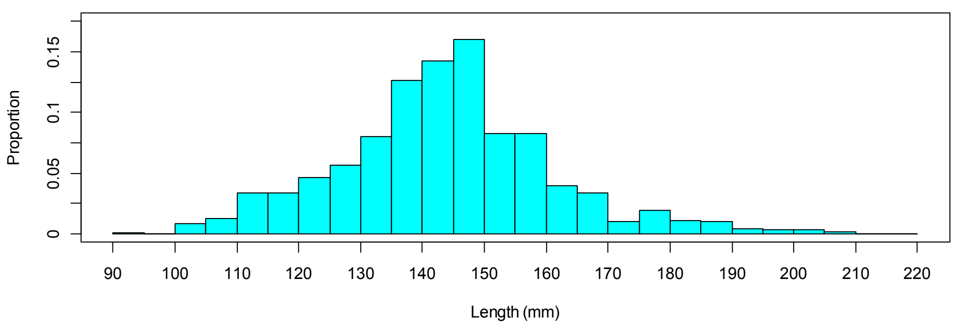
a. McNary Dam (Release V_1)



b. McNary Tailrace (Release R_2)



c. Mid-Reservoir (Release R_3)



d. ROR Yearling Chinook Salmon at John Day Dam

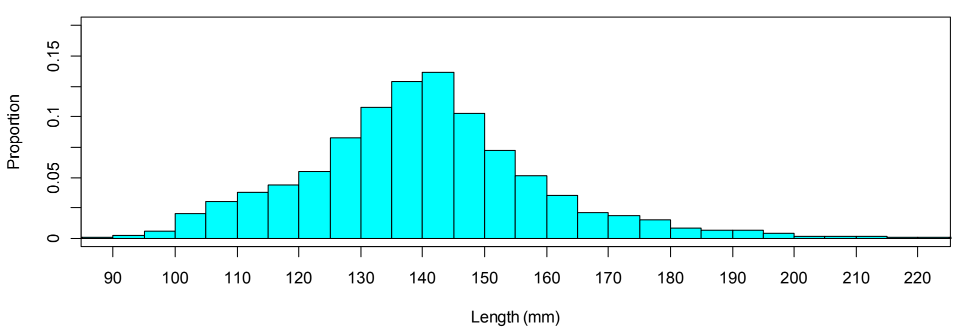
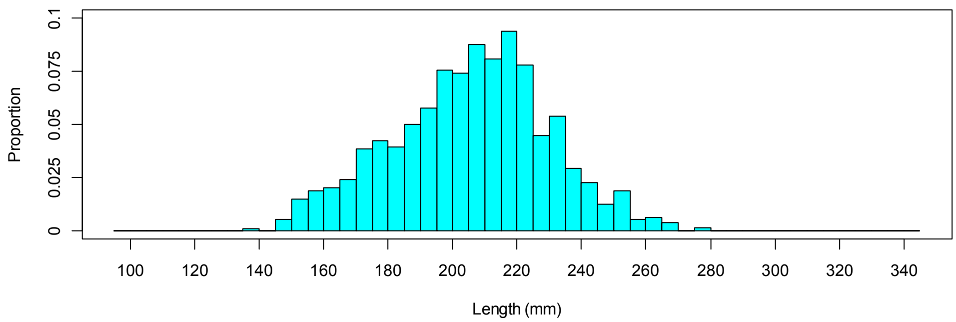
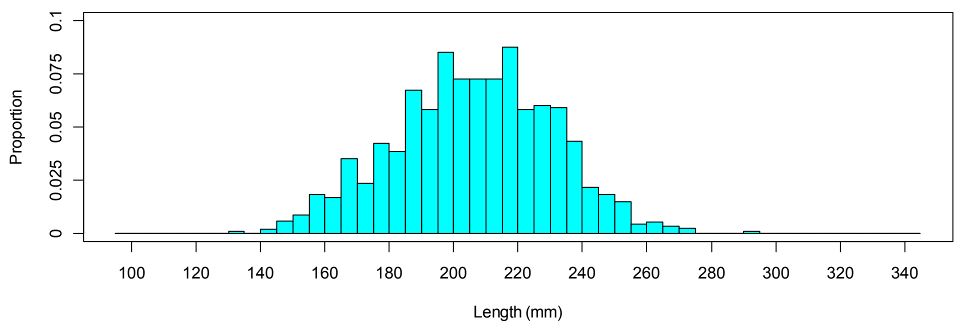


Figure B.1. Relative Frequency Distributions for Fish Lengths (mm) of Yearling Chinook Salmon Smolts used in a) Release V_1, b) Release R_2, c) Release R_3, and d) ROR Fish Sampled at John Day Dam by the Fish Passage Center in 2012

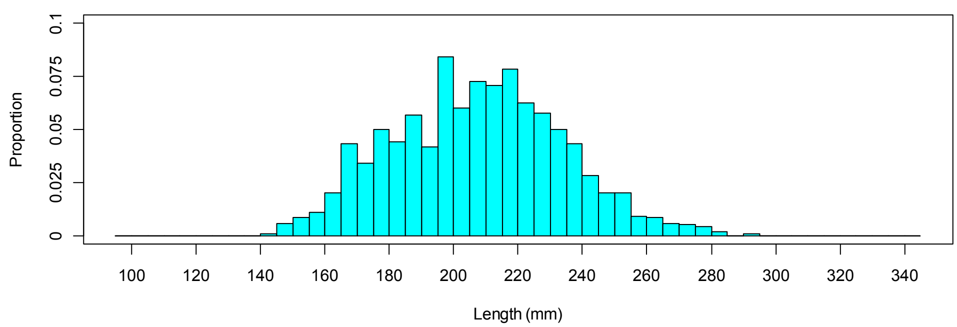
a. McNary Dam (Release V_1)



b. McNary Tailrace (Release R_2)



c. Mid-Reservoir (Release R_3)



d. ROR Steelhead at John Day Dam

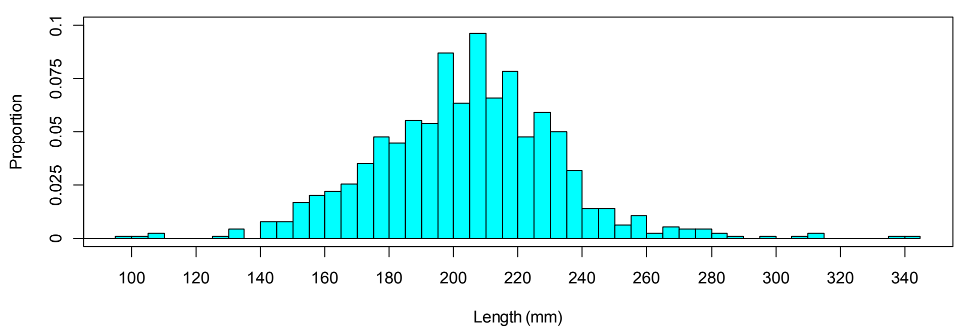
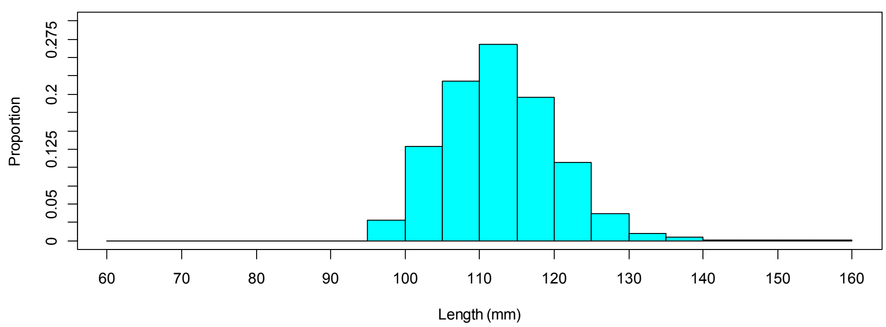
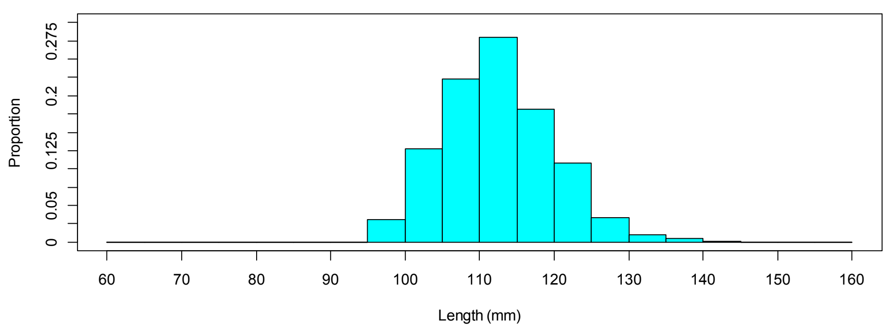


Figure B.2. Relative Frequency Distributions for Fish Lengths (mm) of Steelhead Smolts used in a) Release V_1, b) Release R_2, c) Release R_3, and d) ROR Fish Sampled at John Day Dam by the Fish Passage Center in 2012

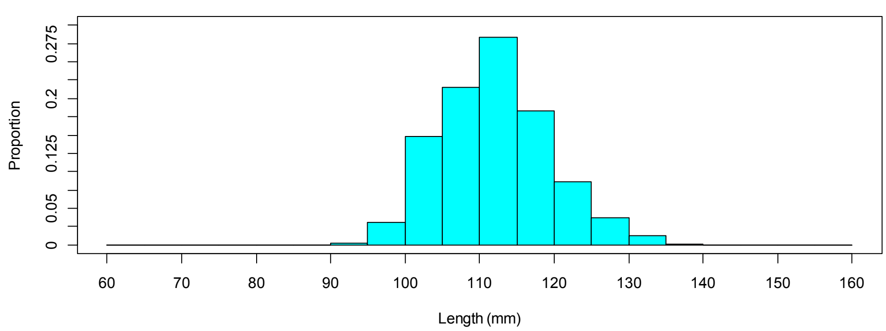
a. McNary Dam (Release V_1)



b. McNary Tailrace (Release R_2)



c. Mid-Reservoir (Release R_3)



d. ROR Subyearling Chinook Salmon at John Day Dam

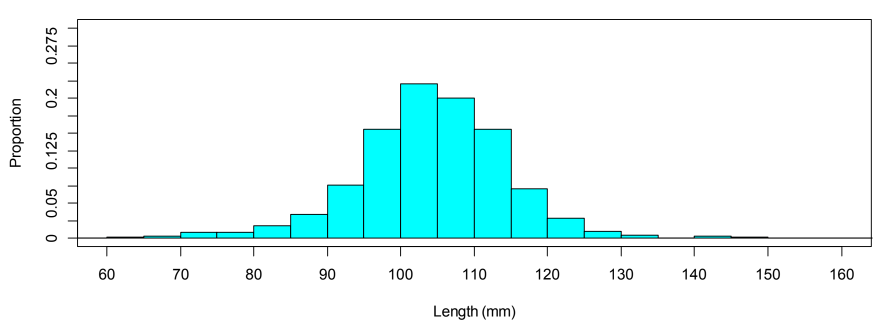
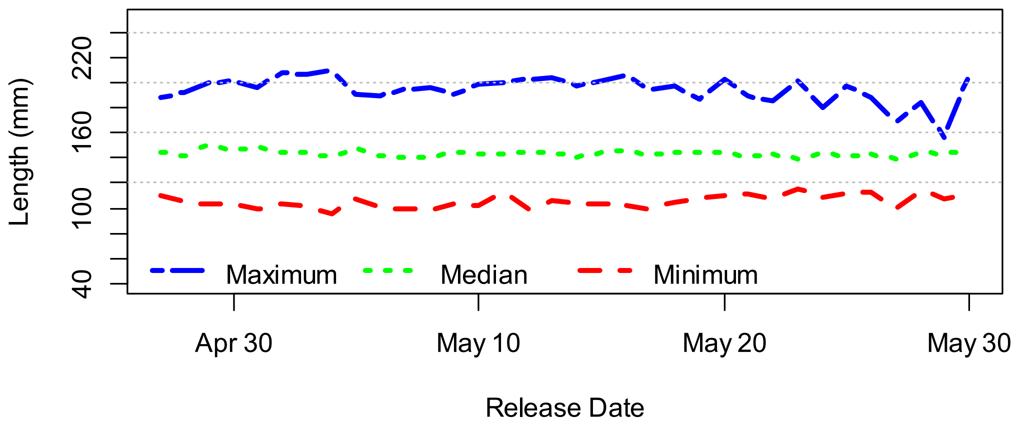
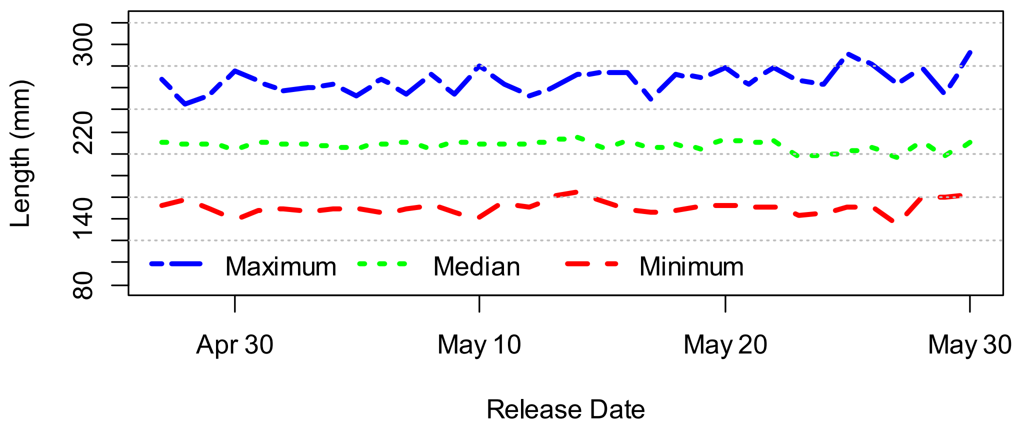


Figure B.3. Relative Frequency Distributions for Fish Lengths (mm) of Subyearling Chinook Salmon Smolts used in a) Release V_1, b) Release R_2, c) Release R_3, and d) ROR Fish Sampled During the Study Period at John Day Dam by the Fish Passage Center in 2012

a. Yearling Chinook Salmon Smolts



b. Steelhead Smolts



c. Subyearling Chinook Salmon Smolts

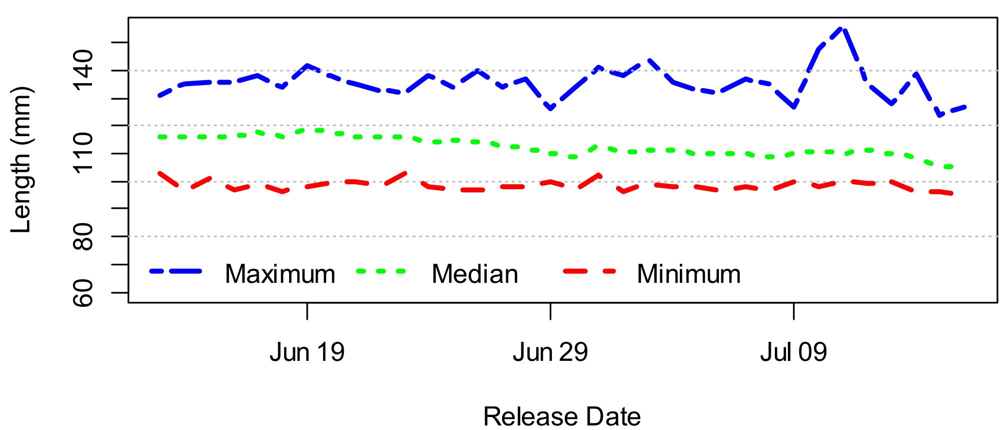
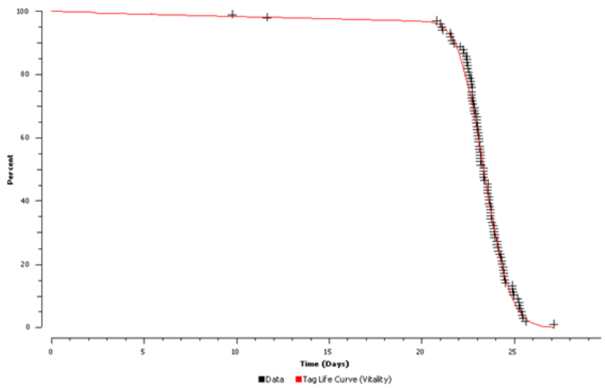
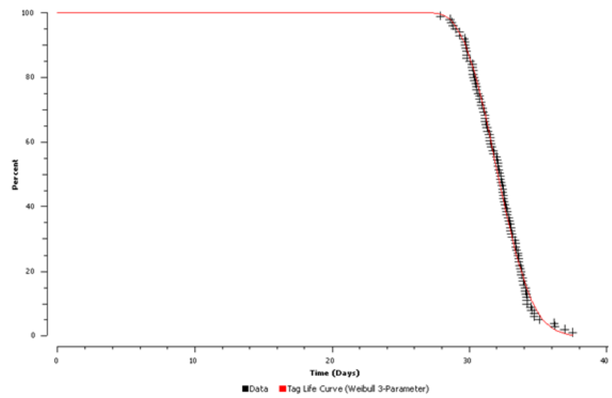


Figure B.4. Range and Median Lengths of Tagged a) Yearling Chinook Salmon, b) Steelhead, and c) Subyearling Chinook Salmon used in the 2012 Survival Studies. Releases were made daily from 27 April to 30 May for spring migrants and 13 June through 16 July for summer migrants.

a. Spring – Yearling Chinook Salmon



b. Spring – Steelhead



c. Summer – Subyearling Chinook Salmon

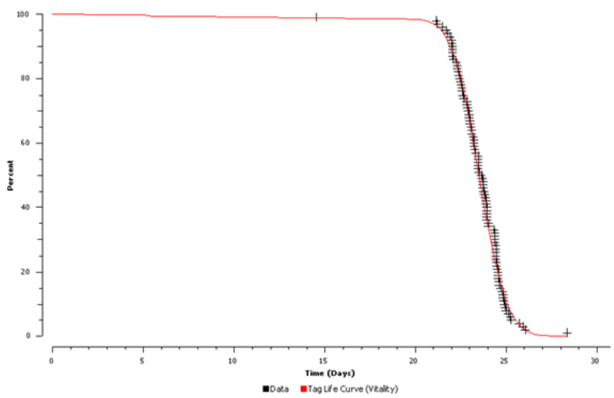
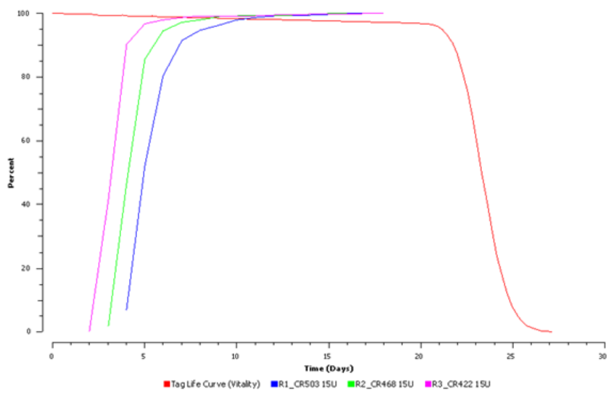
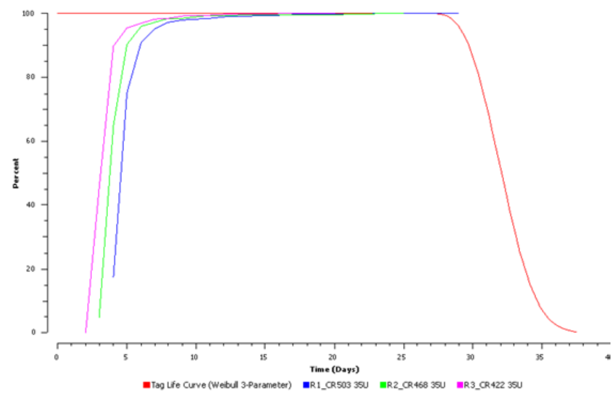


Figure B.5. Observed Time of AMT Failure and Fitted Survivorship Curves using the Vitality Model of Li and Anderson (2009) for a) Yearling Chinook and c) Subyearling Chinook Salmon AMT Lots and a Three-parameter Weibull model for b) Steelhead

a. Yearling Chinook Salmon

b. Steelhead





c. Subyearling Chinook Salmon

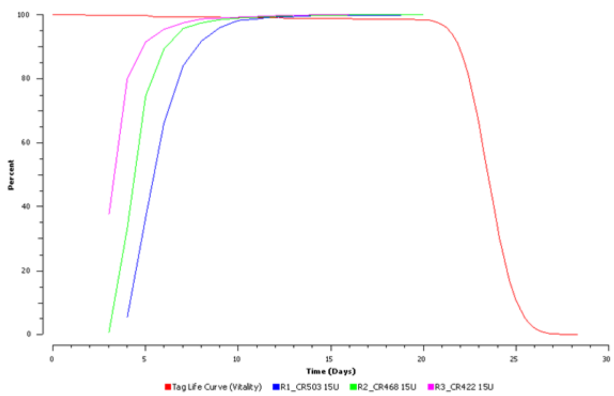


Figure B.6. Plots of the Fitted AMT-life Survivorship Curve and the Arrival-time Distributions of a) Yearling Chinook Salmon Smolts, b) Steelhead Smolts, and c) Subyearling Chinook Salmon Smolts for Releases V_1, R_2, and R_3 at the Acoustic-detection Array Located at rkm 325

Table B.8. Estimated Probabilities (L) of an AMT being Active at a Downstream Detection Site for a) Yearling Chinook Salmon Smolts, b) Steelhead Smolts, and c) Subyearling Chinook Salmon Smolts by Release Group. (Standard errors are in parentheses.)

Release Group		Detection Site			
Stock	rkm	rkm 422	rkm 349	rkm 325	rkm 309
a. Yearling Chinook Salmon					
V_1[(a)]	472	0.9950 (0.0023)	0.9982 (0.0008)	0.9959 (0.0019)	0.9953 (0.0022)
R_2	468	--	--	0.9925 (0.0035)	0.9919 (0.0037)
R_3	422	--	--	0.9941 (0.0027)	0.9935 (0.0030)
b. Steelhead					
V_1[(a)]	472	1.0000 (<0.0001)	1.0000 (<0.0001)	1.0000 (<0.0001)	1.0000 (<0.0001)
R_2	468	--	1.0000 (<0.0001)	1.0000 (<0.0001)	1.0000 (<0.0001)
R_3	422	--	1.0000 (<0.0001)	1.0000 (<0.0001)	1.0000 (<0.0001)
c. Subyearling Chinook Salmon					
V_1[(a)]	472	0.9976 (0.0033)	0.9992 (0.0011)	0.9979 (0.0029)	0.9977 (0.0032)
R_2	468	--	--	0.9963 (0.0050)	0.9960 (0.0053)
R_3	422	--	--	0.9966 (0.0040)	0.9968 (0.0043)

(a) Conditional probabilities of a AMT being active, given they were active when a fish first arrived at the dam face.

B.5 Downstream Mixing

To help induce downstream mixing of the release groups, the R_1 release was 24 h before the R_2 release which, in turn, occurred 32 h before the R_3 release. The same release schedule was used for all three fish stocks. Plots of the arrival timing of the various release groups at downstream detection sites indicate reasonable mixing for CH1, STH, and CH0 smolts (Figure B.7). The arrival modes for V_1 and R_2 were synchronous and slightly earlier than the mode for R_3 for both yearling Chinook salmon and steelhead.

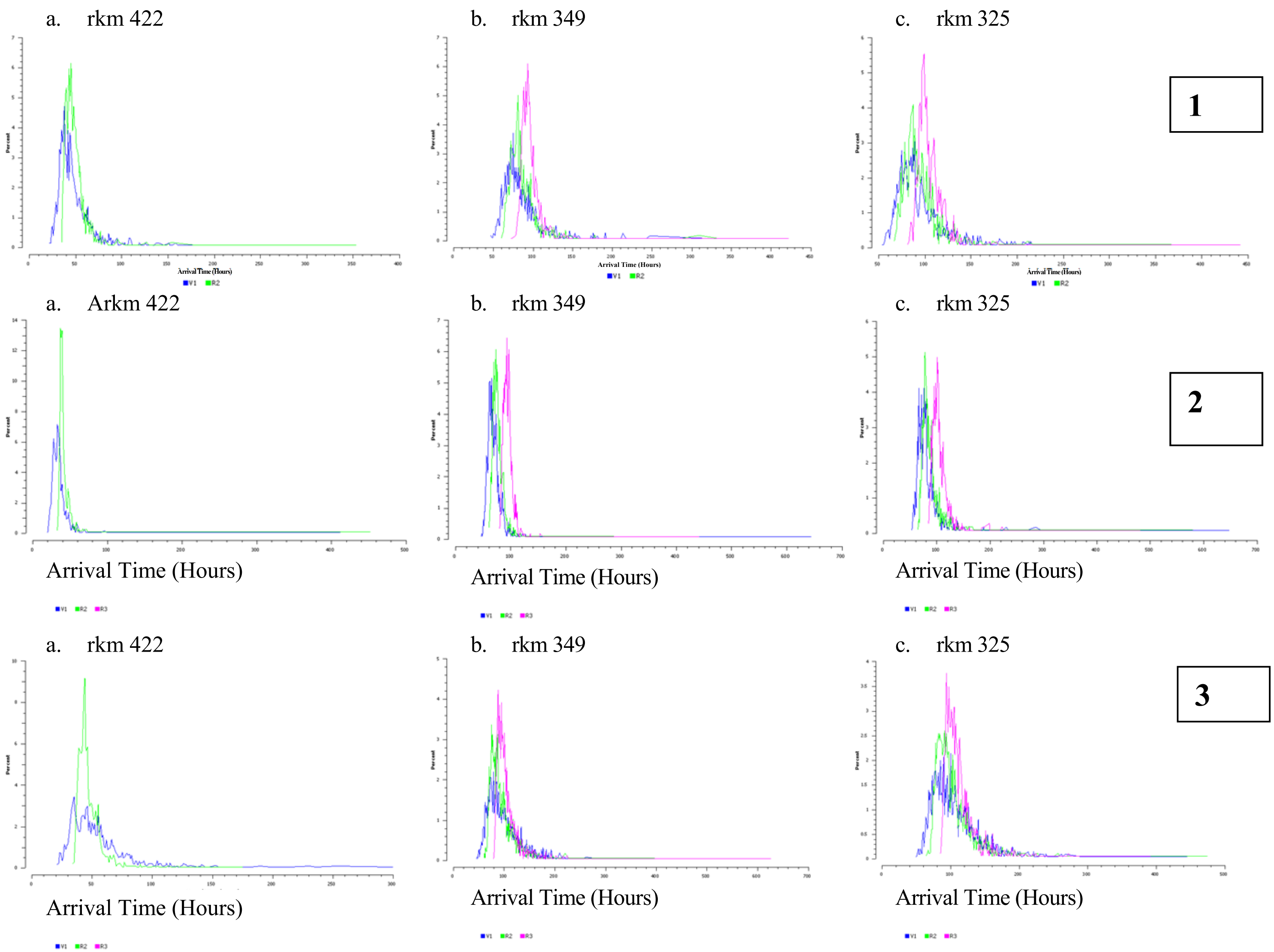


Figure B.7. Frequency Distribution Plots of Downstream Arrival Timing (expressed as percentages) for Yearling Chinook Salmon (1), Steelhead (2), and Subyearling Chinook Salmon (3) Releases V_1, R_2, and R_3 at Detection Arrays Located at a) rkm 422, b) rkm 349, and c) rkm 325. All times adjusted relative to the release time of V_1.

Appendix C

Fish-Tagging and Release Tables

Appendix C

Fish-Tagging and Release Tables

Table C.1, Table C.2, and Table C.3 list tagging and release data for yearling Chinook, steelhead, and subyearling Chinook salmon, respectively.

Table C.1. 2012 Yearling Chinook Salmon Tagged at John Day Dam and Released Live/Dead at Five Sites

Tag Date	Number Tagged	Release Date	Release Location	Number Released
04/26/2012	44	04/27/2012	R1_CR503 (Port Kelley)	44
04/27/2012	80	04/28/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	37
04/28/2012	81	04/29/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
04/29/2012	157	04/30/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	75
04/30/2012	81	05/01/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
05/01/2012	232	05/01/2012	CR349 JDA(b)	5
		05/02/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/03/2012	CR470 MCN(b)	5
05/02/2012	146	05/03/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/05/2012	CR349 JDA(a)	1
05/03/2012	222	05/04/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	31
		05/05/2012	CR349 JDA(a)	1
05/04/2012	145	05/05/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	31

Table C.1. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
05/05/2012	220	05/06/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	74
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	31
		05/07/2012	CR470 MCN(a)	2
05/06/2012	146	05/07/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
		05/08/2012	CR470 MCN(a)	1
05/07/2012	220	05/08/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	75
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/08/2012	154	05/08/2012	CR349 JDA(b)	5
		05/09/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	30
		05/11/2012	CR470 MCN(a)	2
			CR470 MCN(b)	5
05/09/2012	221	05/10/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/10/2012	146	05/11/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/15/2012	CR349 JDA(a)	1
05/11/2012	222	05/12/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/12/2012	146	05/13/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	37
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/15/2012	CR349 JDA(a)	1

Table C.1. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
05/13/2012	221	05/14/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	37
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	31
		05/15/2012	CR349 JDA(a)	1
			CR349 JDA(a)	1
05/14/2012	146	05/15/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/17/2012	CR349 JDA(a)	1
05/15/2012	232	05/15/2012	CR349 JDA(b)	5
			CR470 MCN(b)	5
		05/16/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	37
			R3_CR422 (Crow Butte)	75
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/17/2012	CR349 JDA(a)	1
		05/19/2012	CR349 JDA(a)	1
05/16/2012	145	05/17/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/17/2012	222	05/18/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	75
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/19/2012	CR349 JDA(a)	1
05/18/2012	146	05/19/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/19/2012	222	05/20/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
		05/24/2012	CR470 MCN(a)	1

Table C.1. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
05/20/2012	146	05/21/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/21/2012	221	05/22/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
05/22/2012	156	05/22/2012	CR349 JDA(b)	5
		05/23/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
			CR470 MCN(b)	5
05/23/2012	222	05/24/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/24/2012	146	05/25/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/25/2012	222	05/26/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	37
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/28/2012	CR470 MCN(a)	1
05/26/2012	146	05/27/2012	R1_CR503 (Port Kelley)	47
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	30
			R5_CR325 (Celilo)	31
05/27/2012	217	05/28/2012	CR470 MCN(a)	1
			R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	32
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
		06/02/2012	CR470 MCN(a)	1
05/28/2012	95	05/29/2012	R2_CR468 (Umatilla)	31
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32

Table C.1. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
05/29/2012	130	05/30/2012	R3_CR422 (Crow Butte)	66
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/30/2012	63	05/31/2012	R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	31
05/31/2012	46	06/01/2012	R4_CR346 (JDA Tailrace)	23
			R5_CR325 (Celilo)	23
06/01/2012	41	06/02/2012	R4_CR346 (JDA Tailrace)	21
			R5_CR325 (Celilo)	20

(a) Dead fish release location.
(b) Sacrificed to reach a dead tagged fish quota for spring.

Table C.2. 2012 Juvenile Steelhead Tagged at John Day Dam and Released Live/Dead at Five Sites

Tag Date	Number Tagged	Release Date	Release Location	Number Released
04/26/2012	44	04/27/2012	R1_CR503 (Port Kelley)	44
04/27/2012	81	04/28/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	37
04/28/2012	82	04/29/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
04/29/2012	158	04/30/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
04/30/2012	82	05/01/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
05/01/2012	231	05/01/2012	CR349 JDA(b)	5
		05/02/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/03/2012	CR470 MCN(b)	5
05/02/2012	146	05/03/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/03/2012	221	05/04/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	75
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/04/2012	145	05/05/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
05/05/2012	221	05/06/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
05/06/2012	146	05/07/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32

Table C.2. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
05/07/2012	221	05/08/2012	R1_CR503 (Port Kelley)	43
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/08/2012	156	05/08/2012	CR349 JDA(b)	5
		05/09/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
		05/11/2012	CR470 MCN(b)	5
05/09/2012	220	05/10/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	75
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
05/10/2012	146	05/11/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/11/2012	221	05/12/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	75
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/12/2012	146	05/13/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/13/2012	222	05/14/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/14/2012	146	05/15/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32

Table C.2. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
05/15/2012	232	05/15/2012	CR349 JDA(b)	5
			CR470 MCN(b)	5
		05/16/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	32
		05/17/2012	CR349 JDA(a)	1
05/16/2012	146	05/17/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/17/2012	221	05/18/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	37
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/18/2012	146	05/19/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/19/2012	222	05/20/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/20/2012	146	05/21/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/21/2012	222	05/22/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/22/2012	156	05/22/2012	CR349 JDA(b)	4
		05/23/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
			CR470 MCN(b)	6

Table C.2. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
05/23/2012	222	05/24/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/24/2012	146	05/25/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/25/2012	222	05/26/2012	R1_CR503 (Port Kelley)	44
			R2_CR468 (Umatilla)	38
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/26/2012	142	05/27/2012	R1_CR503 (Port Kelley)	40
			R2_CR468 (Umatilla)	38
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/27/2012	213	05/28/2012	R1_CR503 (Port Kelley)	42
			R2_CR468 (Umatilla)	31
			R3_CR422 (Crow Butte)	76
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/28/2012	94	05/29/2012	R2_CR468 (Umatilla)	30
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/29/2012	125	05/30/2012	R3_CR422 (Crow Butte)	61
			R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/30/2012	64	05/31/2012	R4_CR346 (JDA Tailrace)	32
			R5_CR325 (Celilo)	32
05/31/2012	43	06/01/2012	R4_CR346 (JDA Tailrace)	23
			R5_CR325 (Celilo)	20
06/01/2012	41	06/02/2012	R4_CR346 (JDA Tailrace)	21
			R5_CR325 (Celilo)	20

(a) Dead fish release location.
(b) Sacrificed to reach a dead tagged fish quota for spring.

Table C.3. 2012 Subyearling Chinook Salmon Tagged at John Day Dam and Released Live/Dead at Nine Sites

Tag Date	Number Tagged	Release Date	Release Location	Number Released
06/12/2012	79	06/13/2012	R1_CR503 (Port Kelley)	78
		06/18/2012	CR349 JDA(a)	1
06/13/2012	142	06/14/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
06/14/2012	141	06/15/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	63
06/15/2012	268	06/16/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	126
06/16/2012	142	06/17/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
06/17/2012	329	06/18/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	125
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
		06/21/2012	CR470 MCN(a)	1
06/18/2012	287	06/18/2012	R6_CR307 (TDA Tailrace)	25
			CR234 BON(b)	10
			CR309 TDA(b)	5
			CR349 JDA(b)	5
		06/19/2012	R1_CR503 (Port Kelley)	75
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	35
			R5_CR325 (Celilo)	35
			R7_CR275 (Hood River)	25
		06/20/2012	CR309 TDA(a)	2
			CR349 JDA(a)	2
		06/21/2012	CR470 MCN(b)	5
06/19/2012	514	06/20/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	35
			R5_CR325 (Celilo)	35
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	62
		06/22/2012	CR309 TDA(a)	1

Table C.3. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
06/20/2012	315	06/20/2012	R6_CR307 (TDA Tailrace)	25
		06/21/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	61
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	29
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
		06/22/2012	CR309 TDA(a)	1
			CR349 JDA(a)	2
06/21/2012	568	06/22/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	62
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	62
			R9_CR156 (Knapp)	126
		06/25/2012	CR470 MCN(a)	1
06/22/2012	317	06/22/2012	R6_CR307 (TDA Tailrace)	25
		06/23/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	61
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
		06/25/2012	CR470 MCN(a)	3
06/23/2012	569	06/24/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	126
		06/25/2012	CR470 MCN(a)	1
06/24/2012	316	06/24/2012	R6_CR307 (TDA Tailrace)	25
		06/25/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	62
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63

Table C.3. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
06/25/2012	593	06/26/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	125
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	62
			R9_CR156 (Knapp)	126
			CR234 BON(b)	10
			CR309 TDA(b)	5
			CR349 JDA(b)	5
		06/28/2012	CR349 JDA(a)	1
		06/29/2012	CR470 MCN(b)	5
06/26/2012	317	06/26/2012	R6_CR307 (TDA Tailrace)	25
		06/27/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
06/27/2012	569	06/28/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	126
06/28/2012	316	06/28/2012	R6_CR307 (TDA Tailrace)	25
		06/29/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	62
		07/02/2012	CR309 TDA(a)	1

Table C.3. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
06/29/2012	567	06/30/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	61
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	62
			R9_CR156 (Knapp)	126
		07/02/2012	CR309 TDA(a)	1
06/30/2012	317	06/30/2012	R6_CR307 (TDA Tailrace)	25
		07/01/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	62
		07/02/2012	CR309 TDA(a)	1
07/01/2012	568	07/02/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	62
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	24
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	126
		07/04/2012	CR349 JDA(a)	1
			CR349 JDA(a)	1
07/02/2012	342	07/02/2012	R6_CR307 (TDA Tailrace)	25
			CR234 BON(b)	10
			CR309 TDA(b)	5
			CR349 JDA(b)	5
		07/03/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			CR470 MCN(b)	5

Table C.3. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
07/03/2012	569	07/04/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	126
07/04/2012	317	07/04/2012	R6_CR307 (TDA Tailrace)	25
		07/05/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
07/05/2012	569	07/06/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	125
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	126
			CR470 MCN(a)	1
07/06/2012	315	07/06/2012	R6_CR307 (TDA Tailrace)	25
		07/07/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	62
07/07/2012	568	07/08/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	62
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	126

Table C.3. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
07/08/2012	317	07/08/2012	R6_CR307 (TDA Tailrace)	25
		07/09/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
07/09/2012	593	07/09/2012	CR470 MCN(b)	5
		07/10/2012	R1_CR503 (Port Kelley)	78
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	24
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	126
			CR234 BON(b)	10
			CR309 TDA(a)	1
			CR309 TDA(b)	5
			CR349 JDA(b)	5
07/10/2012	317	07/10/2012	R6_CR307 (TDA Tailrace)	25
		07/11/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
07/11/2012	568	07/12/2012	R1_CR503 (Port Kelley)	79
			R2_CR468 (Umatilla)	63
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	125
07/12/2012	325	07/12/2012	R6_CR307 (TDA Tailrace)	25
		07/13/2012	R1_CR503 (Port Kelley)	87
			R2_CR468 (Umatilla)	63
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63

Table C.3. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
07/13/2012	566	07/14/2012	R1_CR503 (Port Kelley)	81
			R2_CR468 (Umatilla)	59
			R3_CR422 (Crow Butte)	126
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	30
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	125
		07/17/2012	CR470 MCN(a)	1
07/14/2012	230	07/14/2012	R6_CR307 (TDA Tailrace)	25
		07/15/2012	R2_CR468 (Umatilla)	54
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
		07/19/2012	CR309 TDA(a)	1
07/15/2012	398	07/16/2012	R3_CR422 (Crow Butte)	97
			R4_CR346 (JDA Tailrace)	31
			R5_CR325 (Celilo)	31
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	125
		07/19/2012	CR309 TDA(a)	1
07/16/2012	175	07/16/2012	R6_CR307 (TDA Tailrace)	25
		07/17/2012	R4_CR346 (JDA Tailrace)	30
			R5_CR325 (Celilo)	30
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
		07/19/2012	CR349 JDA(a)	1
		07/20/2012	CR470 MCN(a)	1
07/17/2012	289	07/18/2012	R4_CR346 (JDA Tailrace)	24
			R5_CR325 (Celilo)	25
			R6_CR307 (TDA Tailrace)	25
			R7_CR275 (Hood River)	25
			R8_CR233 (BON Tailrace)	63
			R9_CR156 (Knapp)	125
		07/19/2012	CR349 JDA(a)	1
		07/20/2012	CR470 MCN(a)	1

Table C.3. (contd)

Tag Date	Number Tagged	Release Date	Release Location	Number Released
07/18/2012	151	07/18/2012	R6_CR307 (TDA Tailrace)	19
		07/19/2012	R4_CR346 (JDA Tailrace)	25
			R5_CR325 (Celilo)	24
			R7_CR275 (Hood River)	19
			R8_CR233 (BON Tailrace)	63
		07/20/2012	CR234 BON(a)	1
07/19/2012	211	07/20/2012	R6_CR307 (TDA Tailrace)	19
			R7_CR275 (Hood River)	19
			R8_CR233 (BON Tailrace)	55
			R9_CR156 (Knapp)	118
07/20/2012	55	07/21/2012	R8_CR233 (BON Tailrace)	55
07/21/2012	55	07/22/2012	R9_CR156 (Knapp)	55

(a) Dead fish release location.
(b) Sacrificed to reach a dead tagged fish quota for summer.

Appendix D

Hydrophone and Autonomous Node Deployment Tables

Appendix D

Hydrophone and Autonomous Node Deployment Tables

Table D.1. Hydrophone Locations in the McNary Dam-Face Array in 2012

Hydrophone Name	Latitude (NAD83)	Longitude (NAD83)	Elevation (NAVD88, ft)
MCN_FLS_WA_1	45.9285514	-119.2942663	331.32
MCN_FLS_WA_2	45.9285552	-119.2942543	323.86
MCN_FLS_WA_3	45.9285590	-119.2942423	331.32
MCN_FLS_WA_4	45.9285686	-119.2942630	329.38
MCN_FLS_OR_4	45.9286419	-119.2943035	329.24
MCN_FLS_OR_3	45.9286515	-119.2943241	331.17
MCN_FLS_OR_2	45.9286553	-119.2943122	323.72
MCN_FLS_OR_1	45.9286591	-119.2943001	331.17
MCN_F00_F01S	45.9321421	-119.2965986	330.16
MCN_F01_F02S	45.9322745	-119.2966798	327.74
MCN_F02_P01S	45.9325079	-119.2967323	327.44
MCN_F02_P01D	45.9325141	-119.2966875	269.14
MCN_P01_02S	45.9327400	-119.2967889	327.38
MCN_P01_02D	45.9327462	-119.2967442	269.17
MCN_P02_03S	45.9329725	-119.2968458	327.47
MCN_P02_03D	45.9329787	-119.2968010	269.24
MCN_P03_04S	45.9332057	-119.2969037	327.70
MCN_P03_04D	45.9332118	-119.2968587	269.40
MCN_P04_05S	45.9334379	-119.2969598	327.47
MCN_P04_05D	45.9334441	-119.2969150	269.24
MCN_P05_06S	45.9336698	-119.2970167	327.54
MCN_P05_06D	45.9336760	-119.2969718	269.30
MCN_P06_07S	45.9339032	-119.2970738	327.51
MCN_P06_07D	45.9339094	-119.2970289	269.24
MCN_P07_08S	45.9341354	-119.2971306	327.51
MCN_P07_08D	45.9341416	-119.2970859	269.34
MCN_P08_09S	45.9343681	-119.2971869	327.41
MCN_P08_09D	45.9343743	-119.2971421	269.11
MCN_P09_10S	45.9345995	-119.2972436	327.51
MCN_P09_10D	45.9346057	-119.2971989	269.34
MCN_P10_11S	45.9348319	-119.2973001	327.38
MCN_P10_11D	45.9348381	-119.2972552	269.11
MCN_P11_12S	45.9350648	-119.2973575	327.54
MCN_P11_12D	45.9350710	-119.2973128	269.47
MCN_P12_13S	45.9352970	-119.2974141	327.31

Table D.1. (contd)

Hydrophone Name	Latitude (NAD83)	Longitude (NAD83)	Elevation (NAVD88, ft)
MCN_P12_13D	45.9353032	-119.2973693	269.17
MCN_P13_14S	45.9355301	-119.2974713	327.47
MCN_P13_14D	45.9355363	-119.2974264	269.27
MCN_P14S	45.9357579	-119.2975274	327.55
MCN_P14D	45.9357641	-119.2974826	269.40
MCN_S23P	45.9358600	-119.2976266	330.48
MCN_S22S	45.9359851	-119.2976721	330.46
MCN_S21_22D	45.9361830	-119.2977203	302.13
MCN_S21_22S	45.9361830	-119.2977203	329.18
MCN_S20_21D	45.9363483	-119.2977605	301.68
MCN_S20_21S	45.9363483	-119.2977605	328.69
MCN_S19_20D	45.9365112	-119.2978004	301.83
MCN_S19_20S	45.9365112	-119.2978004	328.83
MCN_S18_19D	45.9366731	-119.2978395	301.73
MCN_S18_19S	45.9366731	-119.2978395	328.78
MCN_S17_18D	45.9368356	-119.2978790	301.91
MCN_S17_18S	45.9368356	-119.2978790	328.89
MCN_S16_17D	45.9369966	-119.2979182	301.81
MCN_S16_17S	45.9369966	-119.2979182	328.91
MCN_S15_16D	45.9371595	-119.2979576	301.87
MCN_S15_16S	45.9371595	-119.2979576	328.94
MCN_S14_15D	45.9373221	-119.2979974	301.79
MCN_S14_15S	45.9373221	-119.2979974	328.89
MCN_S13_14D	45.9374845	-119.2980370	301.42
MCN_S13_14S	45.9374845	-119.2980370	328.51
MCN_S12_13D	45.9376463	-119.2980764	301.87
MCN_S12_13S	45.9376463	-119.2980764	328.96
MCN_S11_12D	45.9378092	-119.2981170	301.84
MCN_S11_12S	45.9378092	-119.2981170	328.84
MCN_S10_11D	45.9379709	-119.2981562	302.03
MCN_S10_11S	45.9379709	-119.2981562	329.00
MCN_S09_10D	45.9381338	-119.2981962	301.84
MCN_S09_10S	45.9381338	-119.2981962	328.85
MCN_S08_09D	45.9382958	-119.2982358	301.96
MCN_S08_09S	45.9382958	-119.2982358	328.91
MCN_S07_08D	45.9384576	-119.2982740	301.86
MCN_S07_08S	45.9384576	-119.2982740	328.87
MCN_S06_07D	45.9386195	-119.2983132	301.88
MCN_S06_07S	45.9386195	-119.2983132	328.78
MCN_S05_06D	45.9387816	-119.2983529	302.03
MCN_S05_06S	45.9387816	-119.2983529	328.96
MCN_S04_05D	45.9389447	-119.2983935	301.94

Table D.1. (contd)

Hydrophone Name	Latitude (NAD83)	Longitude (NAD83)	Elevation (NAVD88, ft)
MCN_S04_05S	45.9389447	-119.2983935	329.01
MCN_S03_04D	45.9391057	-119.2984324	302.12
MCN_S03_04S	45.9391057	-119.2984324	329.18
MCN_S02_03D	45.9392686	-119.2984723	302.24
MCN_S02_03S	45.9392686	-119.2984723	329.04
MCN_S01_02D	45.9394299	-119.2985117	302.20
MCN_S01_02S	45.9394299	-119.2985117	329.01
MCN_PUD_3	45.9396630	-119.2985701	332.27
MCN_PUD_2	45.9396721	-119.2985724	324.82
MCN_PUD_4	45.9396746	-119.2985515	330.34
MCN_PUD_1	45.9396812	-119.2985745	332.27
MCN_FLN_S	45.9407083	-119.2976139	329.00

Table D.2. Approximate Global Positioning System Coordinates of Autonomous Nodes Deployed in Arrays Just Above and Below McNary Dam in 2012. Array_Node is a concatenation of an array name and an autonomous node number. The array name is a concatenation of "CR" for Columbia River, with a three-digit number corresponding to river kilometer upstream of the mouth of the Columbia River. Nodes within an array are numbered from the WA to the OR shore. (MCN Secondary Array is at JDA Cabled Array – CR349.0)

Array_Node	Array Function	Latitude Degrees North	Longitude Degrees West	Approximate Depth (ft)	Season
CR472.0_01	MCN Forebay Entrance	45.9458680	-119.2754788	47	sp, su
CR472.0_02		45.9441585	-119.2749115	71	sp, su
CR472.0_03		45.9424310	-119.2743442	71	sp, su
CR472.0_04		45.9404336	-119.2735706	77	sp, su
CR472.0_05		45.9383282	-119.2729002	78	sp, su
CR472.0_06		45.9363308	-119.2721782	84	sp, su
CR472.0_07		45.9345493	-119.2715593	79	sp, su
CR472.0_08		45.9327858	-119.2708630	29	sp, su
CR468.0_01	MCN Egress	45.9335131	-119.3250311	60	sp, su
CR468.0_02		45.9321274	-119.3244124	31	sp, su
CR468.0_03		45.9307058	-119.3237679	29	sp, su
CR422.0_01	MCN Tailrace, MCN Primary	45.8414759	-119.8569511	58	sp, su
CR422.0_02		45.8405815	-119.8565531	61	sp, su
CR422.0_03		45.8396049	-119.8560968	73	sp, su
CR422.0_04		45.8382934	-119.8555380	78	sp, su
CR422.0_05		45.8373816	-119.8551334	73	sp, su
CR422.0_06		45.8363181	-119.8546435	42	sp, su
CR422.0_07		45.8354667	-119.8540333	19	sp, su
CR351.0_01	JDA Forebay Entrance	45.7263480	-120.6850310	102	sp, su
CR351.0_02		45.7252350	-120.6839480	115	sp, su
CR351.0_03		45.7241920	-120.6829290	114	sp, su
CR351.0_04		45.7230820	-120.6816760	118	sp, su
CR351.0_05		45.7219190	-120.6805270	100	sp, su
CR351.0_06		45.7208840	-120.6793880	120	sp, su
CR351.0_07		45.7197450	-120.6781820	110	sp, su
CR351.0_08		45.7186490	-120.6769790	73	sp, su
CR346.0_01	JDA Egress	45.7085740	-120.7246590	19	sp, su
CR346.0_02		45.7074530	-120.7238100	21	sp, su
CR346.0_03		45.7062870	-120.7228740	44	sp, su
CR346.0_04		45.7051500	-120.7219640	64	sp, su
CR325.0_01	JDA Tailrace; JDA Primary; MCN Tertiary	45.6554574	-120.9670791	39	sp, su
CR325.0_02		45.6544704	-120.9663697	42	sp, su
CR325.0_03		45.6535996	-120.9656131	49	sp, su
CR325.0_04		45.6527011	-120.9649274	87	sp, su
CR325.0_05		45.6520335	-120.9644344	67	sp, su
CR325.0_06		45.6511814	-120.9638134	42	sp, su

Table D.2. (contd)

Array_Node	Array Function	Latitude Degrees North	Longitude Degrees West	Approximate Depth (ft)	Season
CR311.0_01	TDA Forebay Entrance	45.6288000	-121.1157960	54	su
CR311.0_02		45.6278630	-121.1142710	60	su
CR311.0_03		45.6269450	-121.1126290	74	su
CR311.0_04		45.6261530	-121.1111270	93	su
CR311.0_05		45.6253450	-121.1096530	45	su
CR307.0_01	TDA Egress	45.6083160	-121.1510940	44	su
CR307.0_02		45.6072850	-121.1500350	47	su
CR307.0_03		45.6063758	-121.1488433	56	su
CR275.0_01	TDA Tailrace; JDA Tertiary(Summer)	45.7091259	-121.4712970	21	su
CR275.0_02		45.7086224	-121.4717591	39	su
CR275.0_03		45.7078330	-121.4724400	61	su
CR275.0_04		45.7072915	-121.4729401	71	su
CR275.0_05		45.7066440	-121.4735049	113	su
CR275.0_06		45.7057667	-121.4734667	126	su
CR236.0_01	BON Forebay Entrance; JDA Tertiary(Spring)	45.6509740	-121.9203458	57	sp, su
CR236.0_02		45.6504350	-121.9198845	74	sp, su
CR236.0_03		45.6498599	-121.9193207	76	sp, su
CR236.0_04		45.6493209	-121.9188595	66	sp, su
CR233.0_01	BON Egress	45.6350167	-121.9624833	62	sp
CR233.0_01		45.6347670	-121.9630170	62	su
CR233.0_02		45.6350270	-121.9613769	47	sp
CR233.0_02		45.6347330	-121.9617830	47	su
CR233.0_03		45.6346314	-121.9606050	54	sp, su
CR156.0_01	BON Tailrace; BON Primary	45.7522167	-122.7590167	49	sp
CR156.0_01		45.7220500	-122.7597000	49	su
CR156.0_02		45.7520000	-122.7599833	59	sp
CR156.0_02		45.7219667	-122.7606833	49	su
CR156.0_03		45.7517666	-122.7610000	62	sp
CR156.0_03		45.7218833	-122.7617167	48	su
CR156.0_04		45.7515667	-122.7621167	61	sp
CR156.0_04		45.7216000	-122.7628167	46	su
CR156.0_05		45.7513166	-122.7633500	55	sp
CR156.0_05		45.7214500	-122.7639500	50	su
CR156.0_06		45.7510000	-122.7647000	41	sp
CR156.0_06		45.7210667	-122.7654000	51	su
CR156.0_07		45.7507167	-122.7659167	32	sp
CR156.0_07		45.7211667	-122.7667167	50	su
CR156.0_08		45.7504000	-122.7672500	21	sp
CR156.0_08		45.7211167	-122.7677833	30	su
CR113.0_01	BON Secondary	46.0561370	-122.8727154	43	sp, su
CR113.0_02		46.0593333	-122.8806833	32	sp, su

Table D.2. (contd)

Array_Node	Array Function	Latitude Degrees North	Longitude Degrees West	Approximate Depth (ft)	Season
CR113.0_03		46.0602333	-122.8813500	52	sp
CR113.0_04		46.0593333	-122.8820167	57	sp, su
CR113.0_05		46.0591670	-122.8831170	56	sp, su
CR113.0_06		46.0591167	-122.8841000	54	sp, su
CR113.0_07		46.0600333	-122.8847834	53	sp
CR113.0_08		46.0590333	-122.8851500	48	sp, su
CR113.0_09		46.0589000	-122.8860833	46	sp, su
CR113.0_10		46.0587833	-122.8871167	36	sp, su
CR113.0_11		46.0586500	-122.8881333	34	sp, su
CR113.0_12		46.0585167	-122.8891000	30	sp, su
CR086.0_01	BON Tertiary	46.1866151	-123.1807629	73	su
CR086.0_02		46.1861112	-123.1804002	73	su
CR086.0_03		46.1855354	-123.1799856	72	su
CR086.0_04		46.1850315	-123.1796747	65	su
CR086.0_05		46.1845276	-123.1793120	54	su
CR086.0_06		46.1840597	-123.1788974	53	su
CR086.0_07		46.1835918	-123.1785865	53	su
CR086.0_08		46.1831239	-123.1783274	77	su

sp = spring only
su = summer only
sp, su = spring and summer

Appendix E

Capture Histories

Appendix E

Capture Histories

This appendix contains detailed capture histories for yearling and subyearling Chinook salmon and juvenile steelhead tagged at McNary Dam in 2012.

E.1 Capture Histories of Yearling Chinook Salmon in Spring

Table E.1. Capture Histories for Array Locations at rkm 422, 349, and 325 for Release Group V_1 for Yearling Chinook Salmon used in Estimating Dam Passage Survival and BRZ-to-BRZ Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	V_1 (Season-Wide)	
Capture History	Dam Passage Survival	BRZ-to-BRZ Survival
1 1 1:	1143	1152
0 1 1:	0	0
1 0 1:	1	1
0 0 1:	0	0
1 2 0:	1	1
0 2 0:	0	0
1 1 0:	35	35
0 1 0:	0	0
2 0 0:	0	0
1 0 0:	65	65
0 0 0:	115	119
Total	**1360**	**1373**

BRZ = Boat restricted zone.

Table E.2. Capture Histories for Array Locations at rkm 349 and 325 for Release Groups R_2 and R_3 for Yearling Chinook Salmon used in Estimating Dam Passage Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	Reference Release (Season-Wide)	
Capture History	R_2	R_3
1 1:	1026	1082
0 1:	0	0
2 0:	2	2
1 0:	48	48
0 0:	122	68
Total	**1198**	**1200**

Table E.3. Capture Histories for Array Locations at rkm 422, 349, and 325 for Release Group V_1 for Yearling Chinook Salmon used in Estimating Dam Passage and BRZ-to-BRZ Daytime and Nighttime Survival. A “1” denotes detection, “0” denotes nondetection, and “2” denotes detection and censoring due to removal.

	V_1 (Season-Wide)			
	Dam Passage Survival		BRZ-to-BRZ Survival	
Capture History	Daytime	Nighttime	Daytime	Nighttime
1 1 1:	669	474	680	472
0 1 1:	0	0	0	0
1 0 1:	1	0	1	0
0 0 1:	0	0	0	0
1 2 0:	1	0	1	0
0 2 0:	0	0	0	0
1 1 0:	19	16	19	16
0 1 0:	0	0	0	0
2 0 0:	0	0	0	0
1 0 0:	32	33	34	31
0 0 0:	69	46	72	47
Total	791	569	807	566

BRZ = Boat restricted zone.

Table E.4. Capture Histories for Array Locations at rkm 422, 349, and 325 for Release Group V_1 for Yearling Chinook Salmon used in Estimating Dam Passage Survival by Route Survival. A “1” denotes detection, “0” denotes nondetection, and “2” denotes detection and censoring due to removal.

	V_1 by Route (Season-Wide)				
Capture History	JBS	non-TSW	Spillway	TSW	Turbine
1 1 1:	268	736	836	100	37
0 1 1:	0	0	0	0	0
1 0 1:	0	1	1	0	0
0 0 1:	0	0	0	0	0
1 2 0:	0	1	1	0	0
0 2 0:	0	0	0	0	0
1 1 0:	6	25	27	2	2
0 1 0:	0	0	0	0	0
2 0 0:	0	0	0	0	0
1 0 0:	18	42	45	3	1
0 0 0:	36	66	74	8	4
Total	328	871	984	113	44

JBS = Juvenile Bypass System; TSW = Temporary Spillway Weir.

E.2 Capture Histories of Juvenile Steelhead Salmon in Spring

Table E.5. Capture Histories for Array Locations at rkm 422, 325, and 309 for Release Group V_1 for Juvenile Steelhead Salmon used in Estimating Dam Passage Survival and BRZ-to-BRZ Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	V_1 (Season-Wide)	
Capture History	Dam Passage Survival	BRZ-to-BRZ Survival
1 1 1:	1082	1085
0 1 1:	0	0
1 0 1:	1	1
0 0 1:	0	0
1 2 0:	0	0
0 2 0:	0	0
1 1 0:	6	6
0 1 0:	0	0
2 0 0:	6	6
1 0 0:	90	90
0 0 0:	112	116
Total	**1297**	**1304**

BRZ = Boat restricted zone

Table E.6. Capture Histories for Array Locations at rkm 325 and 309 for Release Groups R_2, and R_3 for Juvenile Steelhead Salmon used in Estimating all Dam Passage Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	Reference Release (Season-Wide)	
Capture History	R_2	R_3
1 1:	986	1068
0 1:	1	0
2 0:	0	0
1 0:	6	8
0 0:	206	122
Total	**1199**	**1198**

Table E.7. Capture Histories for Array Locations at rkm 422, 325, and 309 for Release Group V_1 for Juvenile Steelhead Salmon used in Estimating Dam Passage and BRZ-to-BRZ Survival Daytime and Nighttime Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	V_1 (Season-Wide)			
	Dam Passage Survival		BRZ-to-BRZ Survival	
Capture History	Daytime	Nighttime	Daytime	Nighttime
1 1 1:	624	458	687	398
0 1 1:	0	0	0	0
1 0 1:	0	1	0	1
0 0 1:	0	0	0	0
1 2 0:	0	0	0	0
0 2 0:	0	0	0	0
1 1 0:	6	0	5	1
0 1 0:	0	0	0	0
2 0 0:	5	1	5	1
1 0 0:	52	38	53	37
0 0 0:	75	37	78	38
Total	762	535	828	476

BRZ = Boat restricted zone.

Table E.8. Capture histories for array locations at rkm 422, 349, and 325 for release group V_1 for juvenile steelhead salmon used in estimating dam passage survival by route survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	V_1 by Route (Season-Wide)				
Capture History	JBS	non-TSW	Spillway	TSW	Turbine
1 1 1:	159	651	905	254	22
0 1 1:	0	0	0	0	0
1 0 1:	0	1	1	0	0
0 0 1:	0	0	0	0	0
1 2 0:	0	4	6	2	0
0 2 0:	0	0	0	0	0
1 1 0:	1	19	27	8	1
0 1 0:	0	0	0	0	0
2 0 0:	0	0	0	0	0
1 0 0:	15	40	47	7	0
0 0 0:	12	60	90	30	7
Total	187	775	1076	301	30

JBS = Juvenile Bypass System; TSW = Temporary Spillway Weir.

E.3 Capture Histories of Subyearling Chinook Salmon in Summer

Table E.9. Capture Histories for Array Locations at rkm 422, 349, and 325 for Release Group V_1 for Subyearling Chinook Salmon used in Estimating Dam Passage Survival and BRZ-to-BRZ Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	V_1 (Season-Wide)	
Capture History	Dam Passage Survival	BRZ-to-BRZ Survival
1 1 1:	2003	2005
0 1 1:	0	0
1 0 1:	0	1
0 0 1:	0	0
1 2 0:	10	10
0 2 0:	0	0
1 1 0:	135	135
0 1 0:	0	0
2 0 0:	0	0
1 0 0:	100	100
0 0 0:	211	216
Total	**2459**	**2467**

BRZ = Boat restricted zone.

Table E.10. Capture Histories for Array Locations at rkm 349 and 325 for Release Groups R_2, and R_3 for Subyearling Chinook Salmon used in Estimating all Dam Passage Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	Reference Release (Season-Wide)	
Capture History	R_2	R_3
1 1:	1649	1740
0 1:	0	1
2 0:	11	17
1 0:	100	109
0 0:	233	117
Total	**1993**	**1984**

Table E.11. Capture Histories for Array Locations at rkm 422, 349, and 325 for Release Group V_1 for Subyearling Chinook Salmon used in Estimating Dam Passage and BRZ-to-BRZ Survival Daytime and Nighttime Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	V_1 (Season-Wide)			
	Dam Passage Survival		BRZ-to-BRZ Survival	
Capture History	Daytime	Nighttime	Daytime	Nighttime
1 1 1:	1258	745	1264	741
0 1 1:	0	0	0	0
1 0 1:	0	0	0	1
0 0 1:	0	0	0	0
1 2 0:	8	2	8	2
0 2 0:	0	0	0	0
1 1 0:	80	55	80	55
0 1 0:	0	0	0	0
2 0 0:	0	0	0	0
1 0 0:	60	40	58	42
0 0 0:	136	75	128	88
Total	1542	917	1538	929

BRZ = Boat restricted zone.

Table E.12. Capture Histories for Array Locations at rkm 422, 349, and 325 for Release Group V_1 for Subyearling Chinook Salmon used in Estimating Dam Passage Survival by Route Survival. A "1" denotes detection, "0" denotes nondetection, and "2" denotes detection and censoring due to removal.

	V_1 by Route (Season-Wide)		
Capture History	JBS	Spillway	Turbine
1 1 1:	260	1576	167
0 1 1:	0	0	0
1 0 1:	0	0	0
0 0 1:	0	0	0
1 2 0:	1	7	2
0 2 0:	0	0	0
1 1 0:	14	112	9
0 1 0:	0	0	0
2 0 0:	0	0	0
1 0 0:	16	75	7
0 0 0:	17	155	39
Total	308	1925	224

JBS = Juvenile Bypass System.

Appendix F

Detection and Survival Probabilities

Appendix F

Detection and Survival Probabilities

F.1 Detection and Survival of Yearling Chinook Salmon

F.1.1 Dam Passage (Season-Wide)

Table F.1. McNary Dam Passage Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9616	0.0140

Survival Summary:

	Estimate	SE†
V1	0.9171	0.0076
R2	0.9050	0.0092
R3	0.9489	0.0071

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9171	0.0076	0.9501	0.0063	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0071

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	0.9991	0.0009	0.9709	0.0049
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.1.2 BRZ-to-BRZ (Season-Wide)

Table F.2. Forebay Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9595	0.0140

Survival Summary:

	Estimate	SE†
V1	0.9151	0.0076
R2	0.9050	0.0092
R3	0.9489	0.0071

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9151	0.0076	0.9504	0.0063	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0071

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	0.9991	0.0009	0.9711	0.0049
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.1.3 Daytime and Nighttime Dam Passage (Season-Wide)

Table F.3. McNary Dam Daytime Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9587	0.0156

Survival Summary:

	Estimate	SE†
V1	0.9144	0.0101
R2	0.9050	0.0092
R3	0.9489	0.0070

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 15U	0.9144	0.0101	0.9580	0.0077	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0070

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 15U	1.0000	0.0000	0.9985	0.0015	0.9729	0.0063
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.4. McNary Dam Nighttime Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9655	0.0167

Survival Summary:

	Estimate	SE†
V1	0.9208	0.0115
R2	0.9050	0.0092
R3	0.9489	0.0070

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 15U	0.9208	0.0115	0.9391	0.0107	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0070

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9680	0.0080
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.1.4 Daytime and Nighttime BRZ-to-BRZ (Season-Wide)

Table F.5. McNary Dam BRZ-to-BRZ Daytime Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9568	0.0156

Survival Summary:

	Estimate	SE†
V1	0.9125	0.0101
R2	0.9050	0.0092
R3	0.9489	0.0071

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9125	0.0101	0.9561	0.0078	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0071

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	0.9985	0.0015	0.9734	0.0062
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.6. McNary Dam BRZ-to-BRZ Nighttime Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9634	0.0168

Survival Summary:

	Estimate	SE†
V1	0.9188	0.0117
R2	0.9050	0.0098
R3	0.9489	0.0076

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9188	0.0117	0.9424	0.0104	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0098
R3_CR422 15U	---	---	---	---	0.9489	0.0076

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9678	0.0081
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.1.5 Dam Passage – by Route (Season-Wide)

Table F.7. McNary Dam JBS Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9355	0.0213

Survival Summary:

	Estimate	SE†
V1	0.8922	0.0173
R2	0.9050	0.0092
R3	0.9489	0.0071

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.8922	0.0173	0.9407	0.0141	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0071

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9787	0.0088
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.8. McNary Dam TSW Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9758	0.0279

Survival Summary:

	Estimate	SE†
V1	0.9307	0.0242
R2	0.9050	0.0092
R3	0.9489	0.0071

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 15U	0.9307	0.0242	0.9736	0.0163	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0071

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9809	0.0137
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.9. McNary Dam Non-TSW Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9706	0.0150

Survival Summary:

	Estimate	SE†
V1	0.9257	0.0090
R2	0.9050	0.0092
R3	0.9489	0.0070

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 15U	0.9257	0.0090	0.9501	0.0079	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0070

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 15U	1.0000	0.0000	0.9986	0.0014	0.9677	0.0065
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.10. McNary Dam Spillway Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9712	0.0146

Survival Summary:

	Estimate	SE†
V1	0.9263	0.0084
R2	0.9050	0.0093
R3	0.9489	0.0071

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9263	0.0084	0.9528	0.0072	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0093
R3_CR422 15U	---	---	---	---	0.9489	0.0071

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	0.9988	0.0012	0.9693	0.0059
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

** Standard error is based on only the inverse Hessian.*
† Standard error is based on bootstrapping.

Table F.11. McNary Dam Turbine Virtual Release Detection and Survival Probabilities for Yearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9552	0.0470

Survival Summary:

	Estimate	SE†
V1	0.9110	0.0434
R2	0.9050	0.0092
R3	0.9489	0.0070

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 15U	0.9110	0.0434	0.9774	0.0247	---	---
R2_CR468 15U	---	---	---	---	0.9050	0.0092
R3_CR422 15U	---	---	---	---	0.9489	0.0070

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9494	0.0353
R2_CR468 15U	---	---	1.0000	0.0000	0.9559	0.0063
R3_CR422 15U	---	---	1.0000	0.0000	0.9581	0.0060

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.2 Detection and Survival of Juvenile Steelhead

F.2.1 Dam Passage (Season-Wide)

Table F.12. McNary Dam Passage Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9908	0.0183

Survival Summary:

	Estimate	SE†
V1	0.9136	0.0078
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9136	0.0078	0.9237	0.0077	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	0.9991	0.0009	0.9945	0.0022
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.2.2 BRZ-to-BRZ (Season-Wide)

Table F.13. Forebay Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9880	0.0183

Survival Summary:

	Estimate	SE†
V1	0.9110	0.0079
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9110	0.0079	0.9239	0.0077	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	0.9991	0.0009	0.9945	0.0022
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping*
.

F.2.3 Dam Passage Daytime and Nighttime (Season-Wide)

Table F.14. McNary Dam Daytime Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9777	0.0198

Survival Summary:

	Estimate	SE†
V1	0.9016	0.0108
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9016	0.0108	0.9238	0.0102	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	1.0000	0.0000	0.9905	0.0039
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.15. McNary Dam Nighttime Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	1.0095	0.0204

Survival Summary:

	Estimate	SE†
V1	0.9308	0.0110
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9308	0.0110	0.9235	0.0119	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	0.9978	0.0022	1.0000	0.0000
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.2.4 BRZ-to-BRZ Daytime and Nighttime (Season-Wide)

Table F.16. McNary Dam BRZ-to-BRZ Daytime Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9823	0.0195

Survival Summary:

	Estimate	SE†
V1	0.9058	0.0102
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9058	0.0102	0.9289	0.0094	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	1.0000	0.0000	0.9928	0.0032
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.17. McNary Dam BRZ-to-BRZ Nighttime Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9979	0.0212

Survival Summary:

	Estimate	SE†
V1	0.9202	0.0124
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9202	0.0124	0.9153	0.0133	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	0.9975	0.0025	0.9975	0.0025
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.2.5 Dam Passage by Route (Season-Wide)

Table F.18. McNary Dam JBS Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	1.0149	0.0256

Survival Summary:

	Estimate	SE†
V1	0.9358	0.0179
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9358	0.0179	0.9088	0.0218	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	1.0000	0.0000	0.9938	0.0063
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.19. McNary Dam TSW Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9764	0.0246

Survival Summary:

	Estimate	SE†
V1	0.9003	0.0173
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 35U	0.9003	0.0173	0.9442	0.0140	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 35U	1.0000	0.0000	1.0000	0.0000	0.9961	0.0039
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.20. McNary Dam non-TSW Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	1.0005	0.0194

Survival Summary:

	Estimate	SE†
V1	0.9226	0.0096
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 35U	0.9226	0.0096	0.9184	0.0103	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 35U	1.0000	0.0000	0.9985	0.0015	0.9939	0.0031
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.21. McNary Dam Spillway Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9938	0.0187

Survival Summary:

	Estimate	SE†
V1	0.9164	0.0084
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 35U	0.9164	0.0084	0.9255	0.0084	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 35U	1.0000	0.0000	0.9989	0.0011	0.9945	0.0025
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.22. McNary Dam Turbine Virtual Release Detection and Survival Probabilities for Juvenile Steelhead

Dam Survival:

	Estimate	SE†
Dam Survival:	0.8314	0.0848

Survival Summary:

	Estimate	SE†
V1	0.7667	0.0772
R2	0.8282	0.0109
R3	0.8982	0.0087

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR325.0		Release to CR325.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 35U	0.7667	0.0772	0.9565	0.0425	---	---
R2_CR468 35U	---	---	---	---	0.8282	0.0109
R3_CR422 35U	---	---	---	---	0.8982	0.0087

Capture Detail for Fitted Model:

	CR422.0		CR325.0		CR309.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 35U	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
R2_CR468 35U	---	---	0.9990	0.0010	0.9940	0.0025
R3_CR422 35U	---	---	1.0000	0.0000	0.9926	0.0026

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.3 Detection and Survival of Subyearling Chinook Salmon

F.3.1 Dam Passage (Season-Wide)

Table F.23. McNary Dam Passage Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9747	0.0114

Survival Summary:

	Estimate	SE†
V1	0.9149	0.0057
R2	0.8864	0.0074
R3	0.9443	0.0055

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9149	0.0057	0.9568	0.0044	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0074
R3_CR422 15U	---	---	---	---	0.9443	0.0055

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9371	0.0053
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.3.2 BRZ-to-BRZ (Season-Wide)

Table F.24. Forebay Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9729	0.0114

Survival Summary:

	Estimate	SE†
V1	0.9132	0.0057
R2	0.8864	0.0077
R3	0.9443	0.0057

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9132	0.0057	0.9569	0.0043	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0077
R3_CR422 15U	---	---	---	---	0.9443	0.0057

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	0.9995	0.0005	0.9371	0.0053
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.3.3 Dam Passage Daytime and Nighttime (Season-Wide)

Table F.25. McNary Dam Daytime Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9722	0.0123

Survival Summary:

	Estimate	SE†
V1	0.9125	0.0073
R2	0.8864	0.0080
R3	0.9443	0.0061

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9125	0.0073	0.9586	0.0054	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0080
R3_CR422 15U	---	---	---	---	0.9443	0.0061

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9404	0.0065
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.26. McNary Dam Nighttime Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9790	0.0137

Survival Summary:

	Estimate	SE†
V1	0.9189	0.0091
R2	0.8864	0.0085
R3	0.9443	0.0065

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9189	0.0091	0.9538	0.0073	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0085
R3_CR422 15U	---	---	---	---	0.9443	0.0065

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9315	0.0089
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.3.4 BRZ-to-BRZ Daytime and Nighttime (Season-Wide)

Table F.27. McNary Dam BRZ-to-BRZ Daytime Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9775	0.0123

Survival Summary:

	Estimate	SE†
V1	0.9175	0.0071
R2	0.8864	0.0074
R3	0.9443	0.0055

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 15U	0.9175	0.0071	0.9601	0.0053	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0074
R3_CR422 15U	---	---	---	---	0.9443	0.0055

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9407	0.0065
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.28. McNary Dam BRZ-to-BRZ Nighttime Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9653	0.0140

Survival Summary:

	Estimate	SE†
V1	0.9061	0.0098
R2	0.8864	0.0103
R3	0.9443	0.0081

Survival Detail for Fitted Model:

	CR472.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9061	0.0098	0.9514	0.0075	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0103
R3_CR422 15U	---	---	---	---	0.9443	0.0081

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	0.9987	0.0013	0.9311	0.0090
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

F.3.5 Dam Passage – by Route (Season-Wide)

Table F.29. McNary Dam JBS Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	1.0078	0.0171

Survival Summary:

	Estimate	SE†
V1	0.9460	0.0131
R2	0.8864	0.0084
R3	0.9443	0.0064

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.9460	0.0131	0.9463	0.0134	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0084
R3_CR422 15U	---	---	---	---	0.9443	0.0064

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9492	0.0133
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.30. McNary Dam Spillway Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.9803	0.0118

Survival Summary:

	Estimate	SE†
V1	0.9201	0.0062
R2	0.8864	0.0074
R3	0.9443	0.0055

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	**SE†**	**Estimate**	**SE***	**Estimate**	**SE†**
R1_CR503 15U	0.9201	0.0062	0.9589	0.0048	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0074
R3_CR422 15U	---	---	---	---	0.9443	0.0055

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	**SE***	**Estimate**	**SE***	**Estimate**	**SE***
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9339	0.0061
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Table F.31. McNary Dam Turbine Virtual Release Detection and Survival Probabilities for Subyearling Chinook Salmon

Dam Survival:

	Estimate	SE†
Dam Survival:	0.8806	0.0284

Survival Summary:

	Estimate	SE†
V1	0.8265	0.0254
R2	0.8864	0.0077
R3	0.9443	0.0058

Survival Detail for Fitted Model:

	CR470.0 to CR422.0		CR422.0 to CR349.0		Release to CR349.0	
	Estimate	SE†	Estimate	SE*	Estimate	SE†
R1_CR503 15U	0.8265	0.0254	0.9634	0.0140	---	---
R2_CR468 15U	---	---	---	---	0.8864	0.0077
R3_CR422 15U	---	---	---	---	0.9443	0.0058

Capture Detail for Fitted Model:

	CR422.0		CR349.0		CR325.0 Survival*Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*
R1_CR503 15U	1.0000	0.0000	1.0000	0.0000	0.9491	0.0166
R2_CR468 15U	---	---	1.0000	0.0000	0.9431	0.0056
R3_CR422 15U	---	---	0.9994	0.0006	0.9408	0.0055

Notes:

* *Standard error is based on only the inverse Hessian.*
† *Standard error is based on bootstrapping.*

Appendix G

JSATS Hydrophone Array Performances

Appendix G

JSATS Hydrophone Array Performances

Appendix G contains data on the detection probabilities at the McNary Dam-face double detection arrays and autonomous arrays (V_1-CR472, D_1-CR422, and D_3-CR325) used in survival estimates.

G.1 Detection Probabilities at Dam-Face Arrays

Detection probabilities for each dam-face array were greater than 98% and the combined detection probability for the double detection array used in the 2012 survival study was greater than 99% for all three species (Table G.1).

Table G.1. Numbers of Tagged Fish Detected and Detection Probabilities for the Dam-face Arrays at McNary Dam (N11 = detected on both arrays; N10 = detected on array 1 but not array 2; N01 = detected on array 2 but not array 1)

Species	Route	Sub-route	N	N11	N10	N01	Detection Probability at Array 1	Detection Probability at Array 2	Combined Detection Probability
CH1	Powerhouse	JBS	332	332	0	0	1.0000	1.0000	1.0000
		Turbine	45	45	0	0	1.0000	1.0000	1.0000
	Powerhouse		377	377	0	0	1.0000	1.0000	1.0000
	Spillway	TSW	113	113	0	0	1.0000	1.0000	1.0000
		non-TSW	874	868	3	3	0.9966	0.9966	1.0000
	Spillway		987	981	3	3	0.9970	0.9970	1.0000
	OVERALL		1364	1358	3	3	0.9978	0.9978	1.0000
STH	Powerhouse	JBS	188	188	0	0	1.0000	1.0000	1.0000
		Turbine	30	30	0	0	1.0000	1.0000	1.0000
	Powerhouse		218	218	0	0	1.0000	1.0000	1.0000
	Spillway	TSW	301	301	0	0	1.0000	1.0000	1.0000
		non-TSW	776	769	7	0	1.0000	0.9910	1.0000
	Spillway		1077	1070	7	0	1.0000	0.9935	1.0000
	OVERALL		1295	1288	7	0	1.0000	0.9946	1.0000
CH0	Powerhouse	JBS	310	310	0	0	1.0000	1.0000	1.0000
		Turbine	225	225	0	0	1.0000	1.0000	1.0000
	Powerhouse		535	535	0	0	1.0000	1.0000	1.0000
	Spillway	non-TSW	1909	1868	32	9	0.9952	0.9832	0.9999
	OVERALL		2444	2403	32	9	0.9963	0.9869	1.0000

G.2 Detection Probabilities at Survival Arrays

Detection probabilities at autonomous and dam-face arrays used in estimating survival of tagged smolts at McNary Dam ranged from 99.9 to 100% for all three species (Table G.2, Table G.3, and Table G.4).

Table G.2. Estimated Detection Probabilities used in Estimating Dam Passage Survival at McNary Dam for Yearling Chinook Based on Node Arrays. Standard errors for the estimates are in parentheses.

Release / Detection Arrays	Detection Probability (SE)
V_1 (rkm 470) / D_1 (rkm 422)	1.0000 (0.0000)
V_1 (rkm 470) / D_2 (rkm 349)	0.9991 (0.0009)
R_2 (rkm 468) / D_2 (rkm 349)	1.0000 (0.0000)
R_3 (rkm 422) / D_2 (rkm 349)	1.0000 (0.0000)

Table G.3. Estimated Detection Probabilities used in Estimating Dam Passage Survival at McNary Dam for Steelhead Based on Node Arrays. Standard errors for the estimates are in parentheses.

Release / Detection Arrays	Detection Probability (SE)
V_1 (rkm 470) / D_1 (rkm 422)	1.0000 (0.0000)
V_1 (rkm 470) / D_2 (rkm 325)	0.9991 (0.0009)
R_2 (rkm 468) / D_2 (rkm 325)	0.9990 (0.0010)
R_3 (rkm 422) / D_2 (rkm 325)	1.0000 (0.0000)

Table G.4. Estimated Detection Probabilities used in Estimating Dam Passage Survival at McNary Dam for Subyearling Chinook Based on Node Arrays. Standard errors for the estimates are in parentheses.

Release / Detection Arrays	Detection Probability (SE)
V_1 (rkm 470) / D_1 (rkm 422)	1.0000 (0.0000)
V_1 (rkm 470) / D_2 (rkm 349)	1.0000 (0.0000)
R_2 (rkm 468) / D_2 (rkm 349)	1.0000 (0.0000)
R_3 (rkm 422) / D_2 (rkm 349)	0.9994 (0.0006)

Distribution

Print and PDF
Copies

OFFSITE

1 B Eppard (Paper and PDF)
USACE Portland District
CENWP-PM-E
333 SW 1st Avenue (R. Duncan Plaza)
Portland, OR 97208-2946

1 E Hockersmith (Paper and PDF)
USACE Walla Walla District
201 North Third Avenue
Walla Walla, WA 99362-1876

5 M Weiland (Paper and PDF)
390 Evergreen Drive
P.O. Box 241
North Bonneville, WA 98639

Print and PDF
Copies

ONSITE

3 **Pacific Northwest National Laboratory**

DR Geist (Paper and PDF)	K7-70
KD Ham (Paper and PDF)	K7-70
ML Johnson (PDF)	K7-62
PNNL Library (Paper and PDF)	P8-55

US Army Corps
of Engineers®

Prepared for the U.S. Army Corps of Engineers, Portland District,
under a Government Order with the U.S. Department of Energy
Contract DE-AC05-76RL01830

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

U.S. DEPARTMENT OF
ENERGY

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)
www.pnl.gov