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Prepared for the U.S. Army Corps of Engineers, Portland District,
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Contract DE-AC05-76RL01830

Compliance Monitoring of Juvenile Yearling Chinook Salmon and Steelhead Survival and Passage at The Dalles Dam, Spring 2010

Pacific Northwest National Laboratory
University of Washington

T.J. Carlson
J.R. Skalski

October 2010

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Pacific Northwest National Laboratory
Richland, Washington 99352

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 are Drs. Thomas J. Carlson and John R. Skalski, respectively. The USACE technical lead is Mr. Brad Eppard. The study was designed to estimate dam passage survival at The Dalles Dam as stipulated by the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) and provide additional performance measures at that site as stipulated in the Columbia Basin Fish Accords for yearling Chinook salmon and steelhead.

This succinct report focuses on spring run stocks, yearling Chinook salmon and steelhead. A separate report scheduled for delivery in December 2010 will present the findings of the survival studies of subyearling Chinook salmon at The Dalles Dam during 2010. Comprehensive technical reports of the 2010 tagging studies at John Day, The Dalles, and Bonneville dams, including fish survival, behavior, and passage results, will be delivered in 2011.

Executive Summary

The purpose of this compliance study was to estimate dam passage survival of yearling Chinook salmon and steelhead smolts at The Dalles Dam during spring 2010. Under the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp), dam passage survival should be greater than or equal to 0.96 and estimated with a standard error (SE) less than or equal 0.015. The study also estimated smolt passage survival from the forebay 2 km upstream of the dam to the tailrace 2 km below the dam[1], as well as the forebay residence time, tailrace egress time, and spill passage efficiency, as required in the Columbia Basin Fish Accords.

A virtual/paired-release design was used to estimate dam passage survival at The Dalles Dam. The approach included releases of acoustic-tagged smolts above John Day Dam that contributed to the formation of a virtual release at the face of The Dalles Dam. A survival estimate from this release was adjusted by a paired release below The Dalles Dam. A total of 3,880 yearling Chinook salmon and 3,885 steelhead smolts were tagged and released in the investigation. The Juvenile Salmon Acoustic Telemetry System (JSATS) tag model number ATS-156dB, weighing 0.438 g in air, was used in this investigation.

The study results are summarized in the following tables.

Table ES.1. Estimates of Dam Passage Survival[2] at The Dalles Dam in 2010

Project	Year	Yearling Chinook Salmon	Steelhead
The Dalles Dam	2010	0.9641 ($\widehat{SE}$ = 0.0096)	0.9534 ($\widehat{SE}$ = 0.0097)

Table ES.2. Fish Accords Performance Measures at The Dalles Dam in 2010

Performance Measures	Yearling Chinook Salmon	Steelhead
Forebay-to-tailrace survival	0.9620 ($\widehat{SE}$ = 0.0097)	0.9526 ($\widehat{SE}$ = 0.0097)
Forebay residence time	0.40 h ($\widehat{SE}$ = 0.014)	1.88 h ($\widehat{SE}$ = 0.253)
Tailrace egress rate	0.84 h ($\widehat{SE}$ = 0.138)	0.97 h ($\widehat{SE}$ = 0.211)
Spill passage efficiency[3]	0.8407 ($\widehat{SE}$ = 0.0081)	0.8765 ($\widehat{SE}$ = 0.0073)

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

[2] Dam passage survival is defined as survival from the upstream face of the dam to a standardized reference point in the tailrace.

[3] By definition in the Fish Accords, SPE includes the spillway and the ice and trash sluiceway at The Dalles Dam. However, the point estimate provided includes only spillway passage, not sluiceway passage.

Table ES.3. Survival Study Summary

<table>
<tr><td colspan="4">Year: 2010</td></tr>
<tr><td colspan="4">Study Site(s): The Dalles Dam</td></tr>
<tr><td colspan="4">Objective(s) of study: Estimate dam passage survival for yearling Chinook salmon and steelhead and associated Fish Accords performance measures.</td></tr>
<tr><td colspan="4">Hypothesis (if applicable): Not applicable; this is a compliance study</td></tr>
<tr><td colspan="2">Fish:
Species-race: yearling Chinook salmon (CH1), steelhead (STH)
Source: John Day Dam fish collection facility</td><td colspan="2">Implant Procedure:
Surgical: Yes
Injected: No</td></tr>
<tr><td colspan="2">Size (median): CH1 STH
Weight: 31.4 g 78.1 g
Length: 152.0 mm 214.0 mm</td><td colspan="2">Sample Size: CH1 STH
release sites: 3 3
releases 94 94
Total # released: 3,880 3,885</td></tr>
<tr><td>Tag:
Type/model: Advanced Telemetry Systems (ATS)-156dB
Weight (gm): 0.438 g (air)</td><td>Analytical Model:
Virtual/paired release</td><td colspan="2">Characteristics of Estimate:
Effects Reflected (direct, total, etc): Direct
Absolute or Relative: Absolute</td></tr>
<tr><td colspan="4">Environmental/Operating Conditions (daily from April 26 through June 1):
Discharge (kcfs): mean 184, minimum 143, maximum 263
Temperature (deg C): mean 12.33, minimum 11.04, maximum 14.00
Total Dissolved Gas (tailrace): mean 114%, minimum 110%, maximum 117%
Treatment(s): None
Unique Study Characteristics: A newly installed spill wall was in place in the spillway stilling basin to improve egress conditions and survival for downstream migrants.</td></tr>
<tr><td colspan="2">Survival and Passage Estimates (value & SE):</td><td>CH1</td><td>STH</td></tr>
<tr><td colspan="2">Dam survival</td><td>0.9641 ($\widehat{SE}$ = 0.0096)</td><td>0.9534 ($\widehat{SE}$ = 0.0097)</td></tr>
<tr><td colspan="2">Forebay-to-tailrace survival</td><td>0.9620 ($\widehat{SE}$ = 0.0097)</td><td>0.9526 ($\widehat{SE}$ = 0.0097)</td></tr>
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<tr><td colspan="2">Spill passage efficiency</td><td>0.8407 ($\widehat{SE}$ = 0.0081)</td><td>0.8765 ($\widehat{SE}$ = 0.0073)</td></tr>
<tr><td colspan="4">Compliance Results: Yearling Chinook salmon study met compliance requirements. Steelhead study met precision standard but not compliance requirement with point estimate.</td></tr>
</table>

Acknowledgments

This study was the result of hard work by dedicated scientists from the 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.

- PNNL: T Carlson, C Arimescu, G Batten, B Bellgraph, S Carpenter, J Carter, K Carter, E Choi, Z Deng, K Deters, G Dirkes, D Faber, E Fischer, T Fu, G Gaulke, K Hall, K Ham, R Harnish, M Hennen, J Hughes, M Hughes, G Johnson, F Khan, J Kim, K Knox, B Lamarche, K Lavender, J Martinez, G McMichael, B Noland, E Oldenburg, G Ploskey, I Royer, N Tavan, S Titzler, N Trimble, M Weiland, C Woodley, and S Zimmerman.

- PSMFC: R Martinson, P Kahut, G Kolvachuk, C Anderson, A Cushing, D Etherington, G George, S Goss, T Monter, T Mitchell, R Plante, M Walker, R Wall, M Wilberding.

- USACE: B Eppard, M Langeslay, B Cordie, D Schwartz, M Zyndol, and mechanics, operators, and biologists at Bonneville, John Day, and The Dalles dams.

- UW: J Skalski, J Lady, A Seaburg, R Townsend, and P Westhagen.

Acronyms and Abbreviations

°C	degree(s) Celsius
3D	three dimensional
BiOp	Biological Opinion
BRZ	boat-restricted zone
FCRPS	Federal Columbia River Power System
CH1	yearling Chinook salmon
FPC	Fish Passage Center
g	gram(s)
h	hour(s)
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)
MOA	Memorandum of Agreement
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
PRI	pulse repetition interval
rkm	river kilometer(s)
RM	river mile(s)
RME	research, monitoring, and evaluation
ROR	run-of-river
RPA	Reasonable and Prudent Alternative
SE	standard error
SPE	spill passage efficiency
STH	steelhead
TDA	The Dalles Dam
T2	Test 2
T3	Test 3
USACE	U.S. Army Corps of Engineers
UW	University of Washington

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1.0 Introduction

The compliance monitoring study reported here was conducted by researchers at Pacific Northwest National Laboratory (PNNL) and the University of Washington (UW) for the U.S. Army Corps of Engineers, Portland District (USACE). The purpose of the study was to estimate dam passage survival at The Dalles Dam as stipulated by the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) and provide additional performance measures at the dam as stipulated in the Columbia Basin Fish Accords for yearling Chinook salmon and steelhead.

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 its estimates, as follows (after the RME Strategy 2 of the RPA):

> Juvenile Dam Passage Performance Standards – The Action Agencies juvenile performance standards are an average across Snake River and lower Columbia River dams of 96% 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 (MOA) between the three lower river tribes and the Action Agencies (known informally as the Fish Accords), contains three additional requirements relevant to the 2010 survival studies (after the MOA Attachment A):

> Dam Survival Performance Standard – Meet the 96% dam passage survival standard for yearling Chinook and steelhead and the 93% standard for subyearling Chinook. Achievement of the standard is based on 2 years of empirical survival data . . . .
>
> Spill Passage Efficiency and Delay Metrics − Spill passage efficiency (SPE) and delay metrics under current spill conditions . . . are not expected to be degraded ("no backsliding") with installation of new fish passage facilities at the dams . . . .
>
> Future Research, Monitoring, and Evaluation − The Action Agencies' dam survival studies for purposes of determining juvenile dam passage performance will also collect information about SPE, BRZ-to-BRZ (boat restricted zone) survival and delay, as well as other distribution and survival information. SPE and delay metrics will be considered in the performance check-ins or with Configuration and Operations Plan updates, but not as principal or priority metrics over dam survival performance standards. Once a dam meets the survival performance standard, SPE and delay metrics may be monitored coincidentally with dam survival testing.

This report summarizes the results of the 2010 spring acoustic-telemetry study of yearling Chinook salmon and steelhead at The Dalles Dam to assess the Action Agencies' compliance with the performance criteria of the BiOp and Fish Accords.

1.2 Study Objectives

The purpose of spring 2010 compliance monitoring at The Dalles Dam was to estimate performance measures for yearling Chinook salmon and steelhead smolts 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). Survival should be estimated with a standard error (SE) ≤ 1.5%.
- SPE, defined in the Fish Accords as the fraction of fish going through the dam via the spillway and surface flow outlets.
- Forebay residence time, defined as the average time smolts take to travel the last 100 m upstream of the dam before passing into the dam, i.e., from the 100-m mark to the dam face.
- Tailrace egress time, defined as the average time smolts take to travel from the dam to the downstream tailrace boundary, i.e., tailrace array 2 km downstream of the dam.
- Forebay-to-tailrace survival, defined as survival from a forebay array 2 km upstream of the dam to a tailrace array 2 km downstream. The forebay-to-tailrace survival estimate satisfies the "BRZ-to-BRZ" survival estimate called for in the Fish Accords.

Results are reported for the two fish stocks by performance measure. This report is designed to provide a succinct and timely summary of BiOp/Fish Accords performance measures. A subsequent, comprehensive technical report will provide more detailed data on survival and fish passage at The Dalles Dam in 2010.

[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

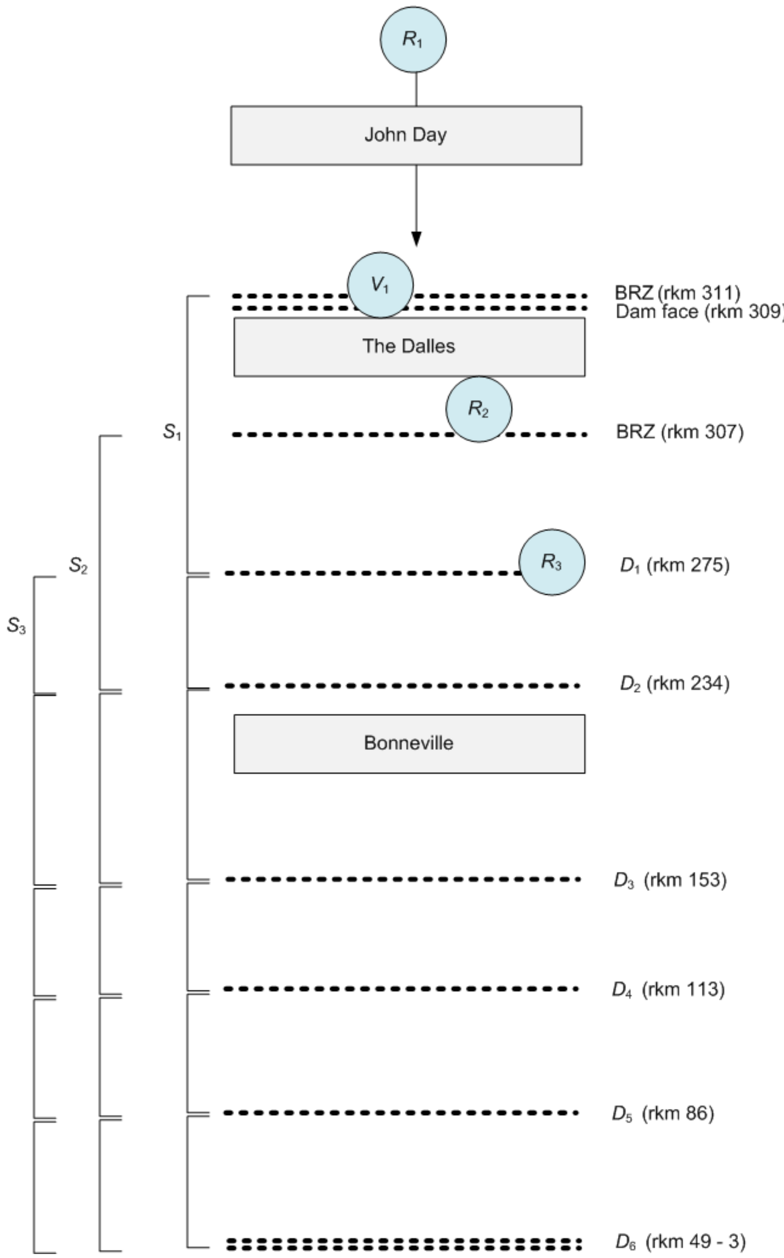
The release-recapture design used to estimate dam passage survival at The Dalles Dam consisted of a novel combination of a virtual release (V_1) of fish at the face of the dam and a paired release below the dam (Figure 2.1) (Skalski et al. 2010). Tagged fish released above John Day Dam were used to supply a source of fish known to have arrived alive at the face of The Dalles Dam. By releasing the fish far enough upstream, they 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] 275) (Figure 2.1). To account and adjust for this extra reach mortality, a paired release below The Dalles 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 acoustic-tagged fish used in the dam passage survival estimates are summarized in Table 2.1.

Table 2.1. Sample Sizes of Acoustic-Tag Releases Used in the 2010 Yearling Chinook Salmon and Steelhead Survival Studies at The Dalles Dam in 2010

Release Location	Yearling Chinook Salmon	Steelhead
Above John Day (R_1)	2287	2288
Virtual Release (V_1)	2037	2048
The Dalles Dam Tailrace (R_2)	796	799
Bonneville Reservoir (R_3)	797	798

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. 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 three-dimensional double-detection array at the face of The Dalles Dam used to construct the virtual–release group was also used to identify the passage routes of fish through the dam. These passage-route data were used to calculate SPE at The Dalles Dam. The 3D tracking data were further used to estimate forebay residence time within the 100-m zone nearest the dam. The fish used in the virtual release at the face of the dam were used to estimate tailrace egress time.



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

Figure 2.1. Schematic of Releases (*R*) and Detection Locations (——) Used in Estimating Dam Passage Survival at The Dalles Dam in 2010. Note, the arrays at rkm 311 and rkm 307 are not actually on the BRZ demarcations.

In addition to the detection arrays identified in Figure 2.1, hydrophone arrays were deployed below Bonneville Dam at rkm 49, 37, 22, 8, and 3. These arrays served as potential additional downstream detection arrays to improve precision in the survival analysis for The Dalles Dam.

A total of 49 acoustic tags were randomly sampled from the tags used in the spring season for a tag-life assessment. 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).

2.2 Handling, Tagging, and Release Procedures

Fish obtained from the John Day Dam juvenile bypass system were surgically implanted with JSATS tags, and then transported to three different release points, as described in the following sections.

2.2.1 Acoustic Tags

The acoustic tags used in the spring 2010 study were manufactured by Advanced Telemetry Systems. Each tag, model number ATS-156dB, measured 12.02 mm in length, 5.21 mm in width, 3.72 mm in thickness, and weighed 0.438 g in air. The tags had a nominal transmission rate of 1 pulse every 3 seconds. Nominal tag life was expected to be about 23 days.

2.2.2 Fish Source

The yearling Chinook salmon and steelhead used in the study were all obtained from the John Day Dam juvenile bypass system. The Pacific States Marine Fisheries Commission diverted fish from the juvenile bypass system into an examination trough, as described by Martinson et al. (2006). Fish $\geq$ 95 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 with 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 surgical blade, a 6- to 8-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 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 18 to 24 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 three 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 cross section (Figure 2.1), and equal numbers of buckets of fish were released at each of the five locations for a given cross-section.

Releases occurred for 37 consecutive days (from April 28 to June 1, 2010). Releases alternated between daytime and nighttime, every other day, over the course of the study. The timing of the releases at the three locations was staggered to help facilitate downstream mixing (Table 2.2).

Table 2.2. Relative Release Times for the Acoustic-Tagged Fish to Accommodate Downstream Mixing. Releases were timed to accommodate the approximately 60-h travel time between R_1 and R_3 and the 15-h travel time between R_1 and R_2.

	Relative Release Times	
Release Location	Daytime Start	Nighttime Start
R_1 (rkm 390)	Day 1: 0900 h	Day 2: 2000 h
R_2 (rkm 307)	Day 3: 0900 h	Day 4: 2000 h
R_3 (rkm 275)	Day 4: 2200 h	Day 5: 0900 h

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 for data from cabled arrays:

- Multipath filter: For data from each individual cabled hydrophone, all tag-code receptions that occur within 0.156 seconds 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 seconds was the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and was computed as 2(PRI_Window+12×PRI_Increment). Both PRI_Window and PRI_Increment were set at 0.006, which was chosen to be slightly larger than the potential rounding error in estimating PRI to two decimal places.
- Multi-detection filter: Receptions were retained only if the same tag code was received at another hydrophone in the same array within 0.3 seconds because receptions on separate hydrophones within 0.3 seconds (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 seconds. Message time was defined as the earliest reception time across all hydrophones for that message. Detection required that at least six messages were received with an appropriate time interval between the leading edges of successive messages.

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

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

The output of the filtering processes for both cabled and autonomous hydrophones was a data set of events that summarized accepted tag detections for all times and locations where hydrophones were operating. Each unique event record included a basic set of fields that 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 tracking of JSATS-tagged fish in the immediate forebay of The Dalles Dam was used to determine routes of passage to estimate spill passage efficiency. 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 2D 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. (2010) for John Day Dam.

2.4 Statistical Methods

2.4.1 Estimation of Dam Passage Survival

Maximum likelihood estimation was used to estimate dam passage survival at The Dalles Dam. The capture histories from all of the replicate releases, both daytime and nighttime, were pooled for the analysis to produce a single season-wide estimate of survival. A joint likelihood model was used to estimate dam passage survival based on the virtual and paired releases corrected for tag life.

The estimate of dam passage survival was computed as a function of three independent reach survival estimates (Figure 2.1) corrected for the probabilities the acoustic tags were still active, i.e.,

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

where $\hat{L}_i$ = estimated probability an acoustic tag is still active associated with the reach survival estimate $\hat{S}_i$.

The joint likelihood used to model the three release groups was fully parameterized. Each release was allowed to have unique survival and detection parameters. The fully parameterized model was chosen for purposes of robustness despite empirical evidence that downstream survival and detection probabilities were likely homogeneous. The variance estimate for $\hat{S}_{\text{Dam}}$ takes into account both the release-recapture sampling error and the error in the tag-life estimates according to Townsend et al. (2006). All calculations were performed using Program ATLAS (http://www.cbr.washington.edu/paramest/atlas/) and cross-verified using R and/or Program USER (http://www.cbr.washington.edu/paramest/user/).

2.4.2 Tag-Life Analysis

The 49 acoustic tags systematically sampled from the tags used in the yearling Chinook salmon and steelhead survival studies were monitored continuously until tag failure. Those failure times were fit to the four-parameter vitality model of Li and Anderson (2009). The vitality model tends to fit acoustic-tag failure times well, because it allows for both early onset of random failure due to manufacturing as well as systematic battery failure later on.

The probability density function for the vitality model can be rewritten as

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

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.

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 309, 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:

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

2.4.3 Tests of Assumptions

2.4.3.1 Burnham et al. (1987) Tests

Tests 2 and 3 (T2 and T3) 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 juvenile bypass system. 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 acoustic-tagged smolts 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

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

where

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

and

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

The *F*-test was used in evaluating tagger effects.

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 311) of The Dalles Dam instead of at the dam face (Figure 2.1).

2.4.5 Estimation of Travel Times

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

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

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

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

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

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 The Dalles Dam to the first detector at the tailrace array 2 km downstream of the dam. The estimated forebay residence times were based on the time from the first detection within 100 m of the dam face to the last detection at the double array in front of The Dalles Dam.

2.4.6 Estimation of Spill Passage Efficiency

Spill passage efficiency was estimated by the fraction

$$\widehat{\text{SPE}} = \frac{\hat{N}_{SP}}{\hat{N}_{SP} + \hat{N}_{SL} + \hat{N}_{PH}},$$

where $\hat{N}_i$ is the estimated abundance of acoustic-tagged fish through the *i*th route (i = spillway [SP], sluiceway, [SL], or powerhouse [PH]). 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

$$\text{Var}\left(\widehat{\text{SPE}}\right) = \frac{\widehat{\text{SPE}}\left(1-\widehat{\text{SPE}}\right)}{\sum_{i=1}^{3}\hat{N}_i} + \widehat{\text{SPE}}^2\left(1-\widehat{\text{SPE}}\right)^2 \cdot \left[\frac{\text{Var}\left(\hat{N}_{SP}\right)+\text{Var}\left(\hat{N}_{SL}\right)}{\left(\hat{N}_{SP}+\hat{N}_{SL}\right)^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{PH}\right)}{\hat{N}_{PH}^2}\right].$$

3.0 Results

3.1 Discharge and Spill Conditions

Total project and spill discharge during 2010 survival studies at The Dalles Dam were 24% and 18% lower, respectively, when compared to 10-year average conditions (Figure 3.1). Daily total project discharge averaged 184 kcfs and ranged between 143 and 263 kcfs. The spill percentage during spring 2010 was 40%.

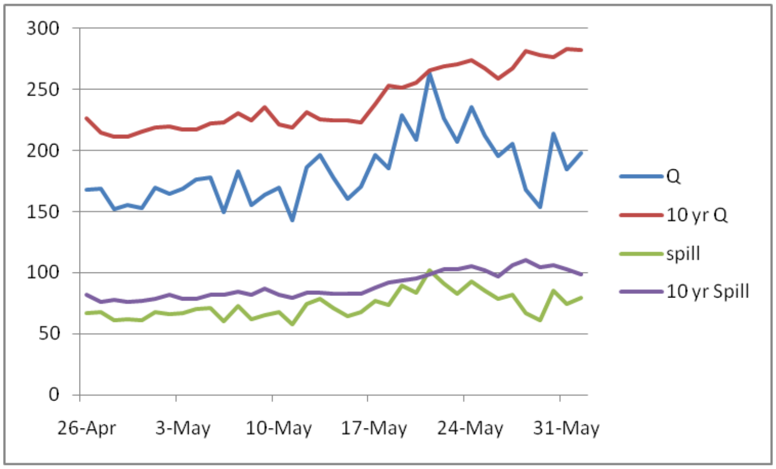
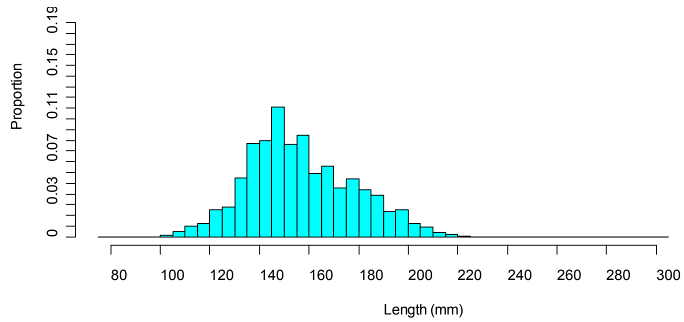


Figure 3.1. Daily and 10-Year Average (2000–2009) Total and Spill Discharge Levels at The Dalles Dam for the Period from April 26 to June 1, 2010

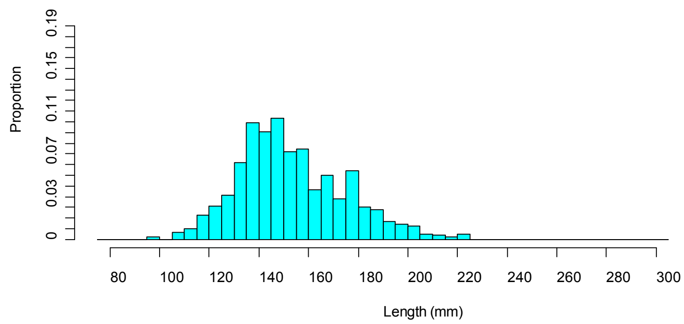
3.2 Fish Size Distribution

Comparison of acoustic-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 3.2) and steelhead (Figure 3.3). For steelhead, the upper size limit for the tagged fish was truncated with none of the very large fish (> 260 mm) being tagged. The length distributions for the three yearling Chinook salmon releases (Figure 3.2) and the three steelhead releases (Figure 3.3) were quite similar. Median length for acoustic-tagged yearling Chinook salmon was 153 mm. For steelhead smolts, the median length of the tagged fish was 214 mm. Median length per release for yearling Chinook salmon decreased by about 25 mm from ~170 mm to ~145 mm as the spring season progressed (Figure 3.4). Median length per release for steelhead was uniform throughout the study (Figure 3.4).

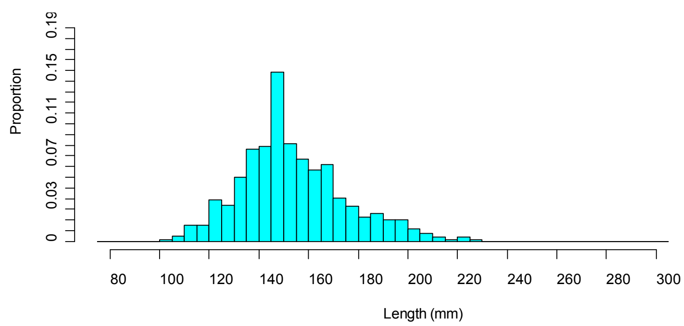
a. The Dalles Dam (Release V_1)



b. The Dalles Tailrace (Release R_2)



c. Hood River (Release R_3)



d. ROR Yearling Chinook at John Day

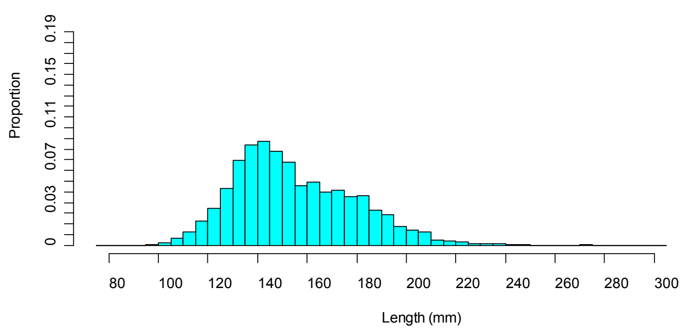
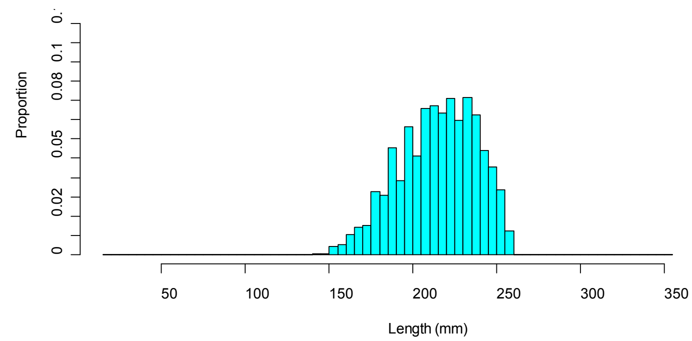
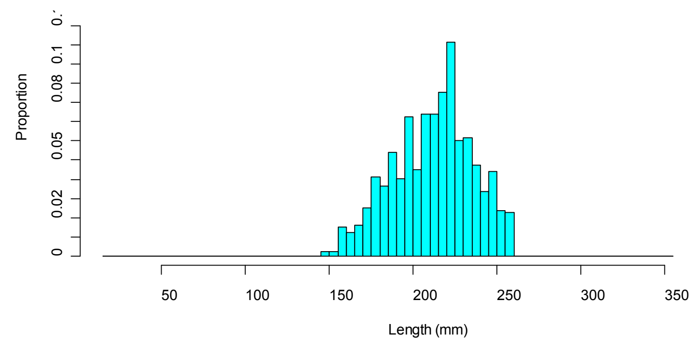


Figure 3.2. Relative Frequency Distributions for Fish Length (mm) of Yearling Chinook Salmon Smolts Used in (a) Release V_1**,** (b) Release R_2**,** (c) Release R_3, and (d) ROR Fish Sampled at John Day Dam by the Fish Passage Center

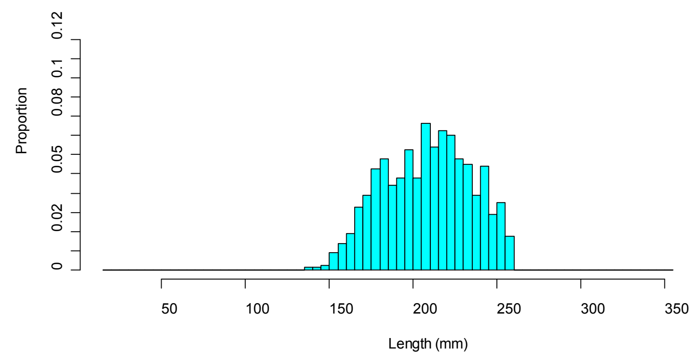
a. The Dalles Dam (Release V_1)



b. The Dalles Tailrace (Release R_2)



c. Hood River (Release R_3)



d. ROR Steelhead at John Day

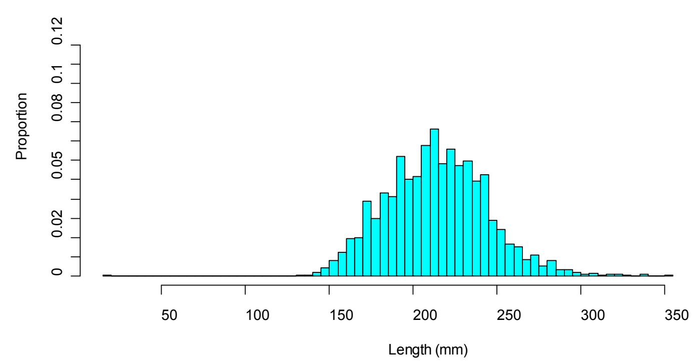
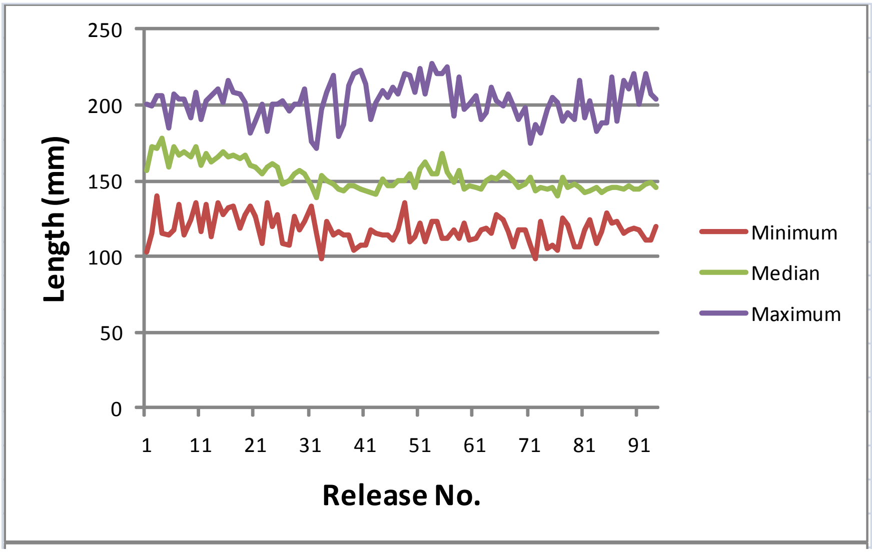


Figure 3.3. Relative Frequency Distributions for Fish Length (mm) of Steelhead Smolts Used in (a) Release V_1, (b) Release R_2, (c) Release R_3, and (d) ROR Fish Sampled at John Day Dam by the Fish Passage Center

a. Yearling Chinook salmon smolts



b. Steelhead smolts

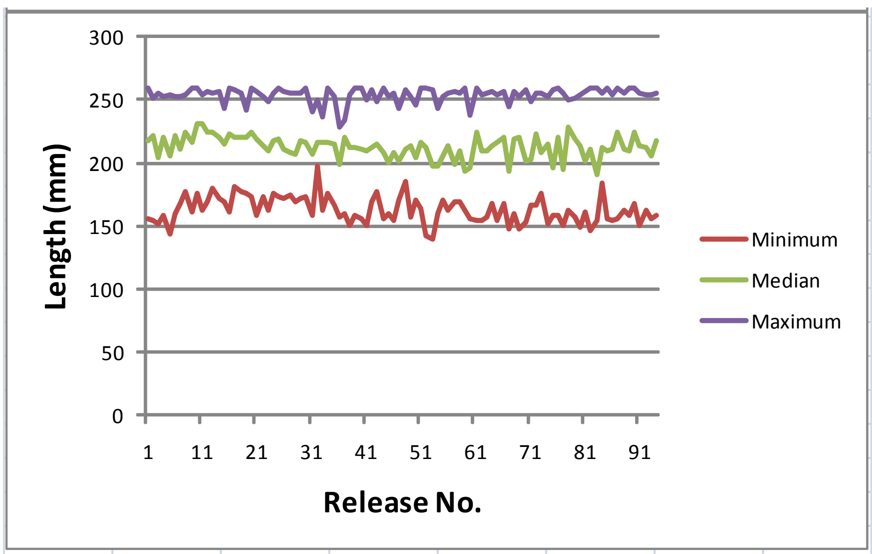


Figure 3.4. Range and Median Lengths of Acoustic-Tagged Yearling Chinook Salmon and Steelhead Used in the 2010 Survival Studies. Releases were made daily from April 26 through June 1 at three release locations: Roosevelt (RM 242, rkm 390), The Dalles Dam tailrace (RM 191, rkm 307), and Hood River (RM 171, rkm 275).

3.3 Handling Mortality and Tag Shedding

Fish were held for 24 h prior to release. The 24-h tagging mortality in spring was 0.20%. No tags were shed during the 24-h holding period.

3.4 Tag-Life Corrections

Mean tag life (n = 49) was 32.73 days. The earliest tag failure was at 7.8 days and the longest at 39.6 days. The failure-time data for the acoustic tags was fit to a four-parameter vitality model of Li and Anderson (2009). The maximum likelihood estimates for the four model parameters were $\hat{r} = 0.02963$, $\hat{s} = -5.59145\times10^{-9}$, $\hat{k} = 0.00173$, and $\hat{u} = 0.05730$ (Figure 3.5). This tag-life survivorship model was subsequently used to estimate the probabilities of tag failure and provide tag-life-adjusted estimates of smolt survival.

3.5 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. These probabilities were calculated by integrating the tag survivorship curve (Figure 3.5) over the observed distribution of fish arrival times (i.e., time from tag activation to arrival) (Tables 3.1 and 3.2). The estimated probabilities of tag activation for the various release groups at the different detection arrays always exceeded 0.98. The tag-life-adjusted survival estimates were based on the estimated probabilities of tag activation reported in Table 3.1 and Table 3.2.

The last distinct detection array used in the survival analysis was rkm 86 (Figure 2.1). Plots of the arrival distributions of the three release groups (i.e., V_1, R_2, and R_3) to that array indicate both the yearling Chinook salmon (Figure 3.6) and steelhead smolts (Figure 3.7) should have arrived well before tag failure became problematic. Tag-life adjustments to survival estimates would be incomplete if fish have arrival times beyond the range of observed tag lives.

3.6 Downstream Mixing

To help induce downstream mixing of the release groups, the R_1 release was 60 h before the R_2 release which, in turn, occurred 15 h before R_3. The release schedule was used for both the yearling Chinook salmon and steelhead smolts. Plots of the arrival timing of the various release groups at downstream detection sites indicate reasonable mixing for both yearling Chinook salmon (Figure 3.8) and steelhead (Figure 3.9) smolts. The survival modes for releases R_2 and R_3 were nearly synchronous. The modes for R_2 and R_3 were slightly later than the arrival mode for V_1 but during the majority of the distribution of arrival times for V_1 (Figure 3.8, Figure 3.9).

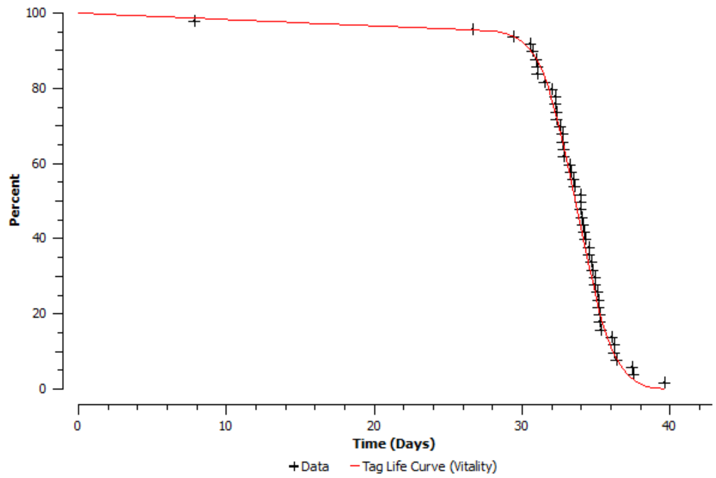


Figure 3.5. Individual Failure Times for the $n = 49$ Acoustic Tags Used in the Tag-Life Study, Along with the Fitted Four-Parameter Vitality Model of Li and Anderson (2009)

Table 3.1. Estimated Probabilities (L) of an Acoustic Tag Being Active When a Yearling Chinook Salmon Smolt Arrived at a Detection Array Used in Estimating Dam Passage Survival at The Dalles Dam in 2010. For the V_1 release, the L values are the conditional probability a tag is active, given it was active at the time the group was formed at detection array at rkm 309. (Standard errors are in parentheses.)

Release Group	Detection Sites					
	D2: Rkm 275	D3: Rkm 234	D4: Rkm 153	D5: Rkm 113	D6: Rkm 86	Rkm (49–3)
V_1	0.9990 (0.000511)	0.9978 (0.001086)	0.9960 (0.001989)	0.9951 (0.002400)	0.9945 (0.002684)	0.9934 (0.003216)
R_2	--	0.9901 (0.004844)	0.9881 (0.005820)	0.9874 (0.006188)	0.9867 (0.006487)	0.9857 (0.007012)
R_3	--	0.9910 (0.004397)	0.9891 (0.005357)	0.9881 (0.005804)	0.9876 (0.006062)	0.9865 (0.006597)

Table 3.2. Estimated Probabilities (L) of an Acoustic Tag Being Active When a Steelhead Smolt Arrived at a Detection Array Used in Estimating Dam Passage Survival at The Dalles Dam in 2010. For the V_1 release, the L values are the conditional probability a tag is active, given it was active at the time the group was formed at detection array at rkm 309. (Standard errors are in parentheses.)

Release Group	Detection Sites					
	D_2: Rkm 275	D_3: Rkm 234	D_4: Rkm 153	D_5: Rkm 113	D_6: Rkm 86	Rkm (49–3)
V_1	0.9989 (0.000541)	0.9978 (0.001060)	0.9959 (0.002008)	0.9950 (0.002428)	0.9945 (0.002677)	0.9934 (0.003178)
R_2	--	0.9900 (0.004851)	0.9880 (0.005816)	0.9872 (0.006246)	0.9867 (0.006464)	0.9856 (0.006984)
R_3	--	0.9907 (0.004527)	0.9889 (0.005422)	0.9879 (0.005884)	0.9874 (0.006119)	0.9863 (0.006662)

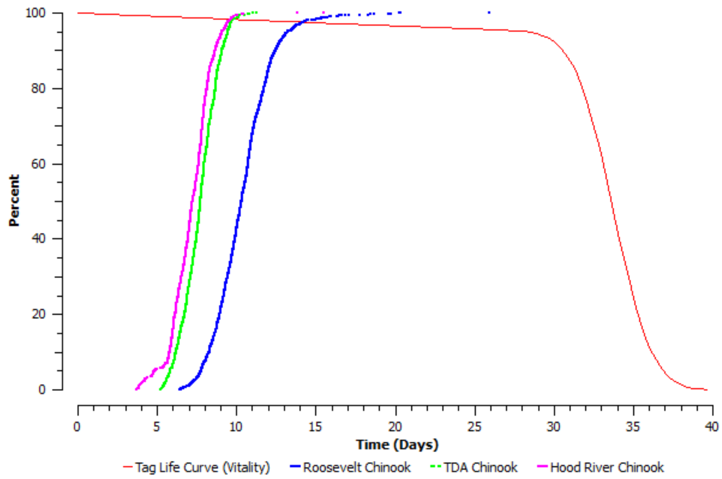


Figure 3.6. Plot of the Fitted Tag-Life Survivorship Curve and the Arrival-Time Distributions of Yearling Chinook Salmon Smolts for Releases V_1, R_2, and R_3 at the Acoustic-Detection Array Located at Rkm 86.0 (Figure 2.1)

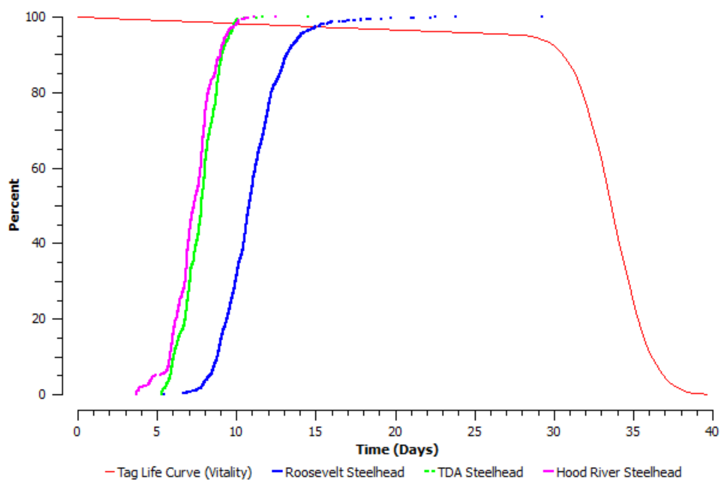
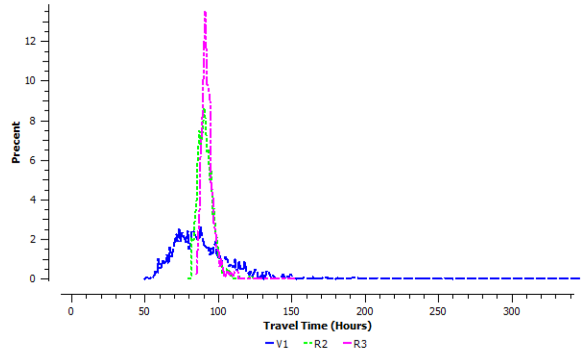
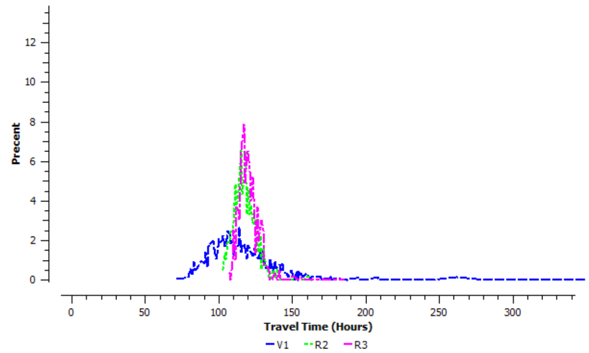


Figure 3.7. Plot of the Fitted Tag-Life Survivorship Curve and the Arrival-Time Distributions of Steelhead Smolts for Releases V_1, R_2, and R_3 at the Acoustic-Detection Array Located at Rkm 86.0 (Figure 2.1)

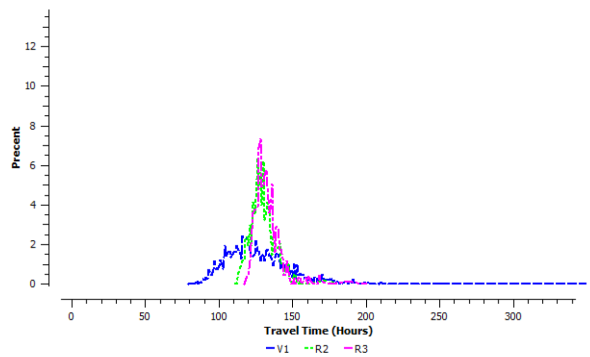
a. Rkm 234



b. Rkm 153



c. Rkm 113



d. Rkm 86

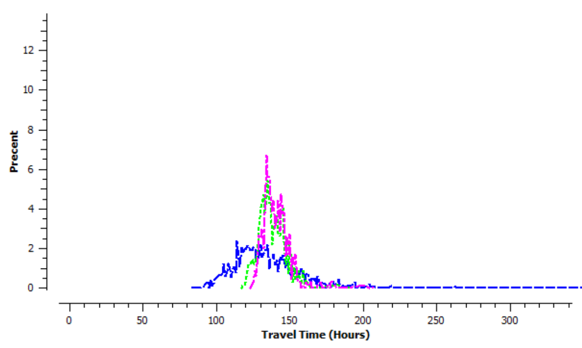


Figure 3.8. Plots of Downstream Arriving Timing for Chinook Salmon Releases V_1, R_2, and R_3 at Detection Arrays Located at (a) Rkm 234, (b), Rkm 153, (c) Rkm 113, and (d) Rkm 86. (See Figure 2.1). All times adjusted relative to the release time of V_1.

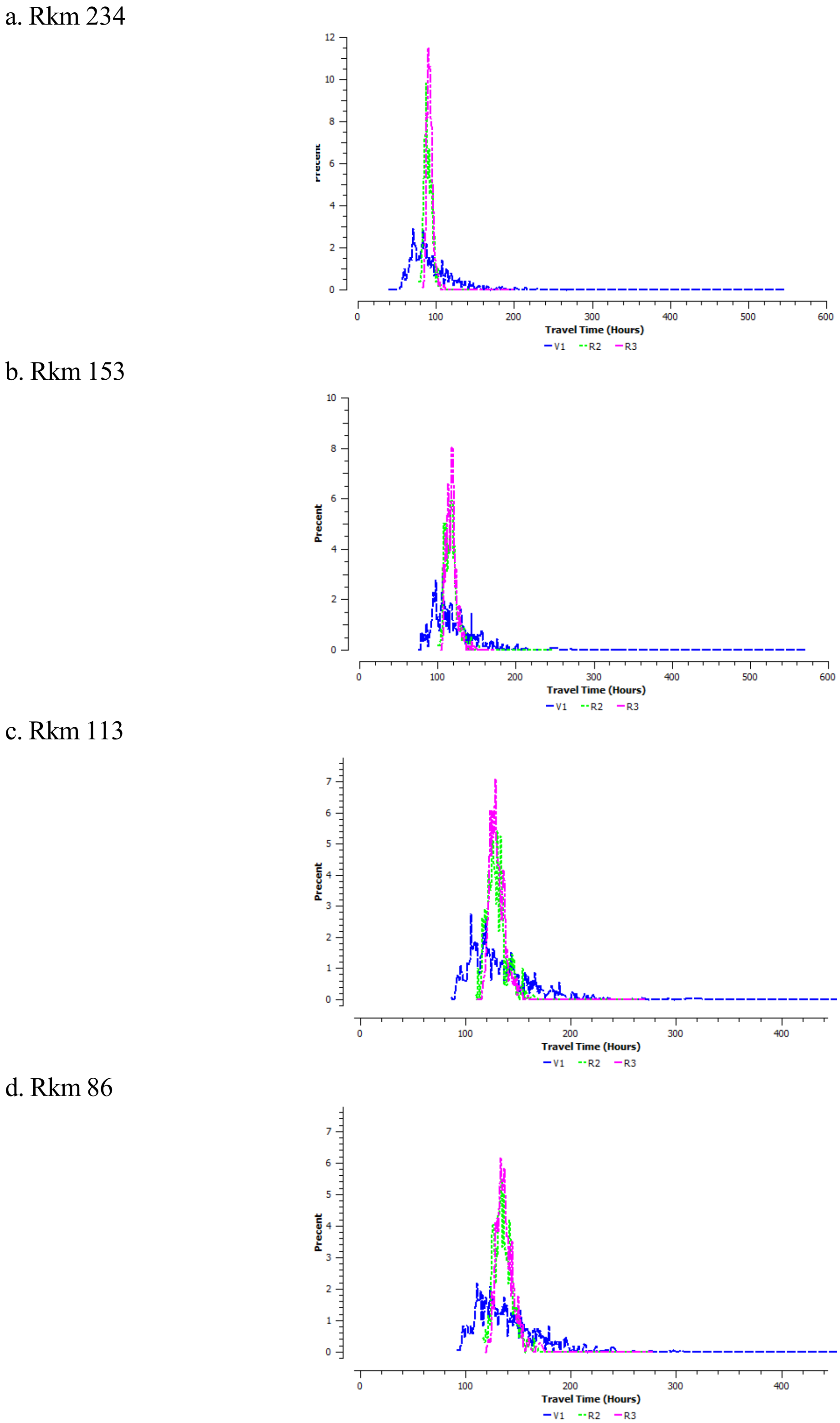


Figure 3.9. Plots of Downstream Arriving Timing for Steelhead Releases V_1, R_2, and R_3 at Detection Arrays Located at (a) Rkm 234, (b), Rkm 153, (c) Rkm 113, and (d) Rkm 86. (See Figure 2.1). All times adjusted relative to the release time of V_1.

3.7 Examination of Tagger Effects

Having various fish handlers tag the same proportions of fish for release at each of the release sites helped minimize but did not necessarily eliminate handling effects in the survival study. The study was therefore designed to balance tagger effort across locations. Implementation produced near perfect balance for both the yearling Chinook salmon (Table 3.3) and steelhead (Table 3.4) releases.

To further assess whether tagger effects may have occurred, reach survivals for the fish tagged by the different staff were calculated using the Cormack-Jolly Seber single release-recapture model. For both yearling Chinook salmon (Table 3.5) and steelhead (Table 3.6), reach survivals were found to be homogeneous ($P > 0.05$) across all reaches examined. For this reason, all fish, regardless of fish tagger, were included in the survival analyses.

Table 3.3. Number of Chinook Salmon Smolts Tagged at Each Release Site by Tagger. Tagger effort was homogeneous $\left(P\left(\chi^2_{10} \geq 1.0336\right) = 0.9998\right)$

	Tagger						
Release Location	#1	#2	#3	#4	#5	#6	Total
R_1	441	356	311	350	372	457	2287
R_2	149	123	110	129	124	161	796
R_3	152	126	109	117	130	163	797
Total Tags	742	605	530	596	626	781	3880

Table 3.4. Number of Steelhead Smolts Tagged at Each Release Site by Tagger. Tagger effort was homogeneous $\left(P\left(\chi^2_{10} \geq 0.5851\right) = 1.0000\right)$

	Tagger						
Release Location	#1	#2	#3	#4	#5	#6	Total
R_1	430	359	331	354	365	449	2288
R_2	155	124	114	126	125	155	799
R_3	157	121	112	126	126	156	798
Total Tags	742	604	557	606	616	760	3885

Table 3.5. Cormack-Jolly-Seber Estimates of Reach Survivals by Release Site and Tagger for Chinook Salmon Smolts. Standard errors in parentheses. *F*-tests below each release and reach test for homogeneity of survival across taggers. No tests were significant (α < 0.05).

Release Site	Tagger	Cormack-Jolly-Seber Survival: Release to Rkm 309	Rkm 309 to 275	Rkm 275 to 234	Rkm 234 to 153	Rkm 153 to 113	Rkm 113 to 86
Roosevelt Chinook	#1	0.8912 (0.0148)	0.9364 (0.0123)	0.9790 (0.0076)	0.9165 (0.0147)	0.9975 (0.0034)	1.0000 (<0.0001)
	#2	0.8934 (0.0164)	0.9527 (0.0119)	0.9910 (0.0057)	0.9512 (0.0134)	0.9790 (0.0102)	1.0000 (<0.0001)
	#3	0.8489 (0.0203)	0.9318 (0.0155)	0.9797 (0.0090)	0.9554 (0.0135)	0.9953 (0.0054)	1.0000 (<0.0001)
	#4	0.8943 (0.0164)	0.9457 (0.0128)	0.9767 (0.0088)	0.9383 (0.0148)	0.9789 (0.0102)	0.9917 (0.0141)
	#5	0.9140 (0.0145)	0.9382 (0.0131)	0.9906 (0.0053)	0.9215 (0.0152)	0.9985 (0.0048)	0.9899 (0.0131)
	#6	0.9059 (0.0137)	0.9348 (0.0121)	0.9798 (0.0072)	0.9282 (0.0136)	0.9880 (0.0070)	1.0000 (0.0165)
	F-test	1.9448	0.3597	0.7243	1.2466	1.5091	0.2137
	P-value	0.0828	0.8763	0.6051	0.2840	0.1832	0.9569

Release Site	Tagger	Release to Rkm 275	Rkm 275 to 234	Rkm 234 to 153	Rkm 153 to 113	Rkm 113 to 86
The Dalles Dam Chinook	#1	0.9731 (0.0132)	0.9798 (0.0118)	0.9295 (0.0216)	1.0000 (0.0073)	1.0000 (<0.0001)
	#2	0.9756 (0.0139)	0.9750 (0.0142)	0.9403 (0.0219)	1.0000 (<0.0001)	1.0000 (0.0260)
	#3	0.9909 (0.0089)	0.9821 (0.0128)	0.9534 (0.0206)	1.0000 (<0.0001)	0.9986 (0.0403)
	#4	0.9690 (0.0152)	0.9760 (0.0137)	0.9275 (0.0237)	0.9916 (0.0101)	0.9933 (0.0230)
	#5	0.9919 (0.0079)	0.9756 (0.0139)	0.9419 (0.0214)	1.0000 (0.0145)	0.9795 (0.0180)
	#6	0.9813 (0.0106)	0.9943 (0.0062)	0.9568 (0.0168)	0.9925 (0.0086)	1.0000 (<0.0001)
	F-test	0.6328	0.3480	0.3221	0.2312	0.1259
	P-value	0.6747	0.8838	0.9000	0.9490	0.9866

Release Site	Tagger	Release to Rkm 234	Rkm 234 to 153	Rkm 153 to 113	Rkm 113 to 86
Hood River Chinook	#1	0.9737 (0.0130)	0.9599 (0.0162)	1.0000 (0.0083)	1.0000 (<0.0001)
	#2	0.9921 (0.0078)	0.9710 (0.0159)	0.9821 (0.0138)	1.0000 (<0.0001)
	#3	0.9816 (0.0128)	0.9445 (0.0223)	1.0000 (<0.0001)	1.0000 (<0.0001)
	#4	0.9829 (0.0119)	0.9485 (0.0207)	1.0000 (<0.0001)	0.9841 (0.0356)
	#5	0.9923 (0.0076)	0.9473 (0.0200)	0.9928 (0.0098)	1.0000 (0.0305)
	#6	0.9945 (0.0060)	0.9510 (0.0172)	1.0000 (<0.0001)	0.9440 (0.0242)
	F-test	0.1386	0.2795	0.9024	0.6280
	P-value	0.9834	0.9246	0.4783	0.6784

Table 3.6. Cormack-Jolly-Seber Estimates of Reach Survivals by Release Site and Tagger for Steelhead Smolts. Standard errors in parentheses. *F*-tests below each release and reach test for homogeneity of survival across taggers. No tests were significant ($\alpha < 0.05$).

Release Site	Tagger	Cormack-Jolly-Seber Survivals: Release to Rkm 309	Rkm 309 to 275	Rkm 275 to 234	Rkm 234 to 153	Rkm 153 to 113	Rkm 113 to 86
Roosevelt Steelhead	#1	0.8930 (0.0149)	0.9505 (0.0111)	0.9699 (0.0089)	0.9107 (0.0153)	0.9978 (0.0041)	1.0000 (<0.0001)
	#2	0.8831 (0.0170)	0.9621 (0.0107)	0.9671 (0.0102)	0.9131 (0.0166)	1.0000 (0.0083)	0.9869 (0.0225)
	#3	0.9063 (0.0160)	0.9600 (0.0113)	0.9831 (0.0077)	0.8978 (0.0186)	0.9824 (0.0102)	1.0000 (<0.0001)
	#4	0.8729 (0.0177)	0.9320 (0.0143)	0.9725 (0.0097)	0.9479 (0.0149)	0.9683 (0.0134)	0.9934 (0.0254)
	#5	0.9151 (0.0146)	0.9372 (0.0133)	0.9776 (0.0084)	0.9069 (0.0172)	0.9805 (0.0105)	0.9737 (0.0208)
	#6	0.9065 (0.0137)	0.9656 (0.0090)	0.9804 (0.0072)	0.9118 (0.0149)	0.9892 (0.0076)	0.9895 (0.0239)
	F-test	1.0452	1.4044	0.5128	1.1099	1.5660	0.2701
	P-value	0.3890	0.2192	0.7668	0.3525	0.1659	0.9297

Release Site	Tagger	Release to Rkm 275	Rkm 275 to 234	Rkm 234 to 153	Rkm 153 to 113	Rkm 113 to 86
The Dalles dam Steelhead	#1	0.9806 (0.0110)	0.9803 (0.0113)	0.9333 (0.0205)	1.0000 (<0.0001)	0.9967 (0.0345)
	#2	0.9758 (0.0138)	0.9752 (0.0141)	0.9527 (0.0205)	0.9805 (0.0151)	0.9944 (0.0206)
	#3	0.9912 (0.0087)	0.9734 (0.0151)	0.9478 (0.0218)	0.9902 (0.0120)	1.0000 (<0.0001)
	#4	0.9920 (0.0078)	0.9840 (0.0112)	0.9843 (0.0114)	1.0000 (0.0075)	1.0000 (<0.0001)
	#5	0.9920 (0.0078)	0.9919 (0.0079)	0.9504 (0.0215)	0.9673 (0.0189)	0.9905 (0.0096)
	#6	0.9742 (0.0127)	1.0000 (<0.0001)	0.9781 (0.0135)	0.9855 (0.0129)	0.9594 (0.0224)
	F-test	0.6342	0.8435	1.0881	0.9839	0.6524
	P-value	0.6736	0.5185	0.3646	0.4258	0.6597

Release Site	Tagger	Release to Rkm 234	Rkm 234 to 153	Rkm 153 to 113	Rkm 113 to 86
Hood River Steelhead	#1	0.9745 (0.0126)	0.9416 (0.0190)	1.0000 (<0.0001)	1.0000 (<0.0001)
	#2	0.9669 (0.0162)	0.9600 (0.0190)	0.9891 (0.0117)	1.0000 (<0.0001)
	#3	0.9732 (0.0152)	0.9565 (0.0202)	0.9900 (0.0120)	1.0000 (<0.0001)
	#4	0.9687 (0.0156)	0.9429 (0.0212)	1.0000 (<0.0001)	0.9875 (0.0238)
	#5	0.9920 (0.0078)	0.9785 (0.0140)	0.9945 (0.0110)	1.0000 (<0.0001)
	#6	0.9430 (0.0187)	0.9151 (0.0239)	0.9846 (0.0138)	0.9620 (0.0314)
	F-test	1.1524	1.1703	0.3951	0.9084
	P-value	0.3303	0.3211	0.8525	0.4743

3.8 Estimates of Dam Passage Survival

The estimates of dam passage survival were based on the virtual/paired-release design using capture history data (Appendix A) and the fitted tag-life curve (Figure 3.5). The estimate was based on the tag-life-adjusted survival estimates for releases V_1, R_2, and R_3. A total of six detection sites were used in the analysis (Figure 2.1) to assure all available information was used in the estimation process. However, because the downriver detection probabilities were very high, often much higher than 0.90 at each location, fewer arrays could have been used with very little or no change in the resulting estimates.

3.8.1 Yearling Chinook Salmon

The estimate of dam passage survival was based on the survival of V_1 to detection array D_1 divided by an estimate of reach survival between the tailrace array (rkm 307) and D_1. Using the tag-life-adjusted survival estimates for yearling Chinook salmon smolts (Table 3.7), dam passage survival at The Dalles Dam was calculated to be

$$\hat{S}_{\text{TDA}} = \frac{\hat{S}_1}{\left(\dfrac{\hat{S}_2}{\hat{S}_3}\right)} = \frac{0.9406}{\left(\dfrac{0.9710}{0.9952}\right)} = \frac{0.9406}{(0.9757)} = 0.9641$$

with an associated standard error of 0.0096. The standard error is based on both the multinomial sampling error of the release-recapture process and the sampling error associated with the estimation of the probabilities of tag activation (Table 3.1).

The estimate of dam survival for yearling Chinook salmon at The Dalles in 2010 exceeded the BiOp requirement for $\hat{S}_{\text{Dam}} \geq 0.96$ and the standard error requirement of $\widehat{\text{SE}} \leq 0.015$.

Table 3.7. Tag-Life-Adjusted Survival Estimates of Reach Survival and Detection Probabilities for Yearling Chinook Salmon Smolts Used in Estimating Dam Passage Survival at The Dalles Dam in 2010. Parameter estimates based on fully parameterized release-recapture models for each group. Standard errors (SE) based on both the inverse hessian matrix and bootstrapping for key parameters (†) and only the inverse hessian matrix for associated parameters (*).

Survival Probabilities

Release Group	Rkm 309 to 275		Rkm 275 to 234		Release to Rkm 234		Rkm 234 to 153		Rkm 153 to 113		Rkm 113 to 86.2	
	Estimate	SE†	Estimate	SE*	Estimate	SE†	Estimate	SE*	Estimate	SE*	Estimate	SE*
V_1	0.9406	0.0053	0.9836	0.0030	---	---	0.9547	0.0051	0.9934	0.0024	0.9944	0.0021
R_2	---	---	---	---	0.9710	0.0084	0.9431	0.0086	0.9995	0.0017	0.9940	0.0033
R_3	---	---	---	---	0.9952	0.0060	0.9556	0.0076	0.9963	0.0029	0.9967	0.0029

Detection Probabilities

Release Group	D_1		D_2		D_3		D_4		D_5		λ Survival × Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*	Estimate	SE*	Estimate	SE*	Estimate	SE*
V_1	0.9995	0.0005	0.9950	0.0017	0.8080	0.0095	0.9393	0.0058	0.9480	0.0054	0.9771	0.0038
R_2	---	---	0.9944	0.0028	0.8025	0.0148	0.9370	0.0091	0.9530	0.0080	0.9835	0.0050
R_3	---	---	0.9973	0.0019	0.7973	0.0147	0.9285	0.0095	0.9388	0.0089	0.9695	0.0066

3.8.2 Steelhead

Using the tag-life-adjusted survival estimate for the three release groups (Table 3.8), dam passage survival for steelhead smolts at The Dalles Dam was estimated to be

$$\hat{S}_{\text{TDA}} = \frac{0.9527}{\left(\frac{0.9785}{0.9792}\right)} = \frac{0.9527}{0.9993} = 0.9534$$

with an associated standard error of 0.0097. Although the estimated standard error met BiOp requirement of $\widehat{\text{SE}} \le 0.015$, the point estimate for steelhead smolts did not meet the BiOp requirement of $\hat{S} \ge 0.96$.

3.9 Estimates of 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 ($V1$) was composed of fish known to have arrived at the forebay (i.e., detection array rkm 311, Figure 2.1) rather than at the dam face. Although the capture history data for V_1 changed (Appendix A, Table A1), the same capture-history data were used for releases R_2 and R_3 (Appendix A, Table A2). Using the same statistical model as was used in estimating dam passage survival, forebay-to-tailrace survival for yearling Chinook salmon was

$$\hat{S}_{\text{forebay-to-tailrace}} = 0.9620\left(\widehat{\text{SE}} = 0.0097\right)$$

and for steelhead,

$$\hat{S}_{\text{forebay-to-tailrace}} = 0.9526\left(\widehat{\text{SE}} = 0.0097\right).$$

As might be expected, the forebay-to-tailrace survival estimates are slightly lower than the respective estimates of dam passage survival due to the additional travel distance above the dam. The Fish Accords do not have compliance standards for either the forebay-to-tailrace survival estimates or its standard error. Nevertheless, standard errors for the estimates of dam passage survival and forebay-to-tailrace should be similar because of the very similar sample sizes used in both calculations.

3.10 Forebay Residence Time

The forebay residence times were based on the times from the first detection within 100 m of the dam face to the last detection at the double array in front of The Dalles Dam. The timing of the first detection within 100 m of the dam was based on 3D tracking of the acoustic-tagged fish and interpretation of the time when the fish first crossed the 100-m distance threshold.

Distribution of forebay residence times ranged from 0.02 h to 6.86 h for yearling Chinook salmon and from 0.02 h to 259.12 h for steelhead (Figure 3.10). Mean residence time for yearling Chinook salmon smolts was estimated to be $\overline{t} = 0.40$ ($\widehat{\text{SE}} = 0.014$, $n = 1522$). For steelhead smolts, mean forebay residence time was estimated to be $\overline{t} = 1.88$ ($\widehat{\text{SE}} = 0.253$, $n = 1487$) (Table 3.9).

Table 3.8. Tag-Life-Adjusted Survival Estimates of Reach Survival and Detection Probabilities for Steelhead Smolts Used in Estimating Dam Passage Survival at The Dalles Dam in 2010. Parameter estimates based on fully parameterized release-recapture models for each group. Standard errors (SE) based on both the inverse hessian matrix and bootstrapping for key parameters (†) and only the inverse hessian matrix for associated parameters (*).

Survival Probabilities

Release Group	Rkm 309 to 275		Rkm 275 to 234		Release to Rkm 234		Rkm 234 to 153		Rkm 153 to 113		Rkm 113 to 86.2	
	Estimate	SE†	Estimate	SE*	Estimate	SE†	Estimate	SE*	Estimate	SE*	Estimate	SE*
V_1	0.9527	0.0048	0.9766	0.0035	---	---	0.9395	0.0059	0.9858	0.0036	0.9875	0.0036
R_2	---	---	---	---	0.9785	0.0078	0.9602	0.0075	0.9911	0.0042	0.9962	0.0037
R_3	---	---	---	---	0.9792	0.0075	0.9511	0.0080	0.9962	0.0031	1.0004	0.0036

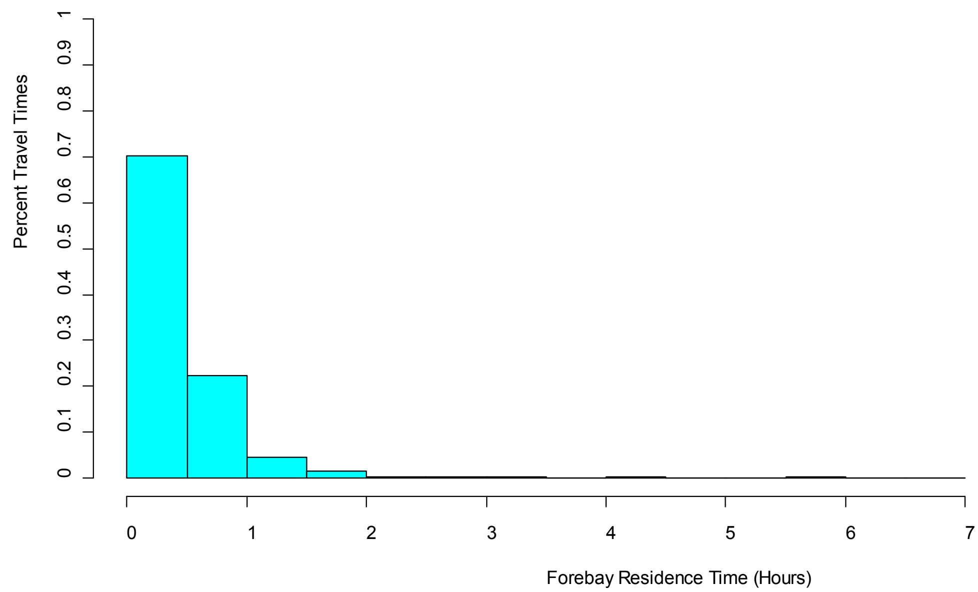
Detection Probabilities

Release Group	D_1		D_2		D_3		D_4		D_5		λ Survival × Capture	
	Estimate	SE*	Estimate	SE*	Estimate	SE*	Estimate	SE*	Estimate	SE*	Estimate	SE*
V_1	0.9984	0.0009	0.9972	0.0013	0.7457	0.0106	0.9272	0.0064	0.9418	0.0061	0.8955	0.0078
R_2	---	---	0.9986	0.0014	0.7779	0.0153	0.9299	0.0095	0.9489	0.0085	0.9117	0.0108
R_3	---	---	0.9959	0.0024	0.7620	0.0158	0.9201	0.0101	0.9325	0.0098	0.8926	0.0119

Table 3.9. Estimated Mean Forebay Residence Time (h) and Mean Tailrace Egress Time for Yearling Chinook Salmon and Steelhead Smolts at The Dalles Dam in 2010

Performance Measure	Yearling Chinook Salmon	Steelhead
Forebay Residence Time	0.40 ($\widehat{SE}$ = 0.014)	1.8841 ($\widehat{SE}$ = 0.253)
Tailrace Egress	0.84 ($\widehat{SE}$ = 0.138)	0.97 ($\widehat{SE}$ = 0.211)

a. Yearling Chinook salmon



b. Steelhead

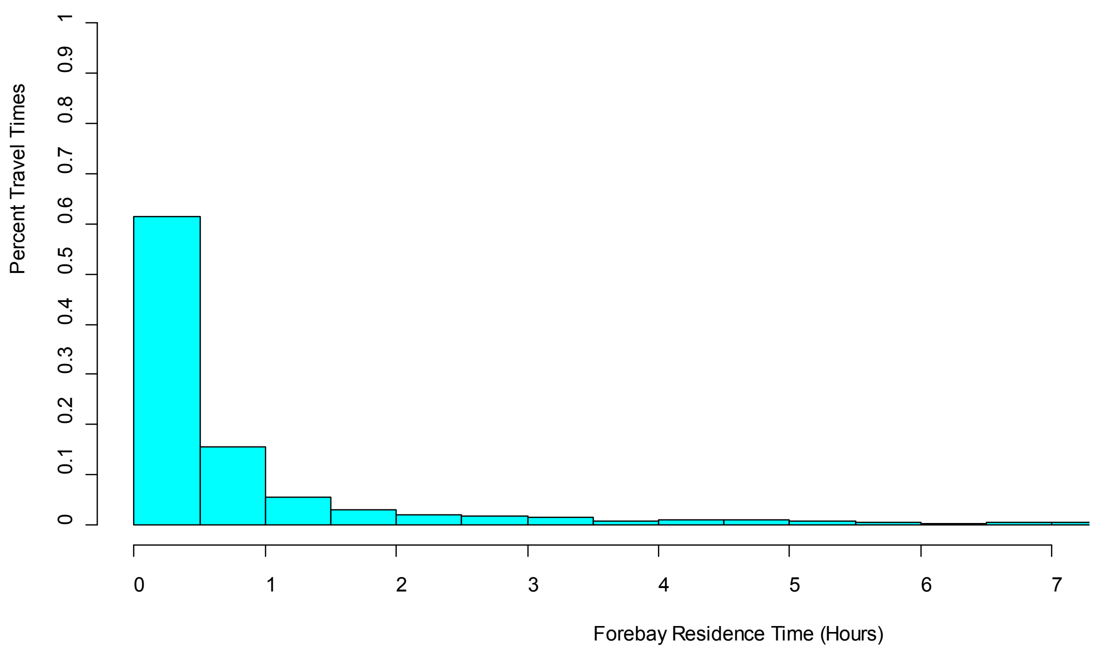
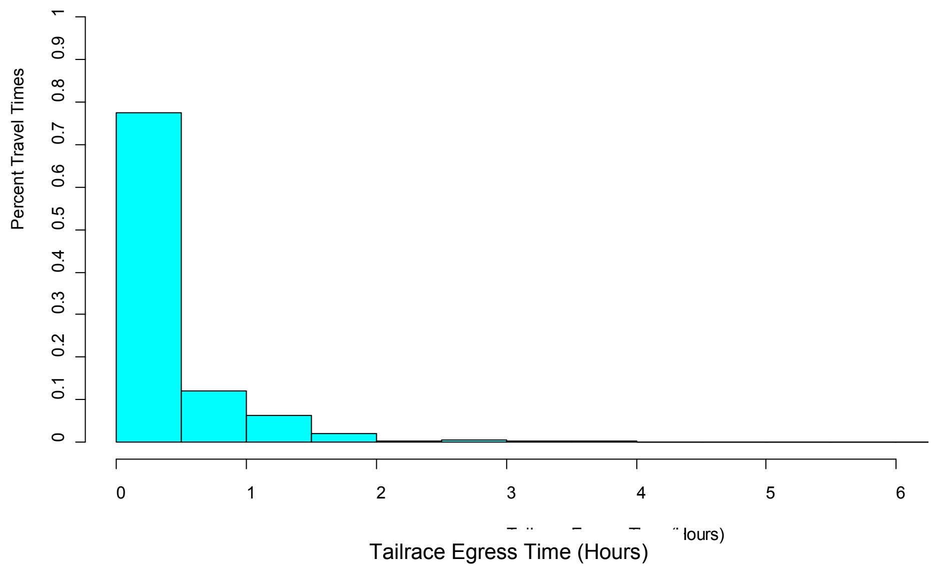


Figure 3.10. Distribution of Forebay Residence Times for (a) Yearling Chinook Salmon and (b) Steelhead Smolts at The Dalles Dam, 2010.

3.11 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 The Dalles Dam to the first detection at the BRZ tailrace array. The range of tailrace egress times for yearling Chinook was 0.10 h to 155.69 h, and for steelhead smolts was 0.10 h to 311.92 h (Figure 3.11). Mean tailrace egress time for yearling Chinook salmon smolts was estimated to be $\bar{t} = 0.84$ ($\widehat{\text{SE}} = 0.138$, $n = 1925$). For steelhead smolts, mean tailrace egress time was estimated to be $\bar{t} = 0.97$ ($\widehat{\text{SE}} = 0.211$, $n = 1938$) (Table 3.9).

a. Yearling Chinook salmon



b. Steelhead

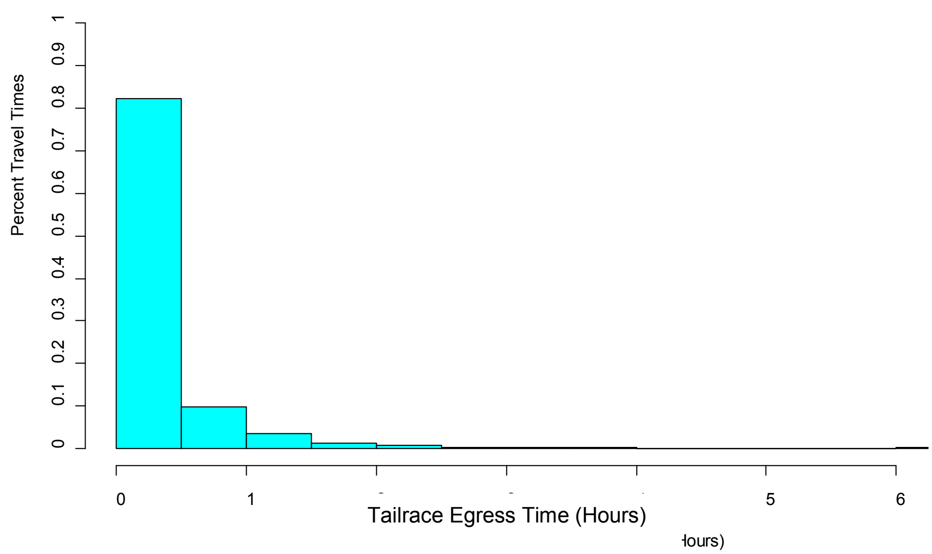


Figure 3.11. Distribution of Tailrace Egress Times for (a) Yearling Chinook Salmon and (b) Steelhead Smolts at The Dalles Dam, 2010

3.12 Estimates of Spill Passage Efficiency

Spill passage efficiency (SPE) is defined as the fraction of the fish that passed through a hydroproject by the spillway. The double-detection array at the face of The Dalles Dam was used to identify and track fish as they entered the forebay. Using the observed counts and assuming detection efficiency was 100%, the number of fish entering the spillway and powerhouse were used to estimate SPE using a binomial sampling model. For yearling Chinook smolts

$$\widehat{\text{SPE}}_{CH} = 0.8407\left(\widehat{\text{SE}} = 0.0081, n = 2040\right)$$

and for steelhead smolts

$$\widehat{\text{SPE}}_{ST} = 0.8765\left(\widehat{\text{SE}} = 0.0073, n = 2049\right).$$

4.0 Discussion

4.1 Historical Context

Historically, telemetry studies have been used to estimate survival rates for yearling Chinook salmon passing The Dalles Dam. For radio-tag studies conducted during 2002, 2004, and 2005 (Counihan et al. 2006a; 2006b; 2006c), survival estimates were generated using the route-specific survival model for radio-tagged fish released by boat in the tailraces of John Day Dam (treatment) and The Dalles Dam (control). As summarized by Johnson et al. (2007, p. 7.4), the mean dam survival rate for yearling Chinook salmon over the three study-years was 0.904.

During the yearling Chinook salmon migration in spring 2006, an acoustic-tag study was used to estimate passage survival at The Dalles Dam (Ploskey et al. 2007). The estimation process involved releases from the John Day and The Dalles Dam tailraces along with downstream detections at The Dalles Dam primary (rkm 275), The Dalles secondary (rkm 234), and Bonneville Dam primary (rkm 153) arrays. Project passage survival was estimated to be 0.928 (SE = 0.013) for yearling Chinook salmon. Steelhead were not tagged in 2006.

During 2008 and 2009, Weiland et al. (2009 and 2010, respectively) performed acoustic-tag studies for fish passage and survival at John Day Dam. These studies included releases and downstream detection arrays that allowed estimation of survival between forebay arrays at The Dalles and Bonneville dams. Specifically, tagged fish were released near Arlington, Oregon (rkm 390) and in the John Day Dam tailrace (rkm 343.4), and regrouped on The Dalles Dam forebay entrance array to create virtual releases for estimating single-release dam-passage survival rates for The Dalles Dam. Tag-life-corrected survival rates from 2 km upstream of The Dalles Dam to the Bonneville Dam forebay, estimated for yearling Chinook salmon and steelhead using a single-release model, were as follows (± ½ 95% CI):

Year	Yearling Chinook Salmon	Steelhead
2008	0.947 ± 0.007	0.959 ± 0.009
2009	0.947 ± 0.007	0.953 ± 0.008

Thus, the 2010 dam passage survivals of 0.964 for yearling Chinook salmon and 0.954 for steelhead are comparable to previous estimates, and were similar between the two tagged spring migrants. Although the 2010 results are new, they may not be unexpected. Passage survivals of yearling Chinook salmon and steelhead are often similar, and this was the case for this acoustic-tag study. Estimates of dam passage survival for the yearling Chinook salmon and steelhead were not significantly different $\left(P(|Z| \geq 0.7767) = 0.4373\right)$ at The Dalles Dam in 2010.

4.2 Statistical Performance

The BiOp requires estimates of dam passage survival with standard errors ≤ 0.015. The numbers of tagged fish released (Table 2.1) and the detection probabilities at the downstream hydrophone arrays (Table 3.1, Table 3.2) in spring 2010 were found to be adequate to achieve this precision requirement. Estimated standard errors for yearling Chinook salmon and steelhead were <0.01. Therefore, the number of tagged fish released for the survival studies in future years should be comparable to those used in 2010 to help assure precision requirements will be achieved. Should levels of hydrophone deployment change, the number of fish tagged may need to be reassessed.

4.3 Model Assumptions

The survival study at The Dalles Dam is the first full-scale application of the virtual/paired-release design of Skalski et al. (2010) in the FCRPS. The virtual-paired release design worked as conceived. The virtual release group (V_1) estimated smolt passage survival from the dam face to a downriver detection array at rkm 275. This array at rkm 275 was selected because it was sufficiently downriver to assure any fish that died during dam passage with a still active tag would not be detected on downstream arrays. A separate release of 50 dead fish with active tags from The Dalles Dam in 2010 resulted in no downstream detections at rkm 275. To account for the extra mortality between the tailrace and the detection array at rkm 275, a paired release using groups R_2 and R_3 was used to estimate reach survival in the upper part of the Bonneville reservoir. The quotient of the survival estimates from the virtual release (V_1) and paired release (R_2 and R_3) was the basis for the estimates of dam passage survival in this report.

Auxiliary analyses found no tagger effects (Table 3.5, Table 3.6) that might confound estimation of dam passage survival. Graphs of arrival timing (Figure 3.8, Figure 3.9) indicate the release timing of the different tag groups was appropriate for adequate downstream mixing of fish. Travel times were also sufficiently short relative to tag life to adequately adjust the release-recapture data for tag failure (Figure 3.6, Figure 3.7). In all cases, the probability that an acoustic tag was active at a downstream detection location was >0.98 (Table 3.1, Table 3.2). The distribution of fish lengths for steelhead smolts used in the tagging study was comparable to the ROR steelhead sampled at John Day Dam by the Fish Passage Center (FPC) (Figure 3.2). For yearling Chinook salmon, fewer small fish and fewer big fish were used in the tagging study than in the observed length frequency distribution sampled at John Day Dam by the FPC (Figure 3.3). Overall, the spring 2010 acoustic-tag studies at The Dalles Dam appear to have been well executed and without flaws that could negate the study results.

In this first year of compliance testing, detection data from all the downstream detection arrays to the mouth of the Columbia River (Figure 2.1) were used in the analysis. This was done intentionally to assure everyone that all available information was used in the survival analysis. However, with individual hydrophones often having detection probabilities much greater than 0.90, little additional information is truly available in the far-field arrays. A separate sensitivity analysis supports this conclusion. In future years, only the three nearest downstream hydrophone arrays will be used in the survival analysis to simplify procedures and avoid any perceived conflicts due to apparent arbitrary detection array selection.

5.0 References

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Appendix A
Capture History Data

Table A.1. Capture Histories at Sites $D_1 - D_6$ (Figure 2.1) for Release Group *V*1 for Chinook Salmon and Steelhead Used in Estimating Dam Passage Survival and BRZ-to-BRZ Survival. A "1" Denotes Detection, "0" Denotes Nondetection, and "2" Denotes Detection and Censoring Due to Removal.

Capture History	Dam Passage Survival		BRZ-to-BRZ Survival	
	Chinook Salmon (V_1)	Steelhead (V_1)	Chinook Salmon (V_1)	Steelhead (V_1)
1 1 1 1 1 1:	1219	997	1219	996
0 1 1 1 1 1:	1	0	1	0
1 0 1 1 1 1:	4	1	4	1
0 0 1 1 1 1:	0	0	0	0
1 1 0 1 1 1:	270	318	270	318
0 1 0 1 1 1:	0	0	0	0
1 0 0 1 1 1:	3	0	3	0
0 0 0 1 1 1:	0	0	0	0
1 1 1 0 1 1:	67	58	67	58
0 1 1 0 1 1:	0	0	0	0
1 0 1 0 1 1:	1	1	1	1
0 0 1 0 1 1:	0	0	0	0
1 1 0 0 1 1:	21	32	21	32
0 1 0 0 1 1:	0	0	0	0
1 0 0 0 1 1:	0	1	0	1
0 0 0 0 1 1:	0	0	0	0
1 1 1 1 0 1:	55	62	55	62
0 1 1 1 0 1:	0	0	0	0
1 0 1 1 0 1:	0	0	0	0
0 0 1 1 0 1:	0	0	0	0
1 1 0 1 0 1:	19	18	19	18
0 1 0 1 0 1:	0	0	0	0
1 0 0 1 0 1:	0	0	0	0
0 0 0 1 0 1:	0	0	0	0
1 1 1 0 0 1:	9	2	9	2
0 1 1 0 0 1:	0	0	0	0
1 0 1 0 0 1:	0	0	0	0
0 0 1 0 0 1:	0	0	0	0
1 1 0 0 0 1:	4	5	4	5
0 1 0 0 0 1:	0	0	0	0
1 0 0 0 0 1:	0	0	0	0
0 0 0 0 0 1:	0	0	0	0
1 1 1 1 2 0:	0	0	0	0
0 1 1 1 2 0:	0	0	0	0
1 0 1 1 2 0:	0	0	0	0
0 0 1 1 2 0:	0	0	0	0
1 1 0 1 2 0:	0	0	0	0
0 1 0 1 2 0:	0	0	0	0
1 0 0 1 2 0:	0	0	0	0
0 0 0 1 2 0:	0	0	0	0
1 1 1 0 2 0:	0	0	0	0
0 1 1 0 2 0:	0	0	0	0

Capture History	Dam Passage Survival		BRZ-to-BRZ Survival	
	Chinook Salmon (V_1)	Steelhead (V_1)	Chinook Salmon (V_1)	Steelhead (V_1)
1 0 1 0 2 0:	0	0	0	0
0 0 1 0 2 0:	0	0	0	0
1 1 0 0 2 0:	0	0	0	0
0 1 0 0 2 0:	0	0	0	0
1 0 0 0 2 0:	0	0	0	0
0 0 0 0 2 0:	0	0	0	0
1 1 1 1 1 0:	28	103	28	103
0 1 1 1 1 0:	0	0	0	0
1 0 1 1 1 0:	1	1	1	1
0 0 1 1 1 0:	0	0	0	0
1 1 0 1 1 0:	8	40	8	40
0 1 0 1 1 0:	0	0	0	0
1 0 0 1 1 0:	0	0	0	0
0 0 0 1 1 0:	0	0	0	0
1 1 1 0 1 0:	1	12	1	12
0 1 1 0 1 0:	0	0	0	0
1 0 1 0 1 0:	0	0	0	0
0 0 1 0 1 0:	0	0	0	0
1 1 0 0 1 0:	1	10	1	10
0 1 0 0 1 0:	0	0	0	0
1 0 0 0 1 0:	0	0	0	0
0 0 0 0 1 0:	0	0	0	0
1 1 1 2 0 0:	0	0	0	0
0 1 1 2 0 0:	0	0	0	0
1 0 1 2 0 0:	0	0	0	0
0 0 1 2 0 0:	0	0	0	0
1 1 0 2 0 0:	0	0	0	0
0 1 0 2 0 0:	0	0	0	0
1 0 0 2 0 0:	0	0	0	0
0 0 0 2 0 0:	0	0	0	0
1 1 1 1 0 0:	7	23	7	23
0 1 1 1 0 0:	0	0	0	0
1 0 1 1 0 0:	0	1	0	1
0 0 1 1 0 0:	0	0	0	0
1 1 0 1 0 0:	5	6	5	6
0 1 0 1 0 0:	0	0	0	0
1 0 0 1 0 0:	0	0	0	0
0 0 0 1 0 0:	0	0	0	0
1 1 2 0 0 0:	0	0	0	0
0 1 2 0 0 0:	0	0	0	0
1 0 2 0 0 0:	0	0	0	0
0 0 2 0 0 0:	0	0	0	0
1 1 1 0 0 0:	11	21	11	21
0 1 1 0 0 0:	0	0	0	0
1 0 1 0 0 0:	0	0	0	0
0 0 1 0 0 0:	0	0	0	0
1 2 0 0 0 0:	57	68	0	0
0 2 0 0 0 0:	0	0	0	0

Capture History	Dam Passage Survival		BRZ-to-BRZ Survival	
	Chinook Salmon (V_1)	Steelhead (V_1)	Chinook Salmon (V_1)	Steelhead (V_1)
1 1 0 0 0 0:	88	118	88	118
0 1 0 0 0 0:	0	3	0	2
2 0 0 0 0 0:	0	0	0	0
1 0 0 0 0 0:	34	48	91	117
0 0 0 0 0 0:	123	99	125	101
Total	2037	2048	2039	2049

Table A.2. Capture Histories at Sites $D_2 – D_6$ (Figure 2.1) for Release Groups R_1 and R_2 for Chinook Salmon and Steelhead Used in Estimating Dam Passage Survival and BRZ-to-BRZ Survival. A "1" Denotes Detection, "0" Denotes Nondetection, and "2" Denotes Detection and Censoring Due to Removal.

Capture History	Chinook Salmon		Steelhead	
	Release Group R_2	Release Group R_3	Release Group R_2	Release Group R_3
1 1 1 1 1:	503	503	456	436
0 1 1 1 1:	4	2	0	2
1 0 1 1 1:	119	121	132	124
0 0 1 1 1:	0	0	0	0
1 1 0 1 1:	35	37	31	30
0 1 0 1 1:	0	0	0	0
1 0 0 1 1:	8	12	13	16
0 0 0 1 1:	0	0	0	0
1 1 1 0 1:	24	31	23	30
0 1 1 0 1:	0	0	0	0
1 0 1 0 1:	8	11	8	8
0 0 1 0 1:	0	0	0	0
1 1 0 0 1:	1	2	2	2
0 1 0 0 1:	0	0	0	0
1 0 0 0 1:	0	0	1	3
0 0 0 0 1:	0	0	0	1
1 1 1 2 0:	0	0	0	0
0 1 1 2 0:	0	0	0	0
1 0 1 2 0:	0	0	0	0
0 0 1 2 0:	0	0	0	0
1 1 0 2 0:	0	0	0	0
0 1 0 2 0:	0	0	0	0
1 0 0 2 0:	0	0	0	0
0 0 0 2 0:	0	0	0	0
1 1 1 1 0:	7	17	49	48
0 1 1 1 0:	0	0	0	0
1 0 1 1 0:	4	3	8	20
0 0 1 1 0:	0	0	1	0
1 1 0 1 0:	0	1	4	5
0 1 0 1 0:	0	0	0	0
1 0 0 1 0:	1	1	0	1
0 0 0 1 0:	0	0	0	0
1 1 2 0 0:	0	0	0	0

Capture History	Chinook Salmon		Steelhead	
	Release Group R_2	Release Group R_3	Release Group R_2	Release Group R_3
0 1 2 0 0:	0	0	0	0
1 0 2 0 0:	0	0	0	0
0 0 2 0 0:	0	0	0	0
1 1 1 0 0:	3	1	6	4
0 1 1 0 0:	0	0	0	0
1 0 1 0 0:	2	3	0	1
0 0 1 0 0:	0	0	0	0
1 2 0 0 0:	0	0	0	0
0 2 0 0 0:	0	0	0	0
1 1 0 0 0:	1	3	6	3
0 1 0 0 0:	0	0	0	0
2 0 0 0 0:	0	1	0	0
1 0 0 0 0:	45	37	34	40
0 0 0 0 0:	31	11	25	24
Total	796	797	799	798

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