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Contract DE-AC05-76RL01830

Compliance Monitoring of Yearling and Subyearling Chinook Salmon and Juvenile Steelhead Survival and Passage at John Day Dam, 2012

FINAL COMPLIANCE REPORT

JR Skalski
RL Townsend
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May 2013

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Pacific Northwest National Laboratory
Richland, Washington 99352

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Preface

This study was conducted by the Pacific Northwest National Laboratory (PNNL) and the University of Washington (UW) for the U.S. Army Corps of Engineers, Portland District (USACE). The PNNL and UW project managers were Drs. Thomas J. Carlson and John R. Skalski, respectively. The USACE technical lead was Mr. Brad Eppard. The study was designed to estimate dam passage survival at John Day Dam as stipulated by the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) and provide additional performance measures as specified in the Columbia Basin Fish Accords.

This report summarizes the results of the compliance studies of yearling and subyearling Chinook salmon and steelhead at John Day Dam in 2012.

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Executive Summary

The purpose of this compliance study was to estimate dam passage survival of yearling and subyearling Chinook salmon and juvenile steelhead at John Day Dam during the spring and summer outmigrations in 2012. Under the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp), dam passage survival should be greater than or equal to 0.96 for spring migrants and greater than or equal to 0.93 for summer migrants, estimated with a standard error (SE) less than or equal to 0.015. The study also estimated survival from the forebay 2 km upstream of the dam to the tailrace 3 km downstream of the dam,[1] as well as the forebay residence time, tailrace egress time, spill passage efficiency (SPE), and fish passage efficiency (FPE), as required in the Columbia Basin Fish Accords (Fish Accords).

A virtual/paired-release design was used to estimate dam passage survival at John Day Dam. The approach included yearling and subyearling Chinook salmon and juvenile steelhead, tagged with acoustic micro-transmitters, released above John Day Dam that contributed to the formation of a virtual release at the face of John Day Dam. A survival estimate from this release was adjusted by a paired release below John Day Dam. A total of 3376 yearling Chinook salmon, 5726 subyearling Chinook salmon, and 3239 juvenile steelhead were used in the virtual releases. Sample sizes for the below-dam paired releases (R_2 and R_3, respectively) were 997 and 995 for yearling Chinook salmon, 986 and 983 for subyearling Chinook salmon, and 1000 and 1000 for juvenile steelhead. The Juvenile Salmon Acoustic Telemetry System (JSATS) tags were manufactured by Advanced Telemetry Systems. Model SS300 tags, weighing 0.304 g in air, were surgically implanted in yearling and subyearling Chinook salmon, and Model SS130 tags, weighing 0.438 g in air, were surgically implanted in juvenile steelhead for this investigation.

The intent of the spring study was to estimate dam passage survival during both 30% and 40% spill conditions. The two spill conditions were to be systematically performed in alternating 2-d test intervals over the course of the spring outmigration. High flow conditions in 2012 interrupted the spill study. Dam passage survival was therefore estimated season-wide regardless of spill conditions.

The study results are summarized in the following tables.

Table ES.1. Estimates of dam passage survival[a] at John Day Dam in 2012.

Spill Operations	Yearling Chinook Salmon	Steelhead	Subyearling Chinook Salmon
Season-wide spring	0.9673 (0.0065)	0.9744 (0.0028)[b]	NA
Season-wide summer	NA	NA	0.9414 (0.0031)[b]

(a) Dam passage survival is defined as survival from the upstream face of the dam to a standardized reference point in the tailrace.
(b) Based on V_1 single release only.

[1] The forebay-to-tailrace survival estimate satisfies the "BRZ-to-BRZ" (boat-restricted zone) survival estimate called for in the Fish Accords.

Table ES.2. Fish Accords performance measures at John Day Dam in 2012. Standard errors are in parentheses.

Performance Measures	Yearling Chinook Salmon	Steelhead	Subyearling Chinook Salmon
Forebay-to-tailrace survival (season-wide)	0.9660 (0.0065)	0.9687 (0.0030)[(a)]	0.9390 (0.0032)[(a)]
Forebay residence time (mean/median)	2.50 (0.14)/1.15	5.79 (0.33)/2.39	2.91 (0.26)/1.02
Tailrace egress rate (mean/median)	2.80 (0.28)/0.50	6.22 (0.48)/0.46	2.95 (0.16)/0.48
Spill passage efficiency[(b)]	0.7456 (0.0075)	0.7452 (0.0076)	0.6962 (0.0061)
Fish passage efficiency	0.9272 (0.0045)	0.9695 (0.0030)	0.8585 (0.0046)

(a) Based on V_1 single release only.
(b) The estimate of SPE includes temporary spill weir (TSW) and non-TSW spill bays.

Table ES.3. Survival study summary.

Year: 2012	
Study Site(s): John Day Dam	
Objective(s) of study: Estimate dam passage survival and other performance measures for yearling Chinook salmon, steelhead, and subyearling Chinook salmon.	
Hypothesis (if applicable): Not applicable; this is a compliance study.	
Fish: Species-race: yearling Chinook salmon (CH1), steelhead (STH), subyearling Chinook salmon (CH0) Source: John Day Dam Smolt Monitoring Facility	Implant Procedure: Surgical: Yes Injected: No

Size (median):	CH1	STH	CH0
Weight (g):	26.4	72.6	13.9
Length (mm):	144	208	113

Sample Size[a]:	CH1	STH	CH0
# release sites:	5	5	5
Total # released:	5368	5239	7695

Tag Type: Advanced Telemetry Systems (ATS)

	Model	Weight (air)
CH1/CH0:	SS300	0.304 g
STH:	SS130	0.438 g

Analytical Model: Virtual/paired-release model

Characteristics of Estimate:

Effects Reflected (direct, total, etc.): Direct
Absolute or Relative: Absolute

Environmental/Operating Conditions (daily from 30 April 2012 through 2 June 2012):

Statistic	Mean	Min	Max
River Discharge (kcfs):	347.9	275.7	410.9
Spill Discharge (kcfs):	129.9	83.9	176.8
Percent Spill (24 h/d):	37.1	29.9	43.7
Temperature (°C):	12.3	10.6	13.8
Total Dissolved Gas % (tailrace):	118..8	115.2	122.4

Treatment(s): None, because high discharge prevented operators from achieving 30% and 40% spill levels.
Unique Study Characteristics: None

Environmental/Operating Conditions (daily from 17 June 2012 through 19 July 2012):

Statistic	Mean	Min	Max
River Discharge (kcfs):	354.9	295.3	432.2
Spill Discharge (kcfs):	134.5	89.7	181.9
Percent Spill (24 h/d):	37.8	29.9	45.5
Temperature (°C):	16.6	14.9	18.6
Total Dissolved Gas % (tailrace):	119.2	116.4	123.4

Treatment(s): None, because high discharge prevented operators from achieving 30% and 40% spill levels.
Unique Study Characteristics: None

Survival and Passage Estimates (value & SE):	CH1	STH	CH0
Dam survival			
• Season-wide spring	0.9673 (0.0065)	0.9744 (0.0028)[b]	NA
• Season-wide summer	NA	NA	0.9414 (0.0031)[b]
Forebay-to-tailrace survival (season-wide)	0.9660 (0.0065)	0.9687 (0.0030)[2]	0.9390 (0.0032)[b]
Forebay residence time (mean/median)	2.50 (0.14)/1.15	5.79 (0.33)/2.39	2.91 (0.26)/1.02
Tailrace egress rate (mean/median)	2.80 (0.28)/0.50	6.22 (0.48)/0.46	2.95 (0.16)/0.48
Spill passage efficiency	0.7456 (0.0075)	0.7452 (0.0076)	0.6962 (0.0061)
Fish passage efficiency	0.9272 (0.0045)	0.9695 (0.0030)	0.8585 (0.0046)

Compliance Results: Estimates of dam passage survival met compliance requirements for CH1, STH, and CH0 for both point estimates and standard errors.

(a) Release sites include all release locations that contributed fish to the virtual-release group. Release numbers include only the fish used in the estimation of dam passage survival.
(b) Based on V_1 single release only.

Acknowledgments

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

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- UW: J Lady and P Westhagen.

Acronyms and Abbreviations

°C	degree(s) Celsius
3D	three dimensional
ATS	Advanced Telemetry Systems
BiOp	biological opinion
BRZ	boat-restricted zone
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
FCRPS	Federal Columbia River Power System
FPE	fish passage efficiency
g	gram(s)
h	hours(s)
JBS	juvenile bypass system
JSATS	Juvenile Salmon Acoustic Telemetry System
kcfs	thousand cubic feet per second
km	kilometer(s)
L	liter(s)
m	meter(s)
mg	milligram(s)
mm	millimeter(s)
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
PRI	pulse repetition interval
PSMFC	Pacific States Marine Fisheries Commission
rkm	river kilometer(s)
RME	research, monitoring, and evaluation
ROR	run-of-river
RPA	reasonable and prudent alternative
s	second(s)
SE	standard error
SPE	spill passage efficiency
STH	steelhead
USACE	U.S. Army Corps of Engineers
UW	University of Washington

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1.0 Introduction

The compliance monitoring studies reported herein were conducted by researchers at the Pacific Northwest National Laboratory (PNNL) and the University of Washington for the U.S. Army Corps of Engineers, Portland District (USACE) in spring and summer 2012. The purpose of these studies was to estimate dam passage survival at John Day Dam as stipulated by the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp; NMFS 2008) and provide additional performance measures at the dam as stipulated in the Columbia Basin Fish Accords for yearling and subyearling Chinook salmon and steelhead (3 Treaty Tribes-Action Agencies 2008).

1.1 Background

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):

> <u>Juvenile Dam Passage Performance Standards</u> – The Action Agencies juvenile performance standards are an average across Snake River and lower Columbia River dams of 96% average 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):

> <u>Dam Survival Performance Standard</u> – 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 . . . .

> <u>Spill Passage Efficiency and Delay Metrics</u> − 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 . . . .

> <u>Future RME</u> − 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. Spill passage efficiency 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 spring acoustic-telemetry studies of yearling and subyearling Chinook salmon and steelhead at John Day Dam to assess the Action Agencies' compliance with the performance criteria of the BiOp and Fish Accords.

1.2 Study Objectives

The purpose of the 2012 compliance monitoring at John Day Dam was to estimate performance measures for yearling and subyearling Chinook salmon and juvenile steelhead as outlined in the FCRPS BiOp and Fish Accords. For each fish stock, the following metrics were estimated using the Juvenile Salmon Acoustic Telemetry System (JSATS) technology:

- Dam passage survival, defined as survival from the upstream face of the dam to a standardized reference point in the tailrace. Performance[1] should be ≥96% survival for spring stocks (i.e., yearling Chinook salmon and steelhead) and ≥93% survival for summer stocks (i.e., subyearling Chinook salmon). Survival should be estimated with a standard error (SE) ≤1.5% (i.e., 95% confidence interval with half-width of ±3%; 3% = 1.96 SE ≈ 2 SE or SE = 1.5%).
- Forebay-to-tailrace survival, defined as survival from a forebay array 2 km upstream of the dam to a tailrace array 3 km downstream of the dam. The forebay-to-tailrace survival estimate satisfies the "BRZ-to-BRZ" survival estimated called for in the Fish Accords.
- Forebay residence time, defined as the time from first detection on the forebay entrance array, 2 km upstream of the dam, to the time of last detection on the dam-face array.
- Tailrace egress time, defined as the average travel time from last detection on the dam-face array to the last detection on the tailrace array 3 km downstream of the dam.
- Spill passage efficiency, defined as the fraction of fish going through the dam via the spillway.
- Fish passage efficiency (FPE), defined as the fraction of fish going through the dam via non-turbine routes.

The intent of the 2012 study was to assess compliance with the dam passage survival standard under alternative 30% and 40% spill conditions. The high river flow conditions during 2012 disrupted the intended spill studies. Consequently, only season-wide estimates of dam passage survival were performed.

Results are reported for the three fish stocks by performance measure. This report is designed to provide a succinct and timely summary of BiOp/Fish Accords performance measures.

1.3 Report Contents and Organization

The ensuing sections of this report present the study methods, results, and related discussion. The final section of the report lists references cited in the main text. The appendixes contain supplemental information about the tests of assumptions and capture-history data used in estimating dam passage survival rates.

[1] Performance as defined in the 2008 FCRPS BiOp, Section 6.0.

2.0 Methods

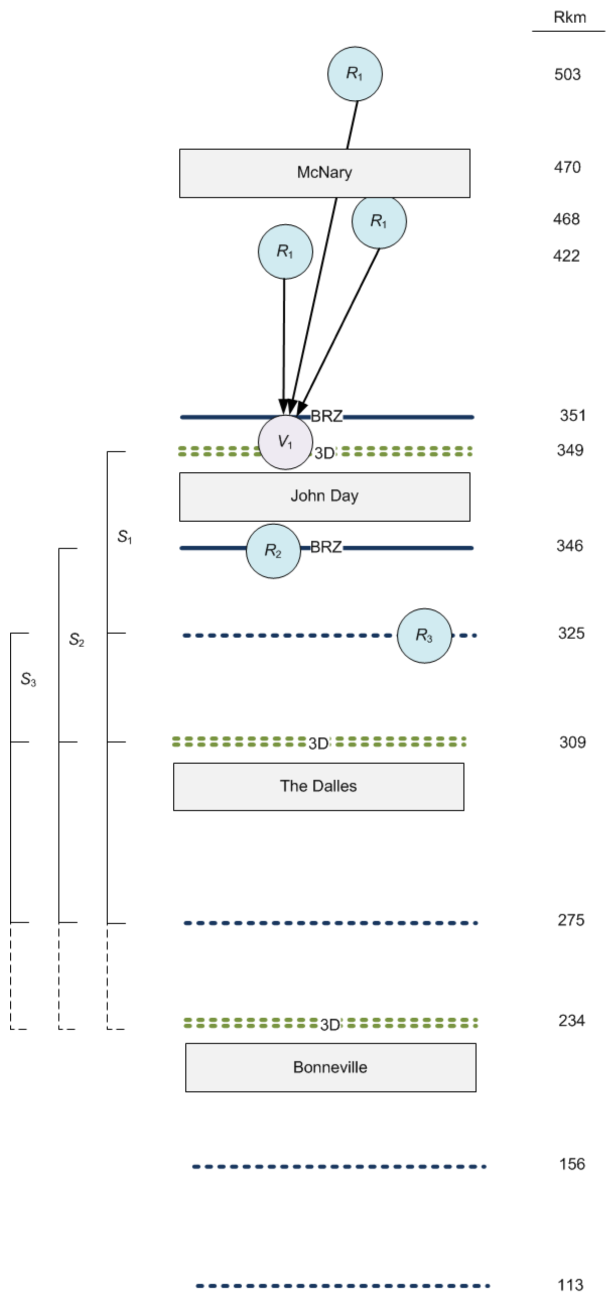
Study methods involved fish release and recapture; the associated fish handling, tagging, and release procedures; acoustic signal processing; and statistical and analytical approaches.

2.1 Release-Recapture Design

The release-recapture design used to estimate dam passage survival at John Day Dam consisted of a novel combination of a virtual release (V_1) of fish at the face of the dam and a paired release below the dam (Figure 2.1) (Skalski et al. 2010a, 2010b). Tagged fish were released above John Day Dam at three locations to supply a source of fish known to have arrived alive at the face of the dam. By releasing the fish far enough upstream, the fish should have arrived at the dam in a spatial pattern typical of run-of-river (ROR) fish. This virtual-release group was then used to estimate survival through the dam and part of the way through the next reservoir (i.e., river kilometer [rkm] 325) (Figure 2.1). To account and adjust for this extra reach mortality, a paired release below John Day Dam (i.e., R_2 and R_3) (Figure 2.1) was used to estimate survival in that segment of the reservoir below the dam. Dam passage survival was then estimated as the quotient of the survival estimates for the virtual release to that of the paired release. The sizes of the releases of the fish tagged with acoustic micro-transmitters used in the dam passage survival estimates are summarized in Table 2.1.

The same release-recapture design was also used to estimate forebay-to-tailrace survival, except that the virtual-release group was constructed of fish known to have arrived at the forebay array (rkm 351). The same below-dam paired release was used to adjust for the extra release mortality below the dam as was used to estimate dam passage survival. The double-detection arrays at the face of the dam (Figure 2.2) were analyzed as two independent arrays to allow estimation of detection probabilities by route of passage and assign the location of the last detection (i.e., the passage route). These passage-route data were used to calculate SPE and FPE at John Day Dam. The fish used in the virtual release at the face of the dam were also used to estimate tailrace egress time.

One manufacturing lot of tags was used for yearling Chinook salmon, another for steelhead, and yet another tag lot for the subyearling Chinook salmon study. A total of 98 tags for yearling Chinook salmon, 100 for steelhead, and 99 for subyearling Chinook salmon were randomly sampled for the tag-life assessments. The tags were activated, held in river water, and monitored continuously until they failed. The information from the tag-life study was used to adjust the perceived survival estimates from the Cormack-Jolly-Seber release-recapture model according to the methods of Townsend et al. (2006).



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

Figure 2.1. Schematic of the virtual/paired-release design used to estimate dam passage survival at John Day Dam. The virtual release (V_1) was composed of fish that arrived at the dam face from releases at rkm 503, 468, and 422. The below-dam release pair was composed of releases R_2 and R_3 with detection arrays used in the survival analysis denoted by dashed lines. During the spring study, the detection array at rkm 275 was unavailable. Instead, the last detection array used in the spring survival analyses was at rkm 234.

Table 2.1. Sample sizes of acoustic-tagged fish releases used in the yearling and subyearling Chinook salmon and steelhead survival studies at John Day Dam in 2012.

Release Location	Yearling Chinook Salmon	Steelhead	Subyearling Chinook Salmon
Above John Day Dam (R_1)	3797	3797	6501
Virtual Release-John Day Dam (V_1)	3376	3239	5726
John Day Dam Tailrace (R_2)	997	1000	986
Celilo, Oregon (R_3)	995	1000	983

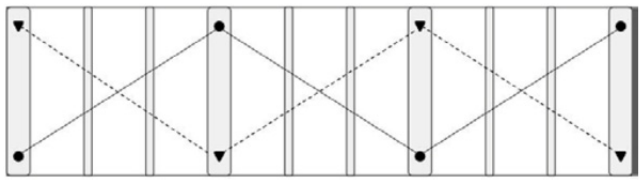


Figure 2.2. Front view schematic of hydrophone deployments at three turbines showing the double-detection arrays. The circles denote the hydrophones of Array 1 and the triangles denote the hydrophones of Array 2.

2.2 Handling, Tagging, and Release Procedures

Fish obtained from the John Day Dam juvenile bypass system (JBS) were surgically implanted with both JSATS and PIT tags and transported to the different release locations, as described in the following sections.

2.2.1 Acoustic Tags

The acoustic tags used in the 2012 studies were manufactured by Advanced Telemetry Systems (ATS). Yearling and subyearling Chinook salmon were tagged with ATS model SS300 acoustic tags that were 10.7 mm long, 5.21 mm wide, 3.03 mm thick, and weighed 0.304 g in air. These tags had a nominal transmission rate of 1 pulse every 3 s and nominal tag life was expected to be about 25 d. The ATS tag model SS130, used for juvenile steelhead, was 11.9 mm long, 5.1 mm wide, 3.7 mm thick, and weighed 0.438 g in air. This tag had a nominal transmission rate of 1 pulse every 3 s and nominal tag life was expected to be 33 d.

2.2.2 Fish Source

The yearling and subyearling Chinook salmon and steelhead used in the studies were all obtained from the John Day Dam JBS. The Pacific States Marine Fisheries Commission diverted fish from the JBS into an examination trough, as described by Martinson et al. (2006). Fish ≥95 and <300 mm in length without malformations or excessive descaling (>20%) were selected for tagging.

2.2.3 Tagging Procedure

The fish to be tagged were anesthetized in an 18.9-L "knockdown" bucket that contained fresh river water and MS-222 (tricaine methanesulfonate; 80 to 100 mg/L). Anesthesia buckets were refreshed repeatedly to maintain the temperature within ±2°C of current river temperatures. Each fish was weighed and measured before tagging.

During surgery, each fish was placed ventral side up and a gravity-fed anesthesia supply line was placed into its mouth. The dilution of the "maintenance" anesthesia was 40 mg/L. Using a micro-sharp, a 5- to 7-mm incision was made in the body cavity between the pelvic girdle and pectoral fin. A passive integrated transponder (PIT) tag was inserted followed by an acoustic tag. Both tags were inserted toward the anterior end of the fish. The incision was closed using a 5-0 Monocryl suture.

After closing the incision, the fish were placed in a dark 18.9-L transport bucket filled with aerated river water. Fish were held in these buckets for 12 to 36 h before being transported for release into the river. The loading rate was five fish per bucket.

2.2.4 Release Procedures

All fish were tagged at John Day Dam and transported by truck to the release locations (Figure 2.1). Transportation routes were adjusted to provide equal travel times to each release location from John Day Dam. Upon arriving at a release site, fish buckets were transferred to a boat for transport to the in-river release location. There were five release locations at each release site across the river (Figure 2.1), and equal numbers of buckets of fish were released at each of the five locations.

Releases in the tailrace occurred for 32 consecutive days in spring (from 2 May to 2 June 2012) and another 32 consecutive days in summer (from 18 June to 19 July 2012). Upstream releases began above McNary Dam on 27 April in spring and 13 June in summer 2012, and fish were first detected on 30 April (spring) and 17 June (summer) at the V_1 array. Releases alternated between daytime and nighttime, every other day, over the course of the study. The timing of the releases at the release sites was staggered to help facilitate downstream mixing (Table 2.2).

Table 2.2. Relative release times for acoustic-tagged fish to accommodate downstream mixing. The virtual release occurred continuously from upstream release sites. Releases were timed to accommodate the approximately 6-h travel time between R_2 and R_3.

	Relative Release Times	
Release Location	Daytime Start	Nighttime Start
V_1 (rkm 349)	Continuous	Continuous
R_2 (rkm 346)	Day 1: 0400	Day 2: 1600
R_3 (rkm 325)	Day 1: 1000	Day 2: 2200

2.3 Acoustic Signal Processing

Transmissions of JSATS tag codes received on cabled and autonomous hydrophones were recorded in raw data files. These files were downloaded periodically and transported to PNNL's North Bonneville offices for processing. Receptions of tag codes within raw data files were processed to produce a data set of accepted tag-detection events. For cabled arrays, detections from all hydrophones at a dam were combined for processing. The following three filters were used:

- Multipath filter: For data from each individual cabled hydrophone, all tag-code receptions that occur within 0.156 s after an initial identical tag code reception were deleted under the assumption that closely lagging signals are multipath. Initial code receptions were retained. The delay of 0.156 s was the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and was computed as 2(PRI_Window+12×PRI_Increment). Both PRI_Window and PRI_Increment were set at 0.006 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 tag code was received at another hydrophone in the same array within 0.3 s because receptions on separate hydrophones within 0.3 s (about 450 m of range) were likely from a single tag transmission.
- PRI filter: Only those series of receptions of a tag code (or "messages") that were consistent with the pattern of transmissions from a properly functioning JSATS acoustic tag were retained. Filtering rules were evaluated for each tag code individually, and it was assumed that only a single tag would be transmitting that code at any given time. For the cabled system, the PRI filter operated on a message, 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.

The receptions of JSATS tag codes within raw data files from autonomous nodes were also processed to produce a data set of accepted tag-detection events, or events for short. A single file was processed at a time, and no information about receptions at other nodes was used. The Multipath and PRI filters described above were used.

The output of this process was a data set of events that summarized accepted tag detections for all times and locations where hydrophones were operating. Each unique event record included a basic set of fields that indicated the unique identification number of the fish, the first and last detection time for the event, the location of detection, and how many messages were detected within the event. This list was combined with accepted tag detections from the autonomous arrays and PIT-tag detections for additional quality assurance/quality control analysis prior to survival analysis. Additional fields capture specialized information, where available. One such example was route of passage, which was assigned a value for those events that immediately 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 can be used to triangulate successive tag position relative to hydrophone locations.

One of the most important quality control steps 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 deviate from the expected upstream to downstream progression through arrays in the river. Except for possible detections on forebay entrance arrays after detection on a nearby dam-face array 1 to 3 km downstream, apparent upstream movements of tagged fish between arrays that were greater than 5 km apart or separated by one or more dams were very rare (<0.015%) and probably represented false positive detections on the upstream array. False positive detections usually will have close to the minimum number of messages and were deleted from the event data set before survival analysis.

Three-dimensional (3D) tracking of JSATS-tagged fish in the immediate forebay of John Day Dam was used to determine routes of passage to estimate SPE and FPE. Acoustic tracking is a common technique in bioacoustics based on time-of-arrival differences among different hydrophones. Usually, the process requires a three-hydrophone array for two-dimensional tracking and a four-hydrophone array for 3D tracking. For this study, only 3D tracking was performed. The methods were similar to those described by Weiland et al. (2009, 2011, 2013).

2.4 Statistical Methods

Statistical methods were used to test assumptions and estimate passage survival, tag life, forebay-to-tailrace survival, travel times, SPE, and FPE, as described below.

2.4.1 Estimation of Dam Passage Survival

Maximum likelihood estimation was used to estimate dam passage survival at John Day Dam based on the virtual/paired-release 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) and differentiated by tag lot. Different tag-life adjustments were made for the different upstream releases contributing to V_1.

The joint likelihood used to model 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 (i.e., $SE \le 0.015$) with the fully parameterized model, 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 both precision and robustness of the survival results. All calculations were performed using Program ATLAS (http://www.cbr.washington.edu/paramest/atlas/).

Dam passage survival was estimated by the function

$$\hat{S}_{\text{Dam}} = \frac{\hat{S}_1}{\left(\frac{\hat{S}_2}{\hat{S}_3}\right)} = \frac{\hat{S}_1 \cdot \hat{S}_3}{\hat{S}_2} \tag{2.1}$$

where $\hat{S}_i$ is the tag-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 tag-life corrections and the release-recapture processes.

In 2012, compliance tests at John Day Dam were planned for dam operation conditions that included alternating 2-d test intervals of either 30% or 40% spill during both spring and summer studies. However, because of high river discharge in 2012, the spill conditions of 30% or 40% spill could not be achieved. Therefore, dam passage survival was estimated season-wide, including all days regardless of spill conditions.

2.4.2 Tag-Life Analysis

For each tag lot of JSATS tags, 98, 100, and 99 acoustic tags were systematically sampled over the course of the yearling Chinook salmon, juvenile steelhead, and subyearling Chinook salmon tagging studies, respectively. The tags were continuously monitored from activation to failure in ambient river water. For each tag lot, the failure times were fit to either the four-parameter vitality model of Li and Anderson (2009) or a three-parameter Weibull distribution. The vitality model tends to fit acoustic-tag failure times well, as it allows for both early onset of random failure due to manufacturing as well as systematic battery failure later on. In the case of the steelhead, no early onset failures occurred. Consequently, the three-parameter Weibull distribution was used to model tag life for the steelhead study.

The survivorship function for the vitality model can be rewritten as

$$S(t)=1-\left(\Phi\left(\frac{1-rt}{\sqrt{u^2+s^2t}}\right)-e^{\left(\frac{2u^2r^2}{s^4}+\frac{2r}{s^2}\right)}\Phi\left(\frac{2u^2r+rt+1}{\sqrt{u^2+s^2t}}\right)\right)^{e^{-kt}} \tag{2.2}$$

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 random failure component, in addition to battery discharge, gives the vitality model additional latitude to fit tag-life data not found in other failure-time distributions such as the Weibull or Gompertz. Parameter estimation was based on maximum likelihood estimation.

The three-parameter Weibull distribution (Elandt-Johnson and Johnson 1980:62) with scale (λ), shape (β), and shift (γ) parameters has the following probability density function

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

with survivorship function

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

cumulative density function (CDF)

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

and hazard function

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

The three-parameter Weibull reduces to the two-parameter Weibull when γ =0; it reduces to the exponential distribution when β =1 and γ =0.

For the virtual-release group (V_1) based on fish known to have arrived at the dam and with active tags, the conditional probability of tag activation, given the tag was active at the detection array at rkm 349, was used in the tag-life adjustment for that release group. The conditional probability of tag activation at time t_1, given it was active at time t_0, was computed by the quotient:

$$P(t_1 | t_0) = \frac{S(t_1)}{S(t_0)} \tag{2.3}$$

where $S(t_0)$ is the average unconditional probability that the tag is active when detected at the V_1 detection array (rkm 349), and $S(t_1)$ is the average unconditional probability that the tag is active when detected at the first downstream survival detection array (rkm 325).

2.4.3 Tests of Assumptions

Approaches to assumption testing are described below.

2.4.3.1 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 with PIT-tagged fish going through the JBS. However, acoustic-tag studies do not use physical recaptures to detect fish. Consequently, there is little or no relevance of these tests in acoustic-tag studies. Furthermore, the very high detection probabilities present in acoustic-tag studies frequently preclude calculation of these tests. For these reasons, these tests were not performed.

2.4.3.2 Tests of Mixing

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

2.4.3.3 Tagger Effects

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

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

$$F_{k-1,\infty} = \frac{s_{\hat{S}}^2}{\left(\frac{\sum_{i=1}^{k} \widehat{\text{Var}}\left(\hat{S}_i \middle| S_i\right)}{k} \right)} \tag{2.4}$$

where

$$s_{\hat{S}}^2 = \frac{\sum_{i=1}^{k} \left(\hat{S}_i - \hat{\bar{S}}\right)^2}{k-1} \tag{2.5}$$

and

$$\hat{\bar{S}} = \frac{\sum_{i=1}^{k} \hat{S}_i}{k} \tag{2.6}$$

The F-test was used in evaluating tagger effects as well as delayed tag effects.

2.4.3.4 Delayed Tag Effects

The fish forming the virtual-release group (i.e., V_1) came from multiple upstream release locations. If delayed effects of handling or tagging occurred, this could affect the performance of the virtual-release group. Consequently, downstream reach survivals and cumulative release survivals are compared among fish released at different upstream locations. The F-test (2.4) evaluates whether reach survivals are homogeneous regardless of release location. Should heterogeneity be detected, uppermost release groups might be eliminated from subsequent survival and other analyses.

2.4.3.5 Tag-Lot Effects

Because only one tag lot was used per survival analysis, examination of tag-lot effects was unnecessary.

2.4.4 Forebay-to-Tailrace Survival

The same virtual/paired-release methods used to estimate dam passage were also used to estimate forebay-to-tailrace survival. The only distinction was the virtual-release group (V_1) was composed of fish known to have arrived alive at the forebay array (rkm 351) of John Day Dam instead of at the dam face (Figure 2.1).

2.4.5 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.,

$$\bar{t} = \frac{\sum_{i=1}^{n} t_i}{n}, \tag{2.7}$$

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

$$\widehat{\text{Var}}(\bar{t}) = \frac{\sum_{i=1}^{n} (t_i - \bar{t})^2}{n(n-1)}, \tag{2.8}$$

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 last detection of a fish at the double array at the dam face at John Day Dam to the last detection at the tailrace array 3 km downstream of the dam (rkm 346). The estimated forebay residence times were based on the time from the first detection at the forebay BRZ array 2 km above the dam to the last detection at the double array on the upstream face of John Day Dam.

2.4.6 Estimation of Spill Passage Efficiency

Spill passage efficiency was estimated by the fraction

$$\widehat{\text{SPE}} = \frac{\hat{N}_{NTSW} + \hat{N}_{TSW}}{\hat{N}_{NTSW} + \hat{N}_{TSW} + \hat{N}_{TUR} + \hat{N}_{JBS}}, \tag{2.9}$$

where $\hat{N}_i$ is the estimated abundance of acoustic-tagged fish through the ith route (i = non-TSW [NTSW], temporary spill weir [TSW], turbines [TUR], and juvenile bypass system [JBS]). The double-detection array was used to estimate absolute abundance (*N*) through a route using the single mark-recapture model (Seber 1982:60) independently at each route. Calculating the variance in stages, the variance of $\widehat{\text{SPE}}$ was estimated as

$$\text{Var}\left(\widehat{\text{SPE}}\right)=\frac{\widehat{\text{SPE}}\left(1-\widehat{\text{SPE}}\right)}{\sum_{i=1}^{4}\hat{N}_i}+\widehat{\text{SPE}}^2\left(1-\widehat{\text{SPE}}\right)^2 \cdot\left[\frac{\text{Var}\left(\hat{N}_{NTSW}\right)+\text{Var}\left(\hat{N}_{TSW}\right)}{\left(\hat{N}_{NTSW}+\hat{N}_{TSW}\right)^2}+\frac{\widehat{\text{Var}}\left(\hat{N}_{TUR}\right)+\text{Var}\left(\hat{N}_{JBS}\right)}{\left(\hat{N}_{TUR}+\hat{N}_{JBS}\right)^2}\right]. \quad (2.10)$$

2.4.7 Estimation of Fish Passage Efficiency

Fish passage efficiency was estimated by the fraction

$$\widehat{\text{FPE}}=\frac{\hat{N}_{NTSW}+\hat{N}_{TSW}+\hat{N}_{JBS}}{\hat{N}_{NTSW}+\hat{N}_{TSW}+\hat{N}_{JBS}+\hat{N}_{TUR}}, \quad (2.11)$$

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

$$\text{Var}\left(\widehat{\text{FPE}}\right)=\frac{\widehat{\text{FPE}}\left(1-\widehat{\text{FPE}}\right)}{\sum_{i=1}^{4}\hat{N}_i}+\widehat{\text{FPE}}^2\left(1-\widehat{\text{FPE}}\right)^2 \cdot\left[\frac{\text{Var}\left(\hat{N}_{NTSW}\right)+\text{Var}\left(\hat{N}_{TSW}\right)+\text{Var}\left(\hat{N}_{JBS}\right)}{\left(\hat{N}_{NTSW}+\hat{N}_{TSW}+\hat{N}_{JBS}\right)^2}+\frac{\widehat{\text{Var}}\left(\hat{N}_{TUR}\right)}{\hat{N}_{TUR}^2}\right]. \quad (2.12)$$

3.0 Results

The results cover four topics: 1) fish collection, rejection, and tagging; 2) discharge and spill conditions; 3) tests of assumptions; and 4) survival and passage estimates.

3.1 Fish Collection, Rejection, and Tagging

The total number of fish handled by PNNL in 2012 and the counts and percentages of fish by handling category are listed in Table 3.1. During the study, 29,645 yearling and subyearling Chinook salmon and juvenile steelhead were handled.

Table 3.1. Total number of fish handled by PNNL during the spring and summer of 2012 and counts of fish in several handling categories.

Handling Category	CH1	%CH1	STH	%STH	CH0	%CH0
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**	

CH1 = yearling Chinook salmon, STH = juvenile steelhead, CH0 = subyearling Chinook salmon.

Staff rejecting fish from tagging recorded the reasons by tallying the maladies observed (Table 3.2). Conditions were based on the general recommendations of the Columbia Basin Rejection Criteria (CBSPSC 2011) and confirmed by the Studies Review Work Group and National Oceanic and Atmospheric Administration in meetings during spring 2012 (B Eppard, personal communication, April 20, 2012). PNNL broadened the criteria to accept more fish. Fish were not accepted for the project if they were moribund, or showed obvious signs of progressed infections/diseases (e.g., fungus or furunculosis presence greater than 5% on one side of fish flank), open wounds that perforated the body cavity, skeletal deformities that would inhibit tag insertion or swimming ability, and descaling greater than 20% where there is no indication of scale growth or slime coat present. If more than 5% of the sample the day before had a particular malady/infection, the following day fish with that malady were accepted after approval by the fish condition study manager.

Table 3.2. Number of observed malady types that warranted rejection of yearling and subyearling Chinook salmon and juvenile steelhead handled by PNNL during spring and summer of 2012.

	CH1	% CH1	STH	% STH	CH0	% CH0	**Total**
Descaling >20%	65	25.7	139	28.1	139	27.8	**343**
Caudal Fin Missing	8	3.2	1	0.2	8	1.6	**17**
Diseases	107	42.3	274	55.5	197	39.4	**43**
Damage/Injury	88	34.8	141	28.5	213	42.6	**442**
Skeletal Deformity	16	6.3	21	4.3	6	1.2	**578**
Total Fish[(a)]	**253**		**494**		**500**		**1247**

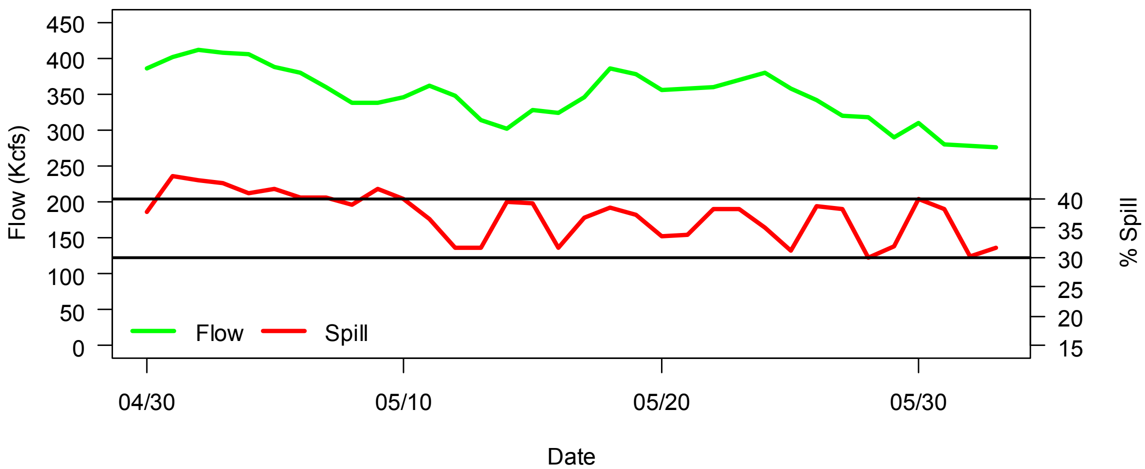
(a) Each species averaged >1 malady per fish; 11.5% for CH1, 15.9% for STH, and 10.8% for CH0 of fish for each species had more than one malady.

CH1 = yearling Chinook salmon, STH = juvenile steelhead, CH0 = subyearling Chinook salmon.

3.2 Discharge and Spill Conditions

High river discharge during spring and summer 2012 prevented formation of the intended 2-d 30% or 40% spill test intervals (Figure 3.1). Dam passage survival was therefore calculated season-wide during the prevailing conditions of spill (i.e., ≥30%) over the entire period.

a. Spring



b. Summer

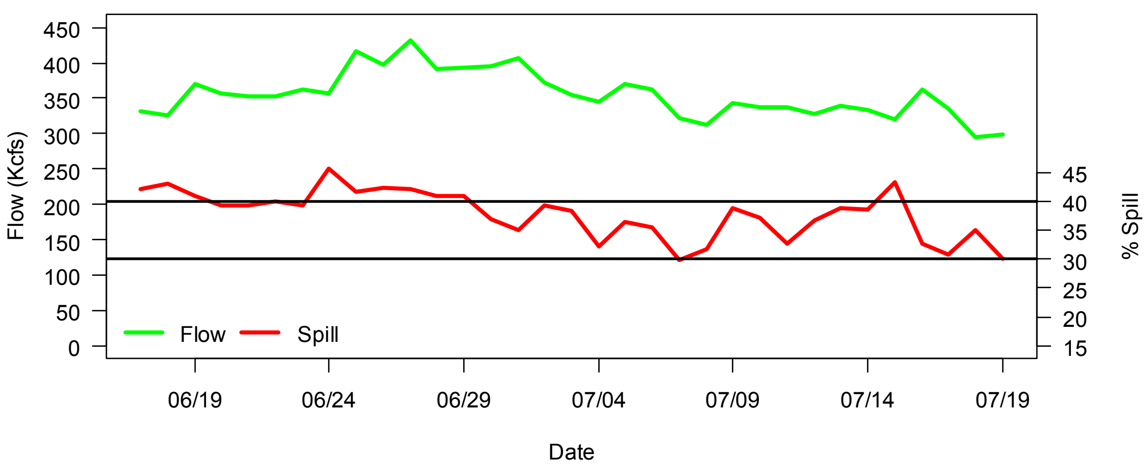
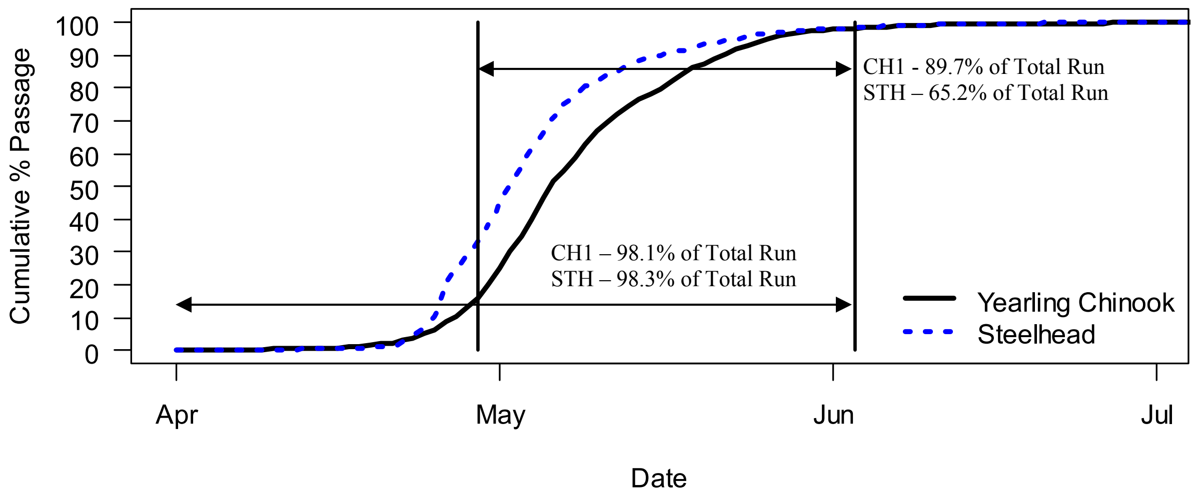


Figure 3.1. Daily average total discharge and percent spill at John Day Dam during a) the spring yearling Chinook salmon and steelhead study, 30 April to 2 June 2012, and b) the summer subyearling Chinook salmon study, 17 June to 19 July 2012.

3.3 Run Timing

The cumulative percentage of yearling Chinook salmon, juvenile steelhead, and subyearling Chinook that had passed John Day Dam by date was calculated from smolt index data obtained from the Fish Passage Center (Figure 3.2). Over the period of the study, from April 30 through June 2, 2012, 89.7% of yearling Chinook salmon and 65.2% of juvenile steelhead had passed John Day Dam. By the end of the study on June 2, 2012, 98.1% of yearling Chinook salmon and 98.3% of juvenile steelhead relative to the total run had passed John Day Dam. Over the period of the study, from June 17 through July 19, 2012, 63.8% of subyearling Chinook salmon had passed John Day Dam. By the end of the study on July 19, 2012, 66.5% of subyearling Chinook salmon had passed John Day Dam relative to the total run.

a. Spring



b. Summer

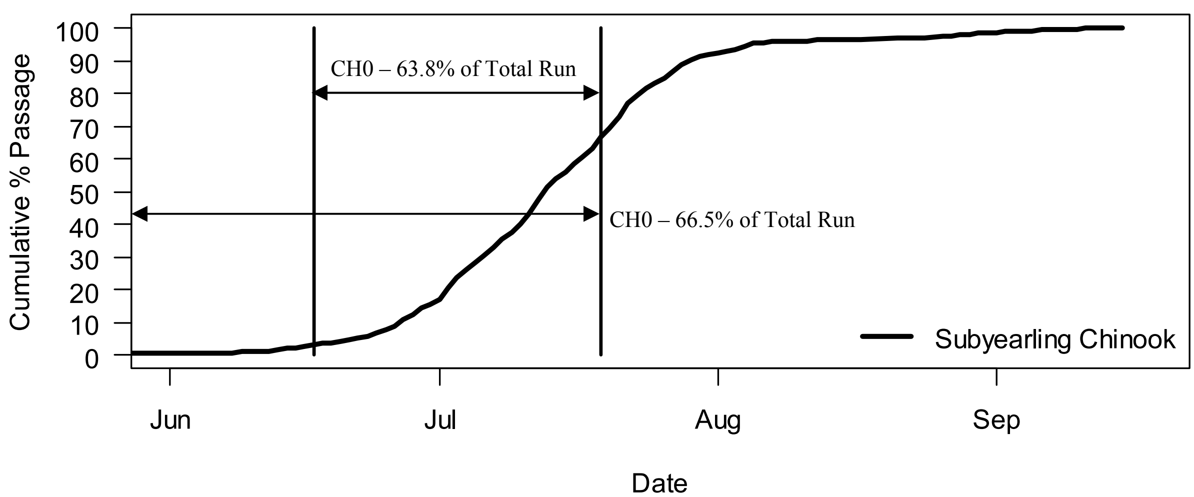


Figure 3.2. Plots of the cumulative percentage of a) yearling Chinook salmon and steelhead that had passed John Day Dam during the spring study and b) subyearling Chinook salmon during the summer study of 2012. Vertical lines mark the beginning and end of the survival studies.

3.4 Assessment of Assumptions

The assessment of assumptions covers tagger effects, tag-lot effects, delayed handling effects, fish size distributions, tag-life corrections, arrival distributions, and downstream mixing.

3.4.1 Examination of Tagger Effects

A total of eight different taggers assisted in tagging all yearling and subyearling Chinook salmon and juvenile steelhead associated with the JSATS survival studies at McNary, John Day, The Dalles, and Bonneville dams in spring and summer 2012. Analyses found tagger effort was homogeneously distributed either across all locations within a replicate release or within the project-specific releases within a replicate (Appendix A). Examination of reach survivals and cumulative survivals from above McNary Dam to below Bonneville Dam found no consistent or repeatable evidence that fish tagged by different staff members had different in-river survival rates (Appendix A). Therefore, fish tagged by all taggers were included in the estimation of survival and other performance measures.

3.4.2 Examination of Tag-Lot Effects

One tag lot was used for the spring yearling Chinook salmon study, another for the spring steelhead study, and yet another for the summer subyearling Chinook salmon study. Therefore, examination of tag-lot effects was unnecessary.

3.4.3 Handling Mortality and Tag Shedding

Fish were held for 12 to 36 h prior to release. The post-tagging mortality in spring was 0.27% and 0.02% for yearling Chinook salmon and steelhead, respectively. One PIT tag was shed during the post-tagging holding period in spring. In summer, post-tagging mortality was 0.18% for subyearling Chinook salmon and no tags were shed.

3.4.4 Effects of Tailrace and Tailwater Release Locations on Survival

Survival rates for yearling Chinook salmon, steelhead, and subyearling Chinook salmon released at four or five adjacent locations across the John Day Dam tailrace and tailwater did not appear to differ significantly based upon overlap of 95% confidence intervals (Figure 3.3, Figure 3.4, and Figure 3.5, respectively). The uppermost plot in each of the figures shows survival rates for dam-passed fish regrouped on tailrace autonomous nodes to form four virtual releases across the tailrace. Regrouping dam-passed fish (V_1) on the tailrace array is problematic because it has the real potential to include some tagged fish that died during dam passage, which would violate survival model assumptions and underestimate survival in downstream reaches. Our intent was to provide some indication of the relative distribution of survival rates for fish regrouped at sites across the tailrace and not to provide robust estimates of dam-passage survival. An underlying assumption is that the probability of regrouping dead fish along with live fish is low and similar across the tailrace, but this assumption may not be valid.

The distribution of numbers of fish released at five locations across the tailrace release site was uniform, as was the distribution of numbers of fish released at five sites across the tailwater release site (see numbers and percentages in the middle and bottom plots in Figure 3.3, Figure 3.4, and Figure 3.5).

We did not specify the number of V_1 fish regrouped on each autonomous node because that distribution can be highly biased by differences in tag detectability, which is inversely related to linear water velocity where each node was deployed.

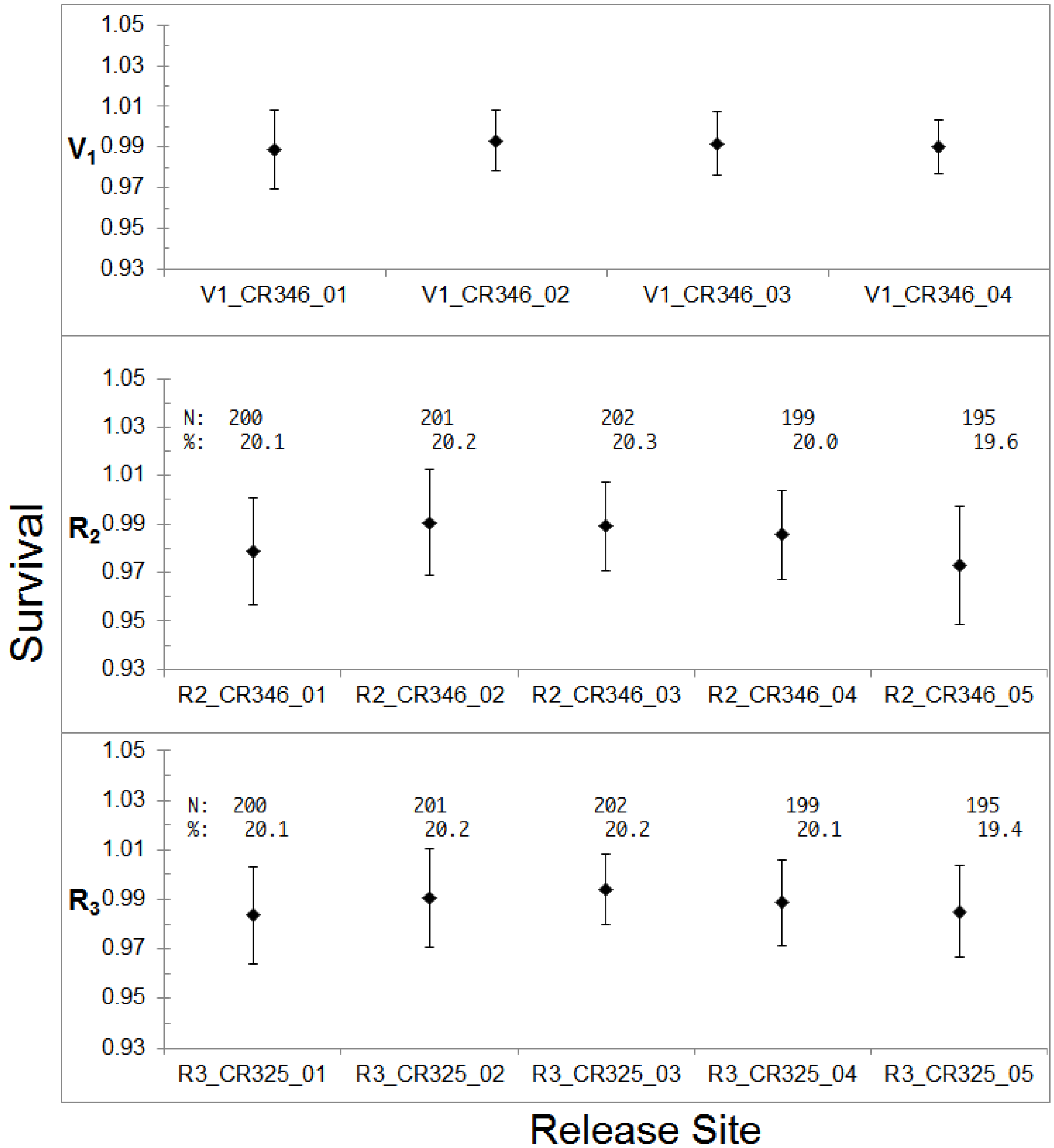


Figure 3.3. Single-release estimates of survival probabilities (y axis) for yearling Chinook salmon released across the Columbia River at four or five locations from the Washington to the Oregon side of the channel (x axis). The top plot shows survival probabilities for the reach from CR346 to CR325 for four virtual releases of fish formed by regrouping dam-passed fish on the tailrace autonomous node that received the most receptions of a tag code. The middle plot shows reach survival probabilities for R_2 fish (John Day Dam-tailrace releases at CR346) to The Dalles Dam (CR309), and the bottom plot shows reach survivals for R_3 fish released in the John Day Dam tailwater near Celilo, Oregon (CR325), after travel to The Dalles Dam (CR309). Two lines of numbers across survival bars show the number (N) and percent of fish released at each location. Vertical error bars represent the extent of the 95% confidence interval.

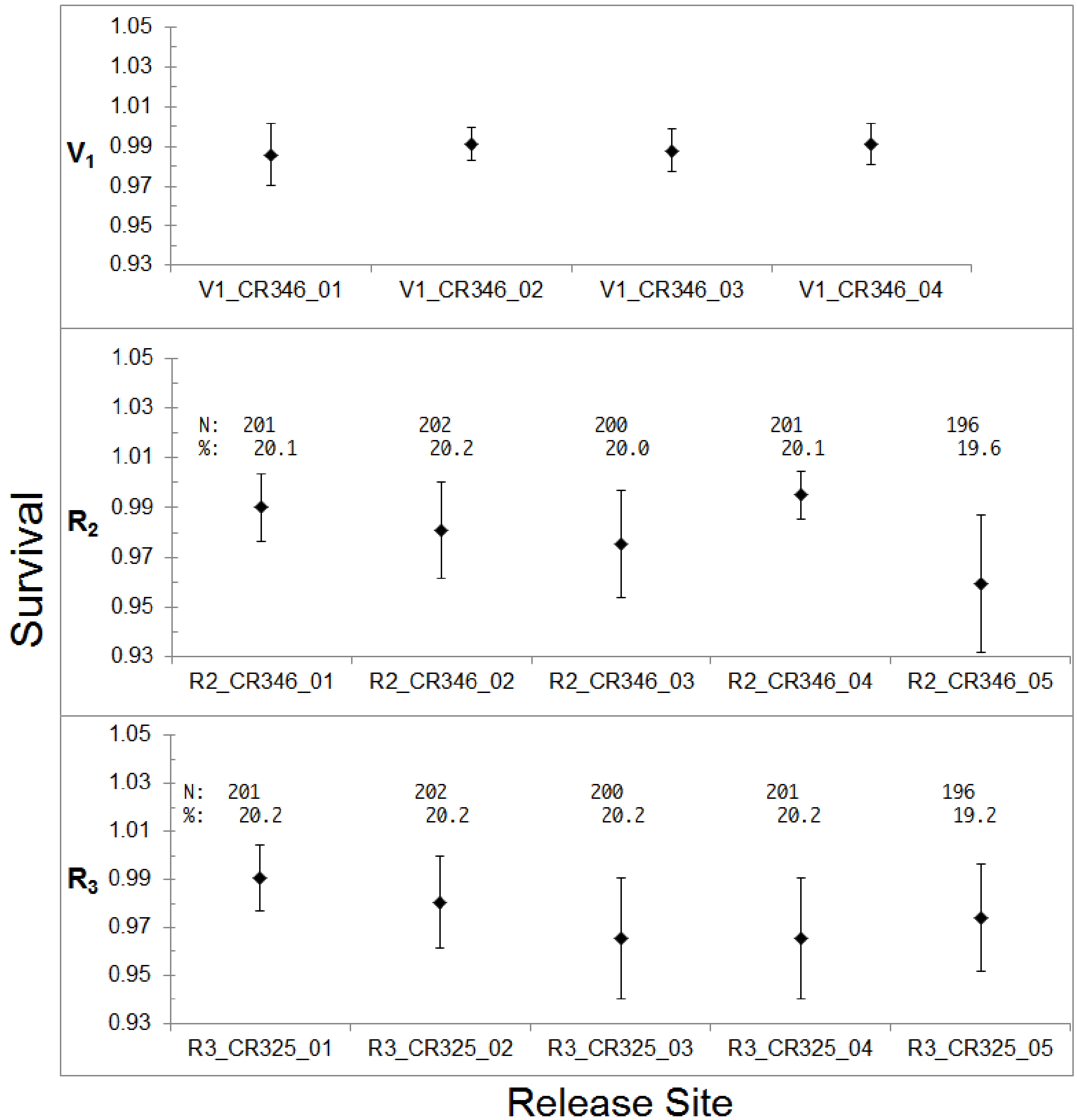


Figure 3.4. Single-release estimates of survival probabilities (y axis) for juvenile steelhead released across the Columbia River at four or five locations from the Washington to the Oregon side of the channel (x axis). The top plot shows survival probabilities for the reach from CR346 to CR325 for four virtual releases of fish formed by regrouping dam-passed fish on the tailrace autonomous node that received the most receptions of a tag code. The middle plot shows reach survival probabilities for R_2 fish (John Day Dam-tailrace releases at CR346) to The Dalles Dam (CR309), and the bottom plot shows reach survivals for R_3 fish released in the John Day Dam tailwater near Celilo, Oregon (CR325), after travel to The Dalles Dam (CR309). Two lines of numbers across survival bars show the number (N) and percent of fish released at each location. Vertical error bars represent the extent of the 95% confidence interval.

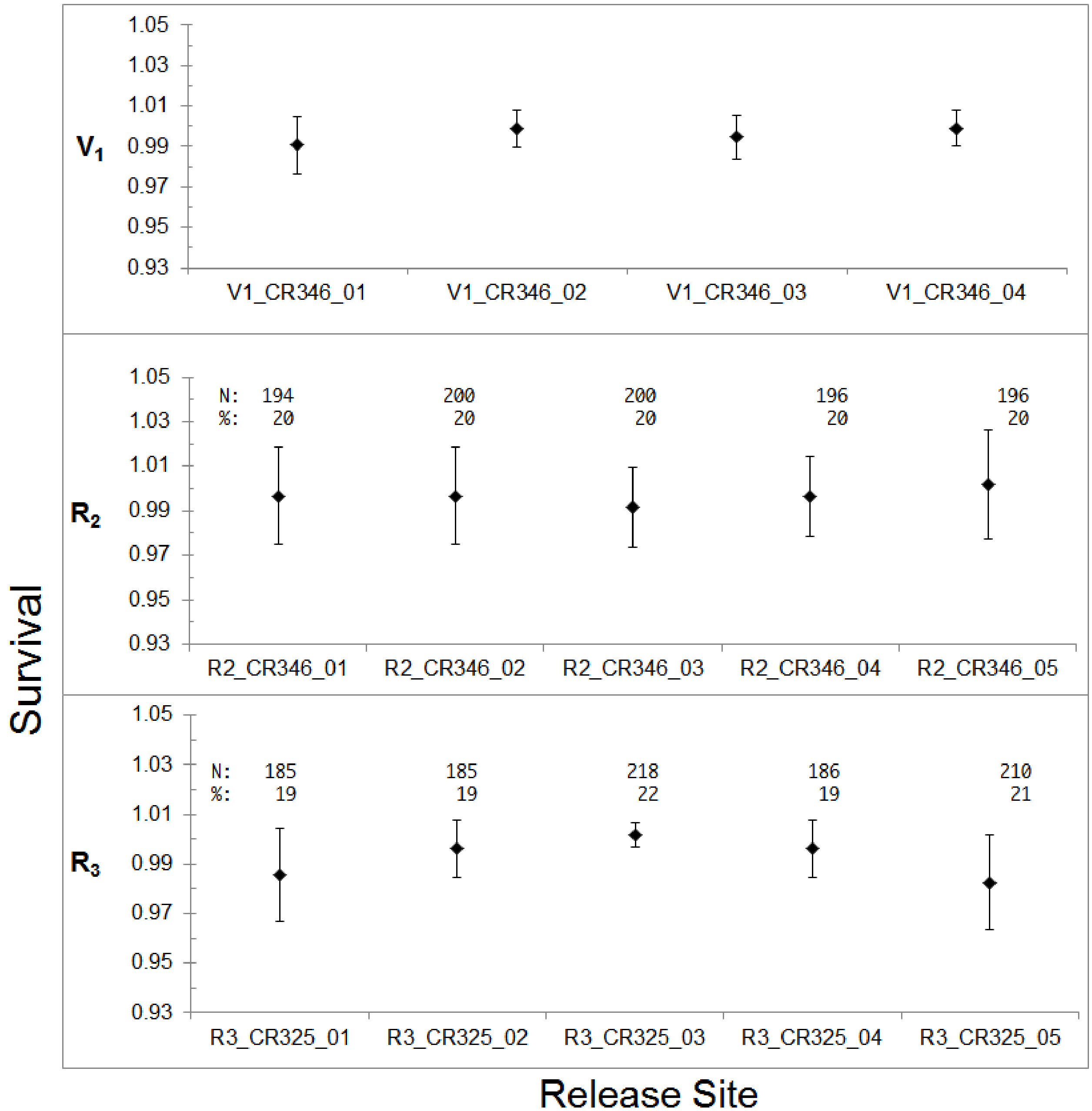


Figure 3.5. Single-release estimates of survival probabilities (y axis) for subyearling Chinook salmon released across the Columbia River at four or five locations from the Washington to the Oregon side of the channel (x axis). The top plot shows survival probabilities for the reach from CR346 to CR325 for four virtual releases of fish formed by regrouping dam-passed fish on the tailrace autonomous node that received the most receptions of a tag code. The middle plot shows reach survival probabilities for R_2 fish (John Day Dam -tailrace releases at CR346) to The Dalles Dam (CR309), and the bottom plot shows reach survivals for R_3 fish released in the John Day Dam tailwater near Celilo, Oregon (CR325), after travel to The Dalles Dam (CR309). Two lines of numbers across survival bars show the number of fish (N) and percent of fish released at each site. Vertical error bars represent the extent of the 95% confidence interval.

3.4.5 Examination of Time In-River on Survivals of Different Release Groups

The virtual release formed from the detections of upriver releases at the face of the dam could result in biased survival estimates if fish from varying upriver release locations had differential downriver survival rates (Figure 2.1). For this reason, reach survivals and cumulative survivals were compared across fish from different upriver release locations. There was no consistent or reproducible evidence to suggest that the amount of time (i.e., distance) in-river had a subsequent effect on downriver survival for either yearling Chinook salmon or juvenile steelhead (Appendix A). There was evidence for subyearling Chinook salmon that the uppermost releases could not be used at Bonneville Dam. However, in constructing the virtual releases at the face of John Day Dam, fish from all available upriver release locations were used in subsequent survival and other parameter estimation.

3.4.6 Fish Size Distributions

Comparison of JSATS-tagged fish with ROR fish sampled at John Day Dam through the Smolt Monitoring Program shows that the length frequency distributions were generally well matched for yearling Chinook salmon (Figure 3.6), steelhead (Figure 3.7), and subyearling Chinook salmon (Figure 3.8). The length distributions for the three yearling Chinook salmon releases (Figure 3.6), the three steelhead releases (Figure 3.7), and the three subyearling Chinook salmon releases (Figure 3.8) also were quite similar. Mean lengths for the acoustic-tagged yearling Chinook salmon were 143.9 mm; for the steelhead, 206.7 mm; and for the subyearling Chinook salmon, 112.9 mm. Mean lengths for yearling Chinook salmon, steelhead, and subyearling Chinook salmon sampled by the Fish Passage Center at the John Day Dam juvenile sampling facility were 143.3 mm, 201.2 mm, and 109.4 mm, respectively. Fish size did not change over the course of the study for yearling Chinook salmon or steelhead (Figure 3.9). For subyearling Chinook salmon, size shifted ever so slightly smaller as the season progressed.

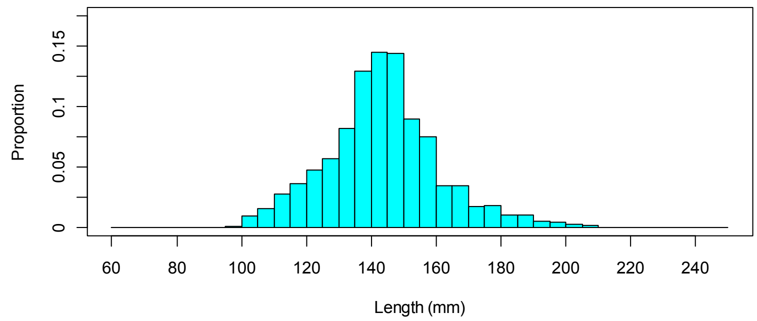
3.4.7 Tag-Life Corrections

During 2012, separate tag lots were used for each fish stock in the spring and summer studies. From each of these tag lots, 98 to 100 tags were systematically sampled to conduct independent tag-life studies. A 3-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 Chinook salmon spring study and the subyearling Chinook salmon summer study Figure 3.10). Average tag lives were 32.2 d, 23.0 d, and 23.3 d for the steelhead, yearling Chinook salmon, and summer subyearling Chinook salmon tag lots, respectively.

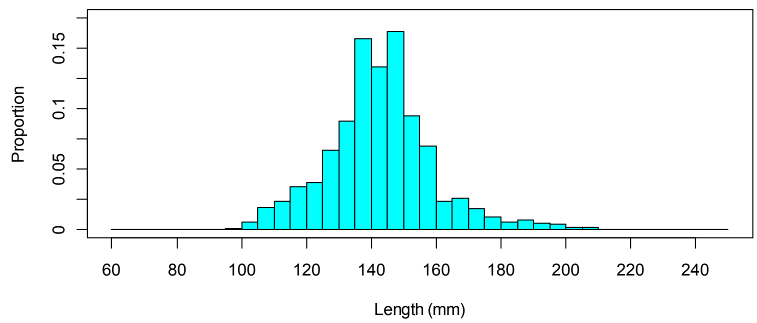
3.4.8 Arrival Distributions

The estimated probability an acoustic tag was active when fish arrived at a downstream detection array depends on the tag-life curve and the distribution of observed travel times for yearling Chinook salmon, steelhead, and subyearling Chinook salmon (Figure 3.11). Examination of the fish arrival distributions to the last detection array used in the survival analyses indicated all fish that arrived had passed through the study area before tag failure became important. These probabilities were calculated by integrating the tag survivorship curve (Figure 3.11) over the observed distribution of fish arrival times (i.e., time from tag activation to arrival). The probabilities of a JSATS tag being active at a downstream detection site were specific to release location and season (Table 3.3). In all cases, the probability a tag was active at a downstream detection site as far as rkm 234 for yearling Chinook salmon was 0.9943 and 1.0000 for juvenile steelhead (Table 3.3). For subyearling Chinook salmon, the probability of an acoustic tag being active at rkm 275 was 0.9979.

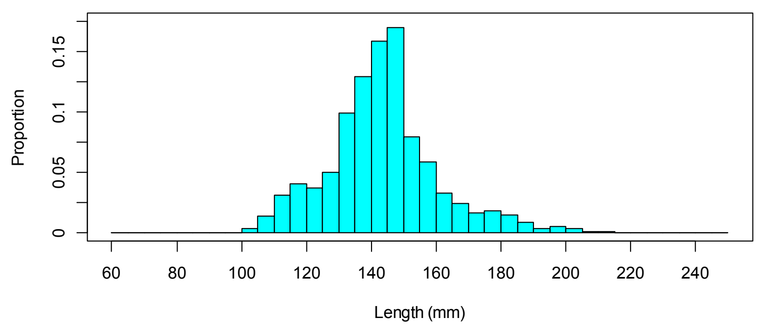
a. John Day Dam (Release V_1)



b. John Day Tailrace (Release R_2)



c. John Day Tailwater (Release R_3)



d. ROR Yearling Chinook Salmon at John Day Dam

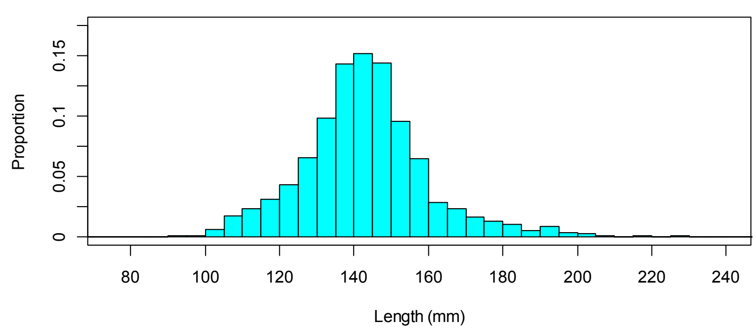
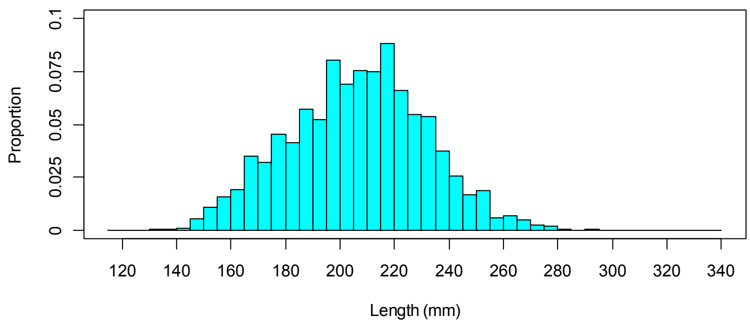
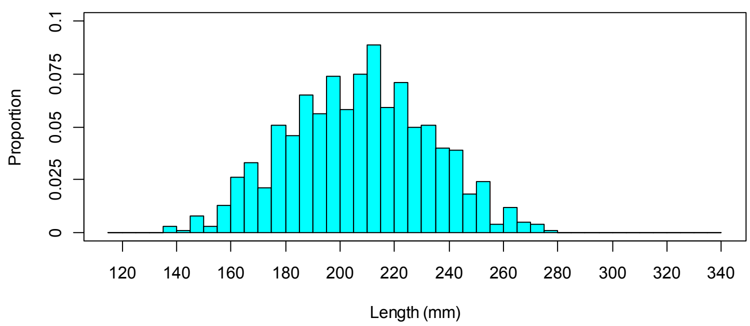


Figure 3.6. Relative frequency distributions for fish lengths (mm) of yearling Chinook salmon used in a) release V_1, b) release R_2, c) release R_3, and d) ROR fish sampled at John Day Dam by the Fish Passage Center in 2012.

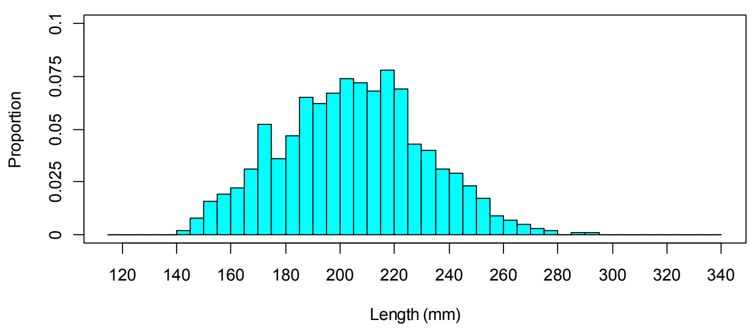
a. John Day Dam (Release V_1)



b. John Day Tailrace (Release R_2)



c. John Day Tailwater (Release R_3)



d. ROR Juvenile Steelhead at John Day Dam

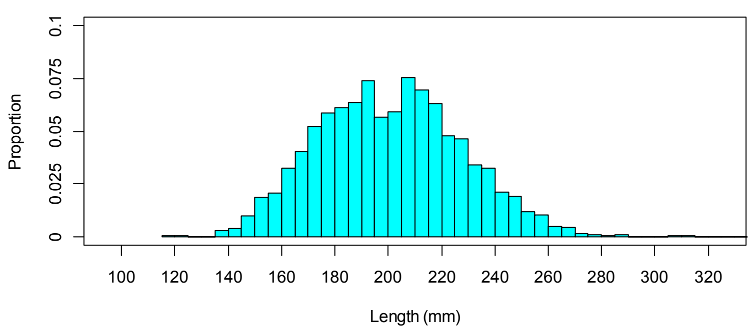
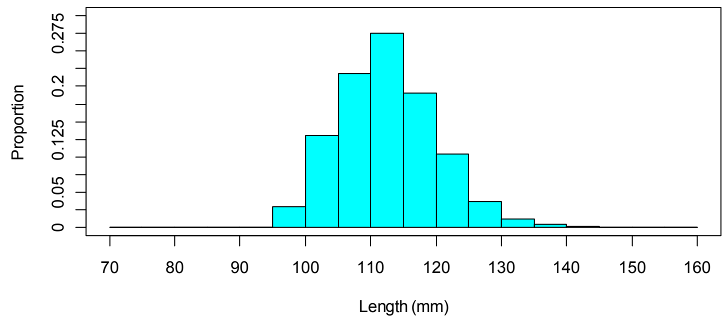
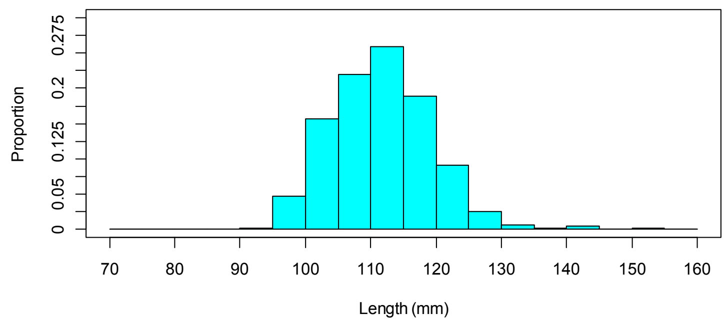


Figure 3.7. Relative frequency distributions for fish lengths (mm) of juvenile steelhead used in a) release V_1, b) release R_2, c) release R_3, and d) ROR fish sampled at John Day Dam by the Fish Passage Center in 2012.

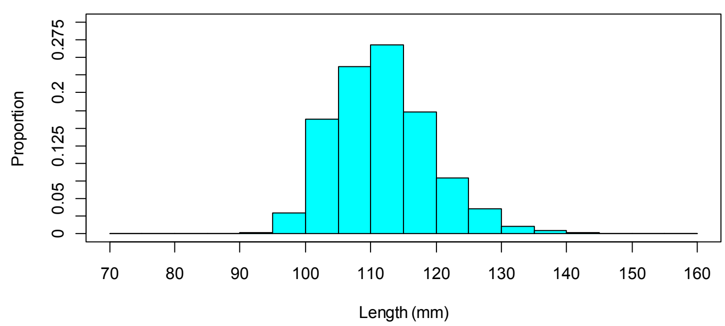
a. John Day Dam (Release V_1)



b. John Day Tailrace (Release R_2)



c. John Day Tailwater (Release R_3)



d. ROR Subyearling Chinook Salmon at John Day Dam

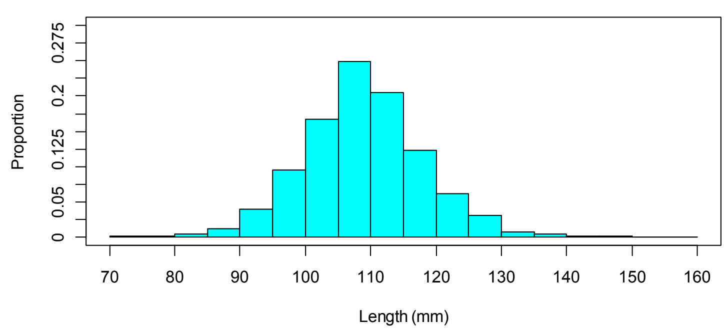


Figure 3.8. Relative frequency distributions for fish lengths (mm) of subyearling Chinook salmon used in a) release V_1, b) release R_2, c) release R_3, and d) ROR fish sampled at John Day Dam by the Fish Passage Center in 2012 during the period of the study.

a. Yearling Chinook salmon

b. Juvenile steelhead

c. Subyearling Chinook salmon

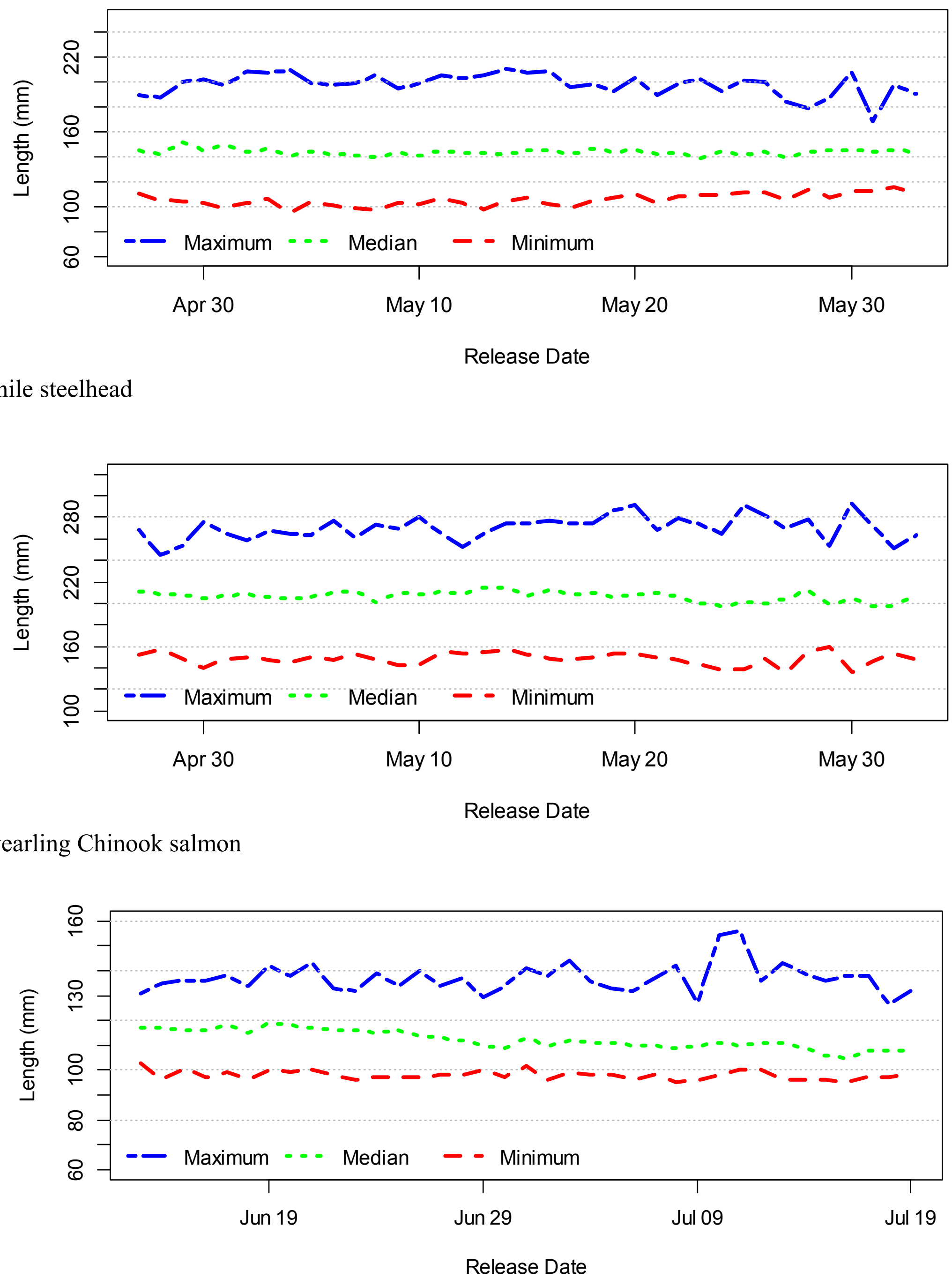
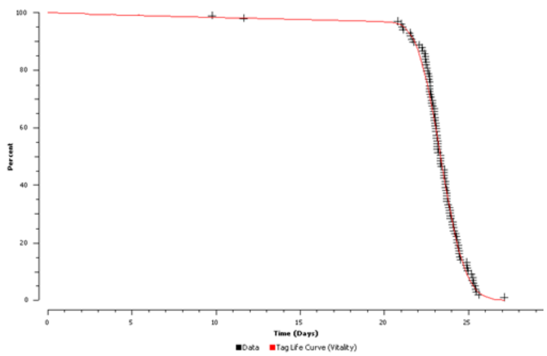
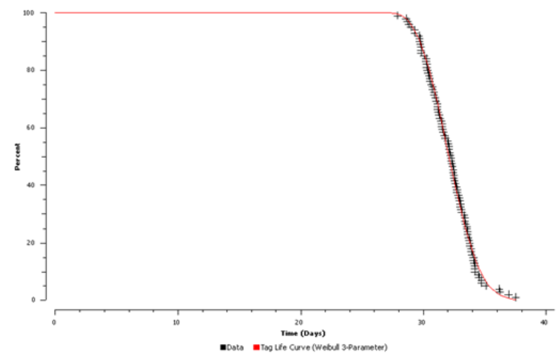


Figure 3.9. Range and median lengths of acoustic-tagged a) yearling Chinook salmon, b) steelhead, and c) subyearling Chinook salmon used over the course of the 2012 survival studies.

a. Spring – Yearling Chinook Salmon



b. Spring – Steelhead



c. Summer – Subyearling Chinook Salmon

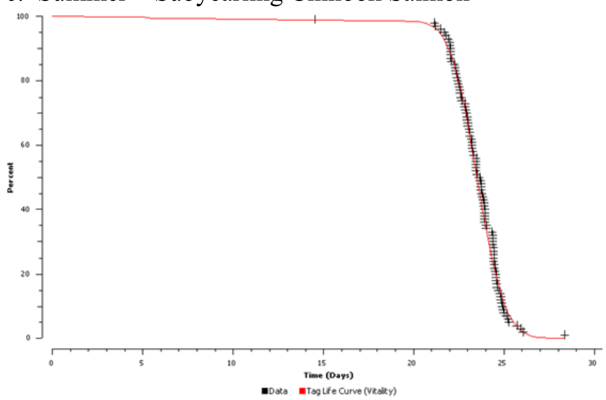
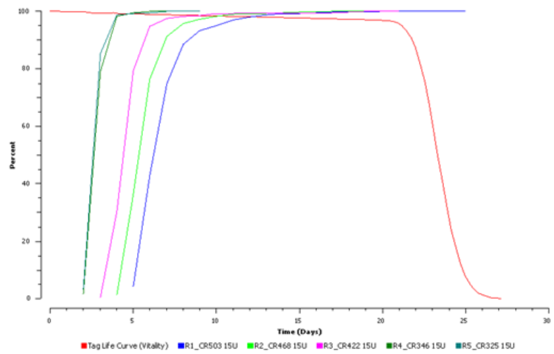
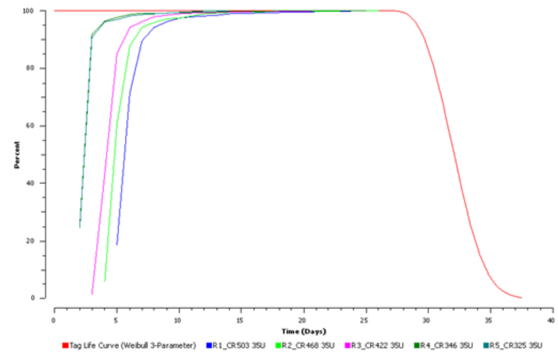


Figure 3.10. Observed time of tag failure and fitted survivorship curves using the vitality model of Li and Anderson (2009) for a) yearling Chinook salmon and c) subyearling Chinook salmon tag lots and a three-parameter Weibull model for b) steelhead.

a. Yearling Chinook Salmon



b. Steelhead



c. Subyearling Chinook Salmon

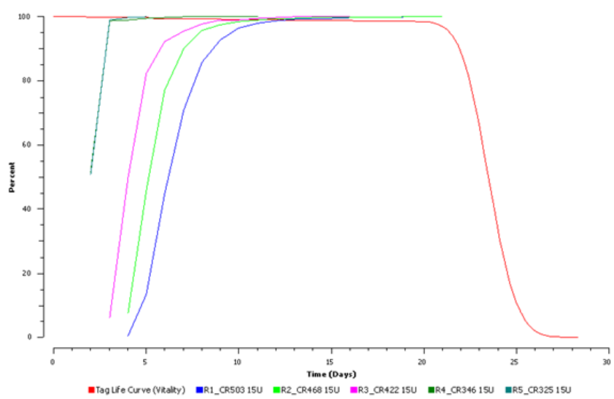


Figure 3.11. Plots of the fitted tag-life survivorship curve and the arrival-time distributions of a) yearling Chinook salmon, b) juvenile steelhead, and c) subyearling Chinook salmon for releases V_1, R_2, and R_3 at the acoustic-detection array located at rkm 234 (spring) or rkm 275 (summer) (Figure 2.1).

Table 3.3. Estimated probabilities (L) of an acoustic tag being active at a downstream detection site for a) yearling Chinook salmon, b) juvenile steelhead, and c) subyearling Chinook salmon by release group. (Standard errors are in parentheses.)

Release Group		Detection Site		
Stock	Rkm	Rkm 325	Rkm 309	Rkm 234
a. Yearling Chinook Salmon				
V_1	503	0.9994 (0.0003)	0.9989 (0.0005)	0.9964 (0.0012)
	468	0.9994 (0.0002)	0.9990 (0.0004)	0.9974 (0.0011)
	422	0.9994 (0.0003)	0.9989 (0.0005)	0.9971 (0.0012)
R_2	346	--	0.9961 (0.0017)	0.9943 (0.0024)
R_3	325	--	0.9963 (0.0016)	0.9944 (0.0024)
b. Steelhead				
V_1	503	1.0000 (<0.0001)	1.0000 (<0.0001)	1.0000 (<0.0001)
	468	1.0000 (<0.0001)	1.0000 (<0.0001)	1.0000 (<0.0001)
	422	1.0000 (<0.0001)	1.0000 (<0.0001)	1.0000 (<0.0001)
R_2	346	--	1.0000 (<0.0001)	1.0000 (<0.0001)
R_3	325	--	1.0000 (<0.0001)	1.0000 (<0.0001)
c. Subyearling Chinook Salmon				
V_1	503	0.9997 (0.0002)	0.9995 (0.0005)	0.9992 (0.0009)
	468	0.9997 (0.0002)	0.9995 (0.0005)	0.9992 (0.0009)
	422	0.9997 (0.0002)	0.9995 (0.0005)	0.9992 (0.0009)
R_2	346	--	0.9983 (0.0019)	0.9979 (0.0023)
R_3	325	--	0.9983 (0.0019)	0.9979 (0.0023)

3.4.9 Downstream Mixing

To help induce downstream mixing of the release groups, the R_2 release was 6 h before the R_3 release. The same release schedule was used for both the spring and summer studies. Plots of the arrival timing of the various release groups at downstream detection sites indicate reasonable mixing for yearling Chinook salmon (Figure 3.12), steelhead (Figure 3.13), and subyearling Chinook salmon (Figure 3.14). The arrival modes for releases R_2 and R_3 were nearly synchronous in all cases.

a. rkm 309 b. rkm 234

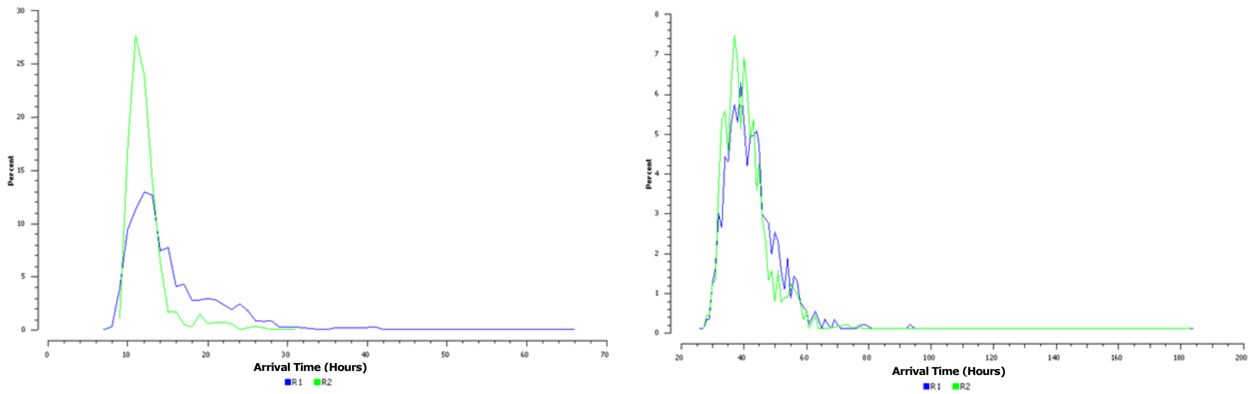


Figure 3.12. Frequency distribution plots of downstream arrival timing (expressed as percentages) for yearling Chinook salmon releases R_2 and R_3 at detection arrays located at a) rkm 309 and b) rkm 234 (see Figure 2.1). All times adjusted relative to the release time of R_2.

a. rkm 309 b. rkm 234

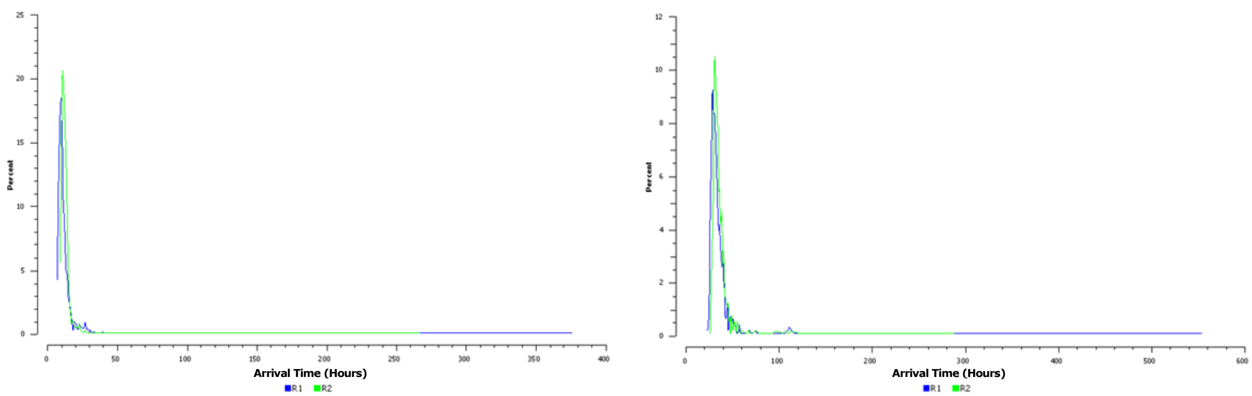


Figure 3.13. Frequency distribution plots of downstream arrival timing (expressed as percentages) for steelhead releases R_2 and R_3 at detection arrays located at a) rkm 309 and b) rkm 234 (see Figure 2.1). All times adjusted relative to the release time of R_2.

a. rkm 309 b. rkm 275

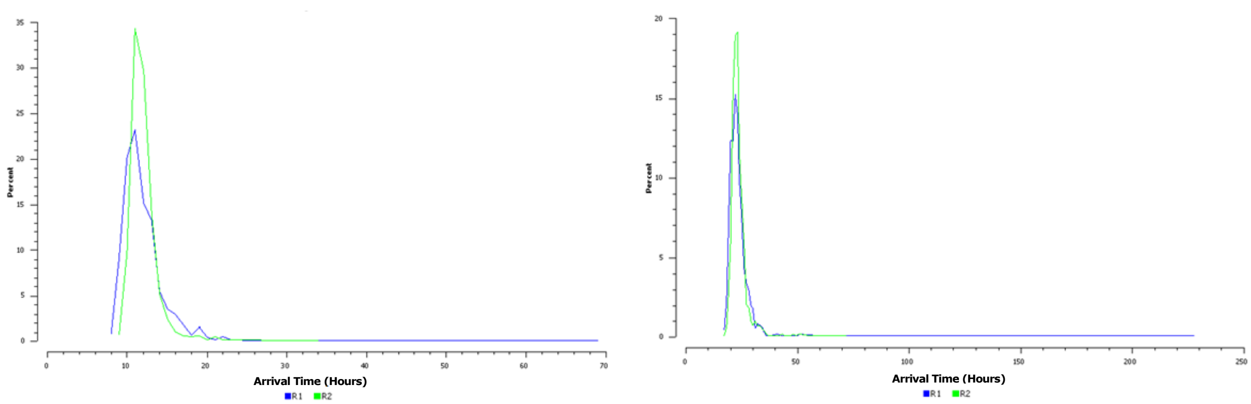


Figure 3.14. Frequency distribution plots of downstream arrival timing (expressed as percentages) for subyearling Chinook salmon releases R_2 and R_3 at detection arrays located at a) rkm 309 and b) rkm 275 (see Figure 2.1). All times adjusted relative to the release time of R_2.

3.5 Survival and Passage Performance

Survival and passage performance metrics include dam passage survival, forebay-to-tailrace passage survival, forebay residence time, tailrace to egress time, SPE, and FPE.

3.5.1 Dam Passage Survival

The high river flows in 2012 disrupted the planned 30% and 40% spill treatments. Season-wide survival estimates were calculated over the prevailing spill conditions.

3.5.1.1 Yearling Chinook Salmon

The estimate of season-wide dam passage survival for yearling Chinook salmon during spring 2012 was calculated to be

$$\hat{S}_{\text{Dam}} = \frac{0.9627}{\left(\frac{0.9848}{0.9896}\right)} = \frac{0.9627}{0.9951} = 0.9673$$

with an estimated standard error of $\widehat{\text{SE}} = 0.0065$ (Table 3.4). This survival estimate exceeds the 2008 BiOp standard of ≥0.96 and with a standard error smaller than required (i.e., SE ≤ 0.015). Note the single-release survival from the virtual-release group (V_1) to rkm 325 (i.e., including 24 km of The Dalles reservoir) also exceeds the 2008 BiOp standard (0.9627) with a standard error of $\widehat{\text{SE}} = 0.0033$.

Table 3.4. Survival, detection, and λ parameters for final model used to estimate dam passage survival for yearling Chinook salmon during the season-wide spring study (30 April to 2 June 2012). Standard errors (SE) based on both the inverse hessian matrix and bootstrapping for key parameters (†) and only the inverse hessian matrix for associated parameters (*).

	CR349 to 325		CR325 to 309		Release to CR309	
Release	$\hat{S}$	$\widehat{\text{SE}}$ †	$\hat{S}$	$\widehat{\text{SE}}$ *	$\hat{S}$	$\widehat{\text{SE}}$ †
V_1	0.9627	0.0033	0.9904	0.0018	---	---
R_2	---	---	---	---	0.9848	0.0046
R_3	---	---	---	---	0.9896	0.0040

	CR325		CR309	
Release	$\hat{p}$	$\widehat{\text{SE}}$ *	$\hat{p}$	$\widehat{\text{SE}}$ *
V_1	0.9997	0.0003	0.9986	0.0007
R_2	---	---	1.0000	<0.0001
R_3	---	---	1.0000	<0.0001

	CR309–234	
Release	$\hat{\lambda}$	$\widehat{\text{SE}}$ *
V_1	0.9218	0.0048
R_2	0.9291	0.0083
R_3	0.9171	0.0089

3.5.1.2 Steelhead

The estimate of season-wide dam passage survival for steelhead in spring 2012 was calculated to be

$$\hat{S}_{\text{Dam}} = \frac{0.9744}{\left(\frac{0.9781}{0.9752}\right)} = \frac{0.9744}{1.0030} \overset{\text{set}}{=} 0.9744$$

Because the paired release of R_2 and R_3 estimated survival between the John Day tailrace (rkm 346) and rkm 325 was >1, the recommended survival estimate for John Day Dam is the conservative estimate for single-release survival through the dam based on the virtual-release group where $\hat{S}_{\text{Dam}} \geq \hat{S}_1$ = 0.9744 with a standard error of $\widehat{\text{SE}}$ =0.0028 (Table 3.5).

Table 3.5. Survival, detection, and λ parameters for final model used to estimate dam passage survival for steelhead during the season-wide spring study (30 April to 2 June 2012). Standard errors (SE) based on both the inverse hessian matrix and bootstrapping for key parameters (†) and only the inverse hessian matrix for associated parameters (*).

	CR349 to 325		CR325 to 309		Release to CR309	
Release	$\hat{S}$	$\widehat{\text{SE}}$ †	$\hat{S}$	$\widehat{\text{SE}}$ *	$\hat{S}$	$\widehat{\text{SE}}$ †
V_1	0.9744	0.0028	0.9954	0.0012	---	---
R_2	---	---	---	---	0.9781	0.0046
R_3	---	---	---	---	0.9752	0.0049

	CR325		CR309	
Release	$\hat{p}$	$\widehat{\text{SE}}$ *	$\hat{p}$	$\widehat{\text{SE}}$ *
V_1	0.9997	0.0003	0.9983	0.0008
R_2	---	---	0.9989	0.0011
R_3	---	---	0.9978	0.0016

	CR309–234	
Release	$\hat{\lambda}$	$\widehat{\text{SE}}$ *
V_1	0.9349	0.0044
R_2	0.9498	0.0070
R_3	0.9270	0.0083

3.5.1.3 Subyearling Chinook Salmon

The estimate of season-wide dam passage survival for subyearling Chinook salmon during summer 2012 was calculated to be

$$\hat{S}_{\text{Dam}} = \frac{0.9414}{\left(\frac{0.9966}{0.9925}\right)} = \frac{0.9414}{1.0041} \stackrel{\text{set}}{=} 0.9414$$

Because the paired release of R_2 and R_3 estimated survival between the John Day tailrace (rkm 346) and rkm 325 was >1, the recommended survival estimate for John Day Dam is the conservative estimate for single-release survival through the dam based on the virtual-release group where $\hat{S}_{\text{Dam}} > \hat{S}_1$ = 0.9414 with a standard error of $\widehat{\text{SE}}$ = 0.0031 (Table 3.6).

In all three cases of yearling Chinook salmon, steelhead, and subyearling Chinook salmon, the R_2–R_3 paired-release estimates of survival between the tailrace and rkm 325 were very similar, with values of 0.9951, 1.0030, and 1.0031, respectively. The average of these values is 1.0007.

In all of the above analyses, the full model that estimated unique survival and capture probabilities for each release group was used in the calculation of dam passage survival. Precision was more than adequate (i.e., $\widehat{\text{SE}} \leq$ 0.015), so there was no need to attempt to find a more parsimonious model to improve precision. In this way, both precision and robustness were preserved.

Table 3.6. Survival, detection, and λ parameters for final model used to estimate dam passage survival for subyearling Chinook during the season-wide spring study (17 June to 19 July 2012). Standard errors (SE) based on both the inverse hessian matrix and bootstrapping for key parameters (†) and only the inverse hessian matrix for associated parameters (*).

	CR349 to 325		CR325 to 309		Release to CR309	
Release	$\hat{S}$	$\widehat{SE}^{\dagger}$	$\hat{S}$	$\widehat{SE}^{*}$	$\hat{S}$	$\widehat{SE}^{\dagger}$
V_1	0.9414	0.00313	0.9906	0.0013	---	---
R_2	---	---	---	---	0.9966	0.0033
R_3	---	---	---	---	0.9925	0.0039

	CR325		CR309	
Release	$\hat{p}$	$\widehat{SE}^{*}$	$\hat{p}$	$\widehat{SE}^{*}$
V_1	0.9996	0.0003	0.9992	0.0004
R_2	---	---	1.0000	<0.0001
R_3	---	---	1.0000	<0.0001

	CR309–275	
Release	$\hat{\lambda}$	$\widehat{SE}^{*}$
V_1	0.9418	0.0032
R_2	0.9371	0.0078
R_3	0.9480	0.0071

3.5.2 Forebay-to-Tailrace Passage Survival

The estimates of forebay-to-tailrace passage survival were calculated analogously to that of dam passage survival except the virtual-release group (V_1) was composed of fish known to have arrived at the forebay (i.e., detection array rkm 351, Figure 2.1) rather than at the dam face. These season-wide survival estimates were based on all release data across the season, regardless of spill conditions. Using the same statistical model as was used in estimating dam passage survival, forebay-to-tailrace survival for yearling Chinook salmon was

$$\hat{S}_{\text{forebay-to-tailrace}} = 0.9660(0.0065)$$

for steelhead,

$$\hat{S}_{\text{forebay-to-tailrace}} = 0.9687(0.0030)$$ [1]

and for subyearling Chinook salmon,

$$\hat{S}_{\text{forebay-to-tailrace}} = 0.9390\ (0.0032)$$ [1]

[1] Based on the single release from V_1 only.

3.5.3 Forebay Residence Time

The forebay residence time was calculated from the first detection at the forebay BRZ array to the last detection at the dam (2 rkm). For yearling Chinook salmon, the mean forebay residence time was estimated to be 2.50 h ($\widehat{\text{SE}}$ = 0.14), for steelhead it was estimated to be 5.79 h ($\widehat{\text{SE}}$ = 0.33), and for subyearling Chinook salmon it was estimated to be 2.91 h ($\widehat{\text{SE}}$ = 0.26) (Figure 3.15, Table 3.7). The distribution of forebay residence times indicates the modes were 1.0 h for yearling Chinook salmon, 1.5 h for steelhead, and 1.0 h for subyearling Chinook salmon. Median residence times were 1.15 h, 2.39 h, and 1.02 h for yearling Chinook salmon, steelhead, and subyearling Chinook salmon, respectively (Table 3.7).

3.5.4 Tailrace Egress Time

The tailrace egress time was calculated based on the time from the last detection of fish at the double array at the face of John Day Dam to the last detection at the BRZ tailrace array (Figure 3.16). Mean tailrace egress time for yearling Chinook salmon was estimated to be $\bar{t}$ = 2.80 h ($\widehat{\text{SE}}$ = 0.28). For juvenile steelhead, mean tailrace egress time was estimated to be $\bar{t}$ = 6.22 h ($\widehat{\text{SE}}$ = 0.48). Mean tailrace egress time for subyearling Chinook salmon was estimated to be $\bar{t}$ = 2.95 h ($\widehat{\text{SE}}$ = 0.16). Median egress times were 0.50, 0.46, and 0.48 h for yearling Chinook salmon, steelhead, and subyearling Chinook salmon, respectively (Table 3.7). The distribution of tailrace egress times indicates the modes were 0.5 h for yearling Chinook salmon, steelhead, and subyearling Chinook salmon (Figure 3.16).

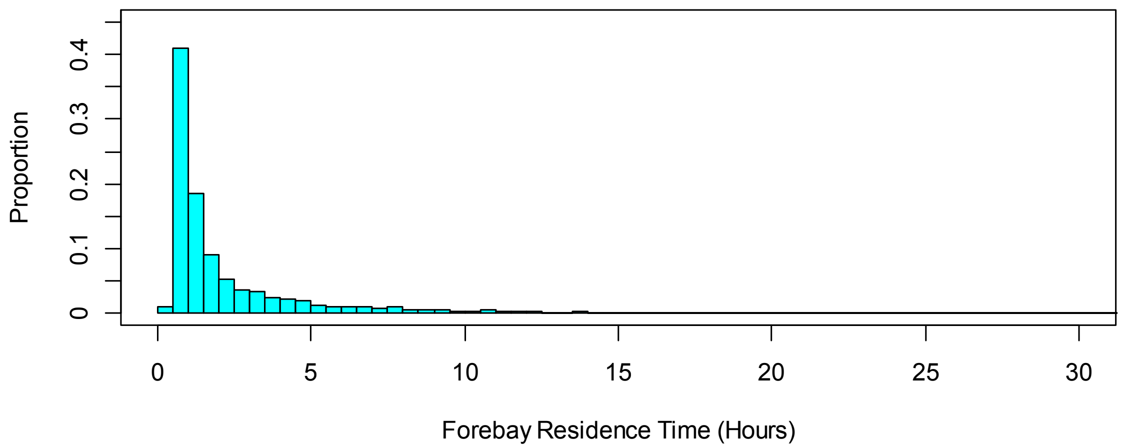
3.5.5 Spill Passage Efficiency

Spill passage efficiency is defined as the fraction of the fish that passed through a hydroproject by the spillway, including the temporary spill weirs. The double-detection array at the face of John Day Dam was used to identify and track fish as they entered the forebay. Given that the combined detection efficiency of double array was 100% for each run of fish passing each route, we were able to use observed counts of fish entering the various routes at John Day Dam to estimate SPE based on a binomial sampling model. For yearling Chinook salmon, SPE = 0.7456 (0.0075); for juvenile steelhead, SPE = 0.7452 (0.0076); and for subyearling Chinook salmon, SPE = 0.6962 (0.0061).

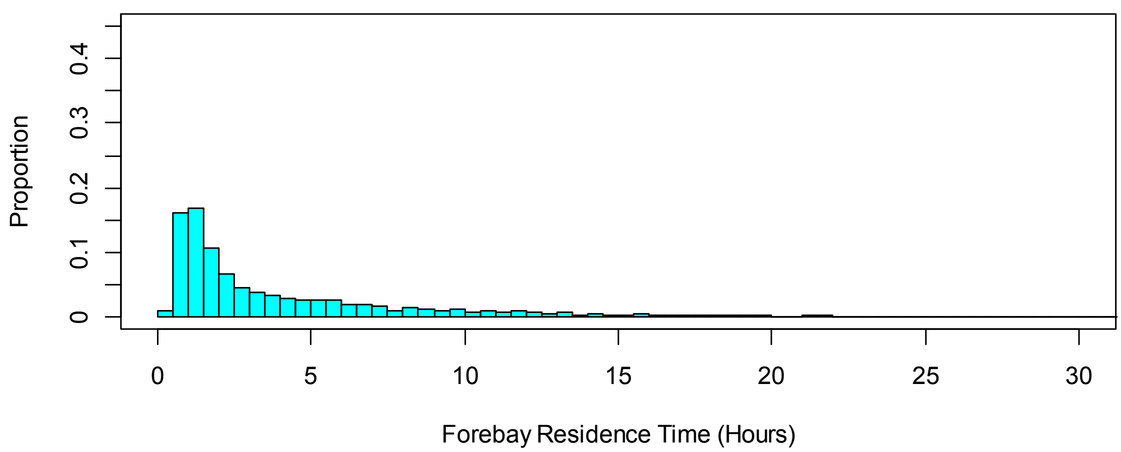
3.5.6 Fish Passage Efficiency

Fish passage efficiency, called SPE in the Fish Accords, is the fraction of the fish that passed through non-turbine routes at the dam. As with SPE, the double-detection array at the face of John Day Dam was used to identify and track fish as they entered the dam. Given 100% combined detection efficiency by the double array for each route and run of fish, we were able to use observed counts of fish entering the various routes at John Day Dam were used to estimate FPE based on a binomial sampling model. For yearling Chinook salmon at John Day Dam in 2012, FPE is estimated to be FPE = 0.9272 (0.0045); for juvenile steelhead, FPE = 0.9695 (0.0030); and for subyearling Chinook salmon, FPE = 0.8585 (0.0046).

a. Yearling Chinook salmon



b. Steelhead



c. Subyearling Chinook salmon

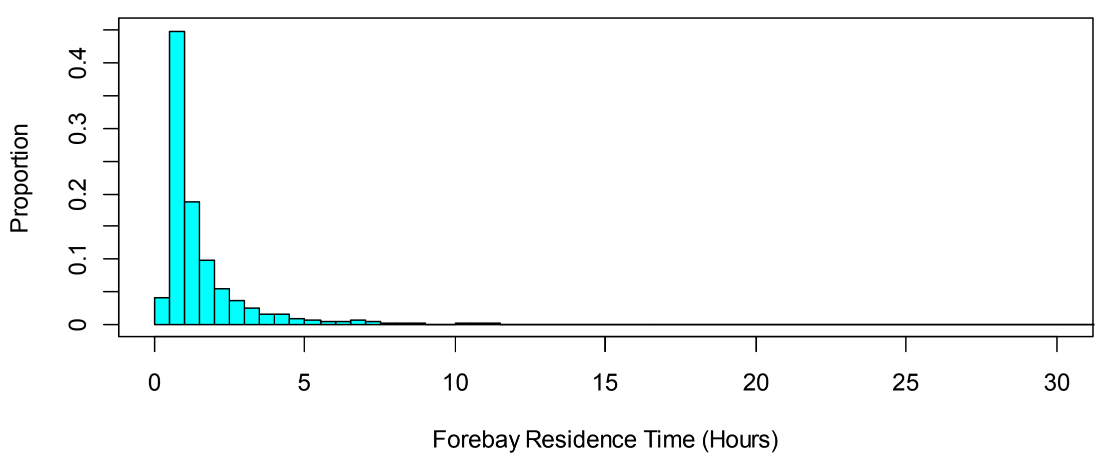
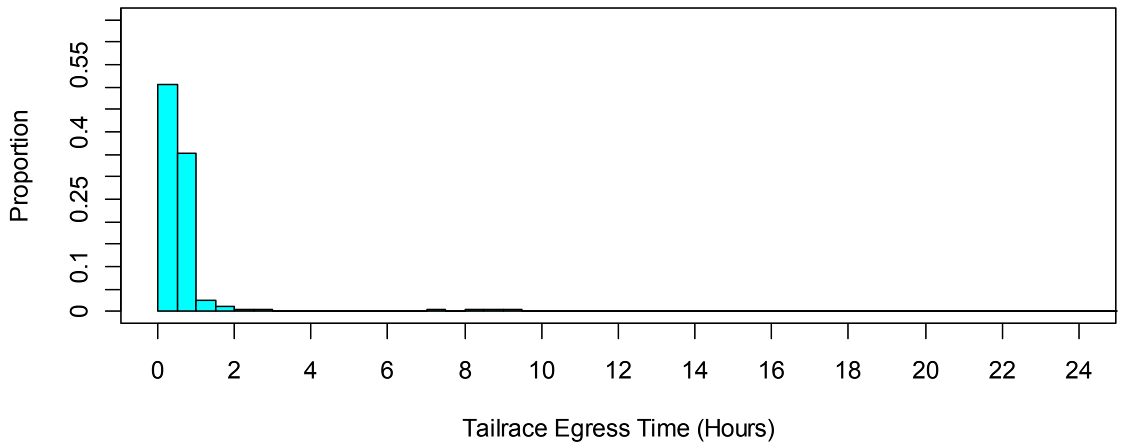


Figure 3.15. Distribution of forebay residence times for a) yearling Chinook salmon, b) steelhead, and c) subyearling Chinook salmon at John Day Dam, 2012.

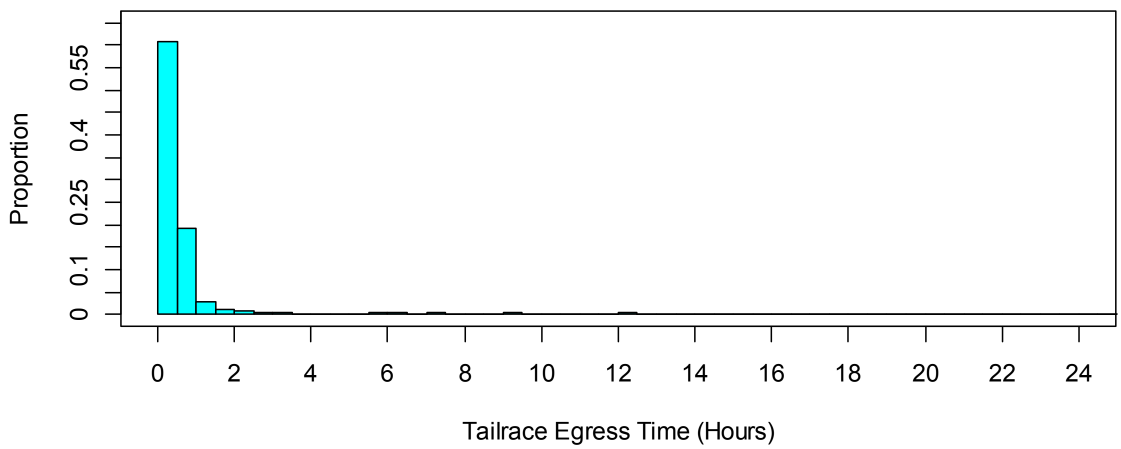
Table 3.7. Estimated mean and median forebay residence times (h) and mean and median tailrace egress times for yearling Chinook salmon, steelhead, and subyearling Chinook salmon at John Day Dam in 2012. (Standard errors in parentheses.)

Performance Measure	Yearling Chinook Salmon	Steelhead	Subyearling Chinook Salmon
Forebay Residence Time			
• Mean	2.50 (0.14)	5.79 (0.33)	2.91 (0.26)
• Median	1.15	2.39	1.02
Tailrace Egress Time			
• Mean	2.80 (0.28)	6.22 (0.48)	2.95 (0.16)
• Median	0.50	0.46	0.48
•			

a. Yearling Chinook salmon



b. Steelhead



c. Subyearling Chinook salmon

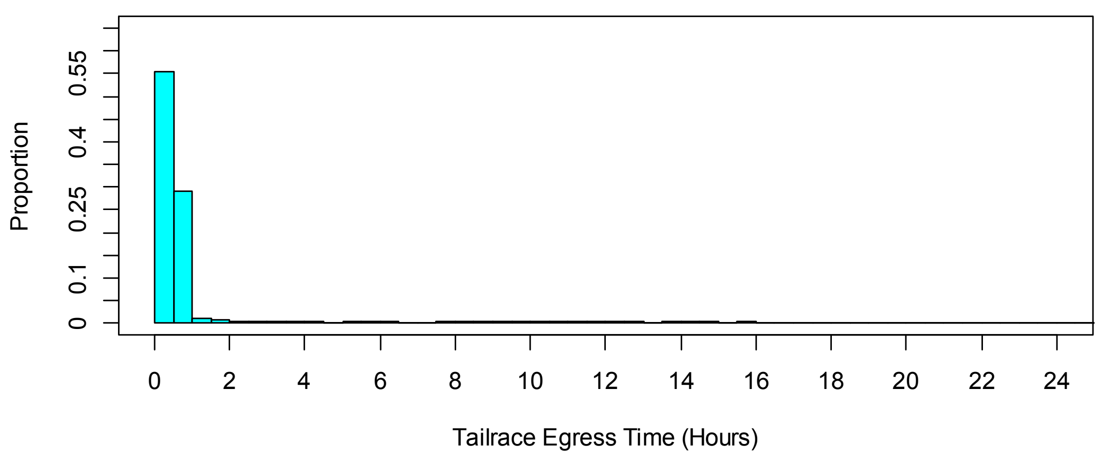


Figure 3.16. Distribution of tailrace egress times for a) yearling Chinook salmon, b) steelhead, and c) subyearling Chinook salmon at John Day Dam, 2012.

4.0 Discussion

The discussion describes the conduct of the 2012 study, study performance, and compares the 2012 estimates with compliance results in 2011 at John Day Dam.

4.1 Study Conduct

The many tests of assumptions (Appendix A) found the acoustic-tag study achieved good downstream mixing, with adequate tag life and no evidence of adverse tagger effects. There was no evidence that delayed tagging/handling effects were present that might affect the performance of the V_1 release at the face of the dam. These results suggest the assumptions of the virtual/paired-release model were fulfilled, permitting valid estimation of dam passage survival and related parameters.

Despite not being able to compare compliance under 30% and 40% spill conditions, the season-wide estimates of dam passage survival in 2012 for yearling and subyearling Chinook salmon and steelhead met the 2008 BiOp standards for point estimates and adequate precision.

4.2 Study Performance

The 2012 spring and summer compliance studies at John Day Dam were interrupted by high flow conditions that precluded conducting the 30% and 40% spill blocks. Early parts of the season were slightly above 40%, while the remainder of the spring and summer studies fluctuated between 30–40% (Figure 3.1). No attempt was made to tease out days near the 30% and 40% spill targets. Instead, a single season-wide estimate of dam passage survival was calculated for each fish stock.

Results of the compliance studies suggest that BiOp survival standards at John Day Dam can be met under prevailing conditions with spills in the range of 30–40%. Ultimate acceptance of the 2012 study results at John Day Dam will depend on whether the fisheries community considers the 2012 flow and spill conditions to be nominal.

4.3 Summary of Compliance Study Results

The compliance studies in 2012 were the second year of investigations at John Day Dam. During 2011, the first year of investigations, compliance studies were conducted in spring on yearling Chinook salmon and steelhead. To date, five compliance studies have been performed at John Day Dam (Table 4.1). There have now been two compliance studies of yearling Chinook salmon and steelhead and one study of subyearling Chinook salmon. All five studies met the 2008 BiOp standards for dam passage survival and associated standard errors.

Table 4.1. Summary of estimates of dam passage survival at John Day Dam from the 2011 and 2012 JSATS compliance studies. (Standard errors in parentheses.)

Fish Stock	Year of Study	
	2011	2012
Yearling Chinook Salmon	0.9678 (0.0071)	0.9673 (0.0065)
Steelhead	0.9867 (0.0061)	0.9744 (0.0028)
Subyearling Chinook Salmon		0.9414 (0.0031)

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Appendix A

Tests of Assumptions

Appendix A

Test of Assumptions

A.1 Tagger Effects

A.1.1 Spring Study

Data from all five release locations in the two-dam study were examined for tagger effects. This was done to maximize the statistical power to detect tagger effects that might have influenced either or both of the McNary and John Day dam studies.

To minimize any tagger effects that might go undetected, tagger effort should be balanced across release locations and within replicates. A total of eight taggers participated in tagging the yearling Chinook salmon and steelhead during the spring study. Tagger 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 A.1).

Tagger effort was examined within each of the 32 replicate releases conducted over the course of the spring study (Table A.2, Table A.3). Tagger 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, tagger effort was conditionally balanced within the individual project releases (i.e., R_1–R_3, R_4–R_5) (Table A.2, Table A.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 A.1.

To test for tagger 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 A.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 to the results. No particular tagger had fish with consistently lower survivals. All taggers had fish releases with the highest and lowest reach survivals. For some unknown reason, there is more heterogeneity among the survival estimates across taggers than expected by binomial change alone, but no identifiable below average taggers were observed. For this reason, all fish tagged by all taggers were included in the subsequent survival analyses.

Table A.1. Numbers of yearling Chinook salmon and steelhead tagged by each staff member by release location (i.e., R_1, R_2, ...). Chi-square tests of homogeneity were not significant for a) yearling Chinook salmon or b) steelhead.

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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.3. (contd)

m. Replicate 13

Release	A	B	D	F	*P*-value
R1_CR503	15	10	10	9	0.9976
R2_CR468	12	8	10	8	
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	0.9999
R2_CR468	0	0	0	0	12	8	10	8	
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	0.9691
R2_CR468	0	0	0	0	11	8	10	9	
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	0.9361
R2_CR468	0	0	0	0	8	10	11	9	
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 A.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 A.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 A.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 A.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 A.4. Estimates of reach survival and cumulative survival for a) yearling Chinook salmon and b) steelhead, along with *P*-values associated with the *F*-tests of homogeneous survival across fish tagged by different staff members.

a. Yearling Chinook salmon

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 A.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 A.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 A.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 A.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 A.4. (contd)

b. Steelhead

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 A.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 A.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 A.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 A.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	

A.1.2 Summer Study

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

Tagger effort was balanced across the nine release locations and eight taggers (Table A.5) $\left(P\left(\chi^2_{56} \geq 4.8194\right) = 1\right)$. Tagger effort was also examined within each of the 32 replicate releases (Table A.6). Tagger 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 A.7). These conditionally balanced designs within the individual replicates and the balance of taggers across projects resulted in the overall balanced design.

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

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

Table A.5. Numbers of subyearling Chinook salmon tagged by each staff member by release location (i.e., R_1, R_2, . . .). Chi-square test of homogeneity was not significant $\left(P\left(\chi^2_{56} \geq 4.8194\right) = 1\right)$.

	Tagger							
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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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.

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 A.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 A.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 A.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 A.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 A.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 A.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 A.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 A.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	

A.2 Examination of Delayed Handling Effects

A.2.1 Spring Study

The purpose of these tests was to assess whether downstream reach survivals were affected by how far upstream yearling and subyearling Chinook salmon and juvenile steelhead were released. Results were used to determine which release groups were used in the construction of virtual-release groups at John Day Dam.

One of the 10 tests (i.e., 10%) of the reach survival comparisons was significant at $\alpha = 0.10$ (Table A.8). In many instances, upriver releases of fish had equal or higher survival than fish released further downriver. Comparisons of cumulative survivals in reaches common to multiple release groups found 1 of 18 tests significant at $\alpha = 0.10$ (i.e., 5.6%) (Table A.9). Once again, there was no relationship between time in-river and cumulative downriver survival.

Consequently, no evidence was found in the spring studies that would indicate delayed handling/tag effects. Therefore, fish from releases $R_{1,}$ . . ., R_3 were used in forming the virtual-release group at John Day Dam.

Table A.8. Comparison of reach survivals between tag releases from different upstream locations for a) yearling Chinook salmon and b) steelhead during the 2012 spring JSATS survival study in the Columbia River. Newly released and previously released fish were not compared within a reach (shaded).

a. Yearling Chinook salmon

Reach	CR503		CR468		CR422		CR346		CR325		*P* (*F*-test)
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	
Release to CR422	0.9060	0.0085	0.9288	0.0082							
CR422 to CR349	0.9506	0.0063	0.9743	0.0052	0.9498	0.0070					0.0037
CR349 to CR325	0.9712	0.0049	0.9568	0.0063	0.9582	0.0060	1.0004	0.0024			0.1500
CR325 to CR309	0.9911	0.0029	0.9908	0.0031	0.9894	0.0032	0.9844	0.0040	0.9896	0.0041	0.4547
CR309 to CR234	0.9357	0.0076	0.9434	0.0075	0.9414	0.0074	0.9474	0.0074	0.9313	0.0083	0.5960
CR234 to CR156 (λ)	0.9271	0.0083	0.9367	0.0080	0.9274	0.0084	0.9530	0.0071	0.9369	0.0082	0.1412

b. Steelhead

Reach	CR503		CR468		CR422		CR346		CR325		*P* (*F*-test)
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	
Release to CR422	0.8521	0.0095	0.9149	0.0081							
CR422 to CR349	0.9489	0.0064	0.9335	0.0075	0.9366	0.0070					0.1183
CR349 to CR325	0.9724	0.0049	0.9783	0.0046	0.9685	0.0052	0.9860	0.0037			0.3637
CR325 to CR309	0.9984	0.0013	0.9950	0.0022	0.9926	0.0026	0.9940	0.0025	0.9751	0.0049	0.2897
CR309 to CR234	0.9574	0.0063	0.9523	0.0069	0.9645	0.0058	0.9599	0.0064	0.9459	0.0074	0.3157
CR234 to CR156 (λ)	0.9054	0.0092	0.9107	0.0094	0.9124	0.0089	0.9300	0.0084	0.9237	0.0088	0.2778

Table A.9. Comparison of cumulative survivals between tag releases from different upstream locations for a) yearling Chinook salmon and b) steelhead during the 2012 spring JSATS survival study in the Columbia River.

a. Yearling Chinook salmon

	CR503		CR468		
Reach	Est	SE	Est	SE	*P* (*F*-test)
CR422 to CR349	0.9506	0.0063	0.9743	0.0051	0.0035
CR422 to CR325	0.9232	0.0078	0.9322	0.0078	0.4146
CR422 to CR309	0.9149	0.0082	0.9236	0.0083	0.4559
CR422 to CR234	0.8561	0.0104	0.8714	0.0105	0.3005

	CR503		CR468		CR422		
Reach	Est	SE	Est	SE	Est	SE	*P* (*F*-test)
CR349 to CR325	0.9712	0.0049	0.9568	0.0063	0.9581	0.0060	0.1482
CR349 to CR309	0.9625	0.0056	0.9480	0.0069	0.9480	0.0067	0.1831
CR349 to CR234	0.9005	0.0090	0.8943	0.0096	0.8925	0.0095	0.8182

	CR503		CR468		CR422		CR346		
Reach	Est	SE	Est	SE	Est	SE	Est	SE	*P* (*F*-test)
CR325 to CR309	0.9911	0.0029	0.9908	0.0031	0.9894	0.0032	0.9844	0.0040	0.4547
CR325 to CR234	0.9273	0.0080	0.9346	0.0079	0.9315	0.0079	0.9325	0.0082	0.9316

b. Steelhead

	CR503		CR468		
Reach	Est	SE	Est	SE	*P* (*F*-test)
CR422 to CR349	0.9489	0.0064	0.9335	0.0075	0.1183
CR422 to CR325	0.9235	0.0077	0.9132	0.0085	0.3692
CR422 to CR309	0.9220	0.0078	0.9087	0.0087	0.2550
CR422 to CR234	0.8827	0.0095	0.8654	0.0104	0.2194

	CR503		CR468		CR422		
Reach	Est	SE	Est	SE	Est	SE	*P* (*F*-test)
CR349 to CR325	0.9724	0.0049	0.9783	0.0046	0.9685	0.0052	0.3637
CR349 to CR309	0.9708	0.0050	0.9735	0.0051	0.9613	0.0058	0.2333
CR349 to CR234	0.9303	0.0078	0.9271	0.0083	0.9272	0.0079	0.9496

	CR503		CR468		CR422		CR346		
Reach	Est	SE	Est	SE	Est	SE	Est	SE	*P* (*F*-test)
CR325 to CR309	0.9983	0.0013	0.9950	0.0022	0.9926	0.0026	0.9940	0.0025	0.3065
CR325 to CR234	0.9567	0.0064	0.9475	0.0072	0.9574	0.0063	0.9541	0.0067	0.7108

A.2.2 Summer Study

Both the tests of homogeneous reach survival and cumulative survivals were significant in the last four or so reaches (Table A.10 and Table A.11). Further examination of the cumulative survivals indicated release groups R_1, R_2, and R_3 had depressed survivals in the reach CR325 and below. *P*-values for tests of homogeneous cumulative survival became nonsignificant when these release groups were omitted from analyses below CR325 (Table A.11).

Releases R_1–R_3 were used in the analyses conducted at McNary, John Day, and The Dalles dams but not in the Bonneville Dam survival analysis or for the associated Fish Accords at that dam. No other release groups required omission in forming virtual-release groups (i.e., V_1) at the other three dams.

Table A.10. Comparison of reach survivals between tag releases from different upstream locations for subyearling Chinook salmon during the summer 2012 JSATS survival study in the Columbia River. Newly released and previously released fish were not compared within a reach (shaded).

	CR503		CR468		CR422		CR346		CR325		CR307		CR275		CR233		CR156		
Reach	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	P (F-test)
Release to CR470	0.9803	0.0030																	
CR470 to CR422	0.9147	0.0057	0.9274	0.0063															
CR422 to CR349	0.9556	0.0044	0.9558	0.0050	0.9443	0.0060													0.9760
CR349 to CR325	0.9367	0.0053	0.9437	0.0055	0.9408	0.0055	1.0005	0.0014											0.6578
CR325 to CR309	0.9918	0.0020	0.9894	0.0026	0.9905	0.0024	0.9962	0.0020	0.9925	0.0034									0.1576
CR309 to CR275	0.9500	0.0049	0.9414	0.0058	0.9318	0.0061	0.9382	0.0077	0.9480	0.0071	0.9952	0.0031							0.2535
CR275 to CR234	0.9911	0.0022	0.9875	0.0029	0.9868	0.0029	0.9908	0.0033	0.9996	0.0012	0.9929	0.0031	0.9944	0.0036					0.0121
CR234 to CR156	0.9518	0.0052	0.9593	0.0053	0.9606	0.0050	0.9670	0.0061	0.9639	0.0063	0.9725	0.0060	0.9753	0.0058	0.9992	0.0069			0.0606
CR156 to CR113	0.9900	0.0028	0.9842	0.0036	0.9889	0.0029	0.9942	0.0028	0.9958	0.0025	0.9962	0.0025	0.9947	0.0029	0.9962	0.0020	1.0037	0.0052	0.0155
CR113 to CR86 (λ)	0.9855	0.0030	0.9923	0.0024	0.9926	0.0023	0.9955	0.0024	0.9885	0.0037	0.9933	0.0031	0.9975	0.0019	0.9970	0.0014	0.9991	0.0009	0.0015

Table A.11. Comparison of cumulative survivals between tag releases from different upstream locations for subyearling Chinook salmon during the 2012 summer JSATS survival study in the Columbia River. *P*-values for tests of homogeneity were computed using all release groups, omitting release R_1, omitting releases R_1 and R_2, or omitting releases R_1, R_2, and R_3.

	CR503 (R1)		CR468 (R2)		
Reach	Est	SE	Est	SE	*P*
CR422 to CR349	0.9556	0.0048	0.9558	0.0050	0.9770
CR422 to CR325	0.8952	0.0069	0.9019	0.0071	0.4986
CR422 to CR309	0.8878	0.0072	0.8924	0.0074	0.6559
CR422 to CR275	0.8434	0.0082	0.8401	0.0087	0.7825
CR422 to CR234	0.8359	0.0086	0.8296	0.0090	0.6128
CR422 to CR156	0.7956	0.0095	0.7958	0.0097	0.9882
CR422 to CR113	0.7877	0.0098	0.7833	0.0099	0.7521

	CR503 (R1)		CR468 (R2)		CR422 (R3)			
Reach	Est	SE	Est	SE	Est	SE	*P*	*P* -r1
CR349 to CR325	0.9367	0.0053	0.9437	0.0055	0.9413	0.0055	0.6515	0.7577
CR349 to CR309	0.9290	0.0056	0.9337	0.0060	0.9323	0.0060	0.8445	0.8690
CR349 to CR275	0.8826	0.0070	0.8789	0.0078	0.8687	0.0081	0.4123	0.3644
CR349 to CR234	0.8747	0.0073	0.8680	0.0082	0.8573	0.0086	0.3048	0.3679
CR349 to CR156	0.8326	0.0084	0.8327	0.0091	0.8234	0.0098	0.7096	0.4868
CR349 to CR113	0.8243	0.0086	0.8195	0.0093	0.8143	0.0102	0.7530	0.7064

	CR503 (R1)		CR468 (R2)		CR422 (R3)		CR346 (R4)				
Reach	Est	SE	Est	SE	Est	SE	Est	SE	*P*	*P* -r1	*P* -r1r2
CR325 to CR309	0.9918	0.0020	0.9894	0.0026	0.9905	0.0024	0.9962	0.0020	0.1576	0.0890	0.0681
CR325 to CR275	0.9422	0.0052	0.9314	0.0063	0.9230	0.0065	0.9346	0.0079	0.2191	0.4743	0.2568
CR325 to CR234	0.9338	0.0056	0.9197	0.0070	0.9108	0.0071	0.9259	0.0084	0.1304	0.3617	0.1698
CR325 to CR156	0.8888	0.0072	0.8823	0.0085	0.8749	0.0084	0.8954	0.0099	0.3672	0.2612	0.1144
CR325 to CR113	0.8799	0.0075	0.8684	0.0090	0.8652	0.0088	0.8902	0.0101	0.1761	0.1186	0.0620

	CR503 (R1)		CR468 (R2)		CR422 (R3)		CR346 (R4)		CR325 (R5)					
Reach	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	*P*	*P* -r1	*P* -r1r2	*P* -r1r2r3
CR309 to CR275	0.9500	0.0049	0.9414	0.0059	0.9318	0.0061	0.9382	0.0077	0.9480	0.0072	0.2597	0.3950	0.2602	0.3526
CR309 to CR234	0.9416	0.0054	0.9296	0.0065	0.9195	0.0066	0.9295	0.0083	0.9476	0.0074	0.0356	0.0493	0.0263	0.1036
CR309 to CR156	0.8962	0.0072	0.8917	0.0081	0.8832	0.0079	0.8989	0.0100	0.9133	0.0097	0.1633	0.1089	0.0706	0.3013
CR309 to CR113	0.8873	0.0076	0.8776	0.0085	0.8735	0.0082	0.8936	0.0103	0.9095	0.0102	0.0410	0.0258	0.0296	0.2727

Table A.11. (contd)

Reach	CR503 (R1) Est	CR503 (R1) SE	CR468 (R2) Est	CR468 (R2) SE	CR422 (R3) Est	CR422 (R3) SE	CR346 (R4) Est	CR346 (R4) SE	CR325 (R5) Est	CR325 (R5) SE	CR307 (R6) Est	CR307 (R6) SE	*P*	*P* -r1	*P* -r1r2	*P* -r1r2r3
CR275 to CR234	0.9911	0.0023	0.9875	0.0030	0.9868	0.0029	0.9908	0.0033	0.9996	0.0012	0.9929	0.0031	0.0139	0.0091	0.0101	0.0557
CR275 to CR156	0.9434	0.0058	0.9474	0.0060	0.9479	0.0057	0.9581	0.0068	0.9635	0.0064	0.9656	0.0067	0.0490	0.1229	0.2070	0.7118
CR275 to CR113	0.9339	0.0063	0.9324	0.0067	0.9374	0.0062	0.9525	0.0072	0.9594	0.0068	0.9619	0.0070	0.0015	0.0045	0.0494	0.6166

Reach	CR503 (R1) Est	CR503 (R1) SE	CR468 (R2) Est	CR468 (R2) SE	CR422 (R3) Est	CR422 (R3) SE	CR346 (R4) Est	CR346 (R4) SE	CR325 (R5) Est	CR325 (R5) SE	CR307 (R6) Est	CR307 (R6) SE	CR275 (R7) Est	CR275 (R7) SE	*P*	*P* -r1	*P* -r1r2	*P* -r1r2r3
CR234 to CR156	0.9518	0.0052	0.9594	0.0053	0.9606	0.0050	0.9671	0.0061	0.9639	0.0063	0.9725	0.0061	0.9753	0.0058	0.0623	0.2921	0.3769	0.5409
CR234 to CR113	0.9423	0.0057	0.9442	0.0060	0.9499	0.0056	0.9614	0.0066	0.9597	0.0066	0.9689	0.0065	0.9700	0.0064	0.0029	0.0207	0.1625	0.5917

Reach	CR503 (R1) Est	CR503 (R1) SE	CR468 (R2) Est	CR468 (R2) SE	CR422 (R3) Est	CR422 (R3) SE	CR346 (R4) Est	CR346 (R4) SE	CR325 (R5) Est	CR325 (R5) SE	CR307 (R6) Est	CR307 (R6) SE	CR275 (R7) Est	CR275 (R7) SE	CR233 (R8) Est	CR233 (R8) SE	*P*	*P* -r1	*P* -r1r2	*P* -r1r2r3
CR156 to CR113	0.9902	0.0028	0.9841	0.0035	0.9889	0.0030	0.9942	0.0028	0.9957	0.0025	0.9963	0.0026	0.9947	0.0029	0.9961	0.0020	0.0161	0.0116	0.3612	0.9736

Appendix B

Capture Histories Used in Estimating Dam Passage Survival

Appendix B

Capture Histories Used in Estimating Dam Passage Survival

B.1 Yearling Chinook Salmon

	V1 (Season-Wide)	
Capture History	Dam Passage Survival	BRZ-to-BRZ Survival
111	2953	2953
011	1	2
101	4	4
001	0	0
120	0	0
020	0	0
110	257	257
010	0	0
200	0	0
100	33	33
000	128	133
Total	3376	3382

	Season-Wide Dam Passage Survival	
Capture History	R2	R3
11	907	898
01	0	0
20	0	0
10	71	83
00	19	14
Total	997	995

B.2 Steelhead

	V1 (Season-Wide)	
Capture History	Dam Passage Survival	BRZ-to-BRZ Survival
111	2931	2932
011	1	1
101	5	5
001	0	0
120	0	0
020	0	0
110	204	204
010	0	1
200	0	0
100	15	15
000	83	102
Total	3239	3260

	Season-Wide Dam Passage Survival	
Capture History	R2	R3
11	928	902
01	1	2
20	0	0
10	49	71
00	22	25
Total	1000	1000

B.3 Subyearling Chinook Salmon

Capture History	V1 (Season-Wide) Dam Passage Survival	BRZ-to-BRZ Survival
111	5019	5019
011	2	2
101	4	5
001	0	0
120	0	0
020	0	0
110	312	312
010	0	0
200	0	0
100	52	52
000	337	352
Total	5726	5742

Capture History	Season-Wide Dam Passage Survival R2	R3
11	919	923
01	0	0
20	0	0
10	62	51
00	5	9
Total	986	983

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