PNNL-20095 Rev 1

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Under a Government Order with the U.S. Department of Energy
Contract DE-AC05-76RL01830

Monitoring of Subyearling Chinook Salmon Survival and Passage at Bonneville Dam, Summer 2010

Summary Report

GR Ploskey
MA Weiland
TJ Carlson

September 2012

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Pacific Northwest National Laboratory
Richland, Washington 99352

Preface

This study was conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers (USACE) Portland District. The PNNL project manager was Dr. Thomas J. Carlson. The USACE technical lead was Mr. Brad Eppard. The study was designed to estimate dam and tailwater passage survival at Bonneville Dam using a single-release survival model, and provides conservative estimates of survival relative to requirements of the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp; NOAA 2008). The study also provides additional performance measures at that site as stipulated in the Columbia Basin Fish Accords.

This summary report focuses on the summer run of subyearling Chinook salmon. A separate summary report presented the findings of the yearling Chinook salmon and steelhead survival studies at Bonneville Dam during spring 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.

This report was originally published in February 2011. It was revised in August 2012, based on review comments from the Studies Review Work Group of these USACE's Anadromous Fish Evaluation Program. This revision of the summer 2010 summary report forf Bonneville Dam changed survival, efficiency, and travel time estimates to match estimates published in the final technical report. Survival estimates in the first summary report published in February 2011 were made using Atlas software that was designed to make tag-life corrections for a single-release survival model but not for a virtual single-release model (VSRM). In May 2011, Atlas software was updated to allow a virtual release of fish when the single-release model was used, and subsequent calculations of tag-life corrections for the VSRM were accurate for the final report. There also were sample size differences between the initial summary report and the final technical report that resulted in slight differences in metric estimates. Fish sampled in juvenile bypass systems were excluded from samples used to estimate metrics for the final report and for this revision of the summary report, but those fish were incorrectly included in earlier samples for the initial summary report. This revision of the report also provides greater detail on the fate of fish collected for tagging, including the number and percent of collected fish that died before surgery or that were excluded from tagging for various reasons, tagged, or rejected from tagging because of maladies. Appendix A was rearranged to improve the logic of the table presentation.

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Executive Summary

Researchers at the Pacific Northwest National Laboratory collaborated with others at the Pacific States Marine Fisheries Commission, U.S. Army Corps of Engineers Portland District, and the University of Washington To conduct a 2010 study primarily to estimate survival rates of subyearling Chinook salmon smolts passing through 1) the Bonneville Dam forebay, 2) the forebay, dam, and 81 km of tailwater, and 3) through the dam and its various routes and 81 km of tailwater. The study also estimated additional passage performance measures, most of which were stipulated in the Columbia Basin Fish Accords, evaluated effects of two spill treatments on passage and survival metrics, and evaluated the performance of behavioral guidance device (BGS) in the Powerhouse 2 (B2) forebay.

The 2010 study was not an official compliance test as described by the 2008 Federal Columbia River Power System Biological Opinion, because passage conditions for the dam had not been finalized. The Powerhouse 1 (B1) sluiceway was expanded for 2010 to roughly triple the amount of flow passing through surface flow outlets from the B1 forebay, but flow was not accurately measured in 2010 and some of the floating sluiceway gates were sticking during the fish passage season. Both should be remedied for 2011. In addition, regional fishery managers wanted to add one more year of evaluation of a BGS installed in the B2 forebay. Managers also wanted to evaluate effects of two spill treatments on fish-passage metrics and survival in summer 2010. One spill treatment consisted of 24-h 95,000 cfs spill and the other consisted of 85,000 cfs day and 120,000 cfs night spill. Unit 11, which is adjacent to the Bonneville Powerhouse 2 Corner Collector (B2CC) and critical for proper functioning of that surface flow outlet, was out of service throughout 2010. The Portland District also wanted researchers to evaluate the performance of two independent cabled arrays deployed on every dam face (B1, the spillway, and B2) to make certain that the arrays would be ready for an official compliance test in 2011.

Acoustically tagged subyearling Chinook salmon smolts released in the Columbia River upstream of John Day Dam (near Arlington, Oregon), in The Dalles tailrace, and in the tailwater near Hood River, Oregon, that were detected either at the Bonneville Dam forebay entrance array or at the face of the dam were available to form virtual releases. Single-release passage-survival estimates were made for fish passing through two river reaches: 1) the dam and 81 km of tailwater and 2) the forebay, dam, and 81 km of tailwater. A total of 4449 subyearling Chinook salmon smolts were tagged and released to support survival studies at John Day Dam, The Dalles Dam, and Bonneville Dam in summer 2010. The Juvenile Salmon Acoustic Telemetry System tag model number ATS-156dB, weighing 0.438 g in air, was used in this investigation.

This report provides a concise summary of summer 2010 results, except for route-specific passage survival estimates, which will be provided in a comprehensive report in 2011. Dam-passage survival to the Bonneville tailrace could not be estimated in 2010 because there were no reference releases of fish in the Bonneville tailrace. Forebay-to-tailrace survival could not be estimated for the same reason.

The study results are summarized in the following tables.

Table ES.1. Passage Survival Estimates by Source of Subyearling Chinook Salmon Smolts Used to Form Virtual Releases at the Dam Face During the Entire Summer Study (06/13 through 07/20) and During Days When Spill Treatments were Delivered Successfully (07/02 through 07/18). Survival is for the reach from Bonneville Dam (CR234) to the primary array located 81 km downstream (CR153).

Performance Measures	Year	All Summer (6/13 to 7/20)[a]	During 24-h 95,000-cfs Spill (7/2 to 7/18)[b]	During 85,000-cfs Day and 120,000-cfs Night Spill (7/2 to 7/18)[b]
Passage Survival (dam and 81 km of tailwater)	2010	0.958 ($\widehat{SE}$ = 0.0055)	0.926 ($\widehat{SE}$ = 0.0089)	0.903 ($\widehat{SE}$ = 0.0111)

(a) The survival estimate for the entire summer study was based on virtual releases of fish regrouped from The Dalles tailrace and Hood River, Oregon, releases only because virtual release survival for fish released upstream of John Day and The Dalles dams near Roosevelt, Washington, was significantly lower than that of fish releases in the Bonneville pool.
(b) Survival estimates for the two spill treatments were based on virtual releases of fish regrouped from all upstream release sites to maximize power to detect differences.

Table ES.2. Performance Measures at Bonneville Dam in 2010 for Subyearling Chinook Salmon Smolts

Performance Measures	All Summer (6/13 to 7/20)[a]	During 24-h 95,000 cfs Spill (7/2 to 7/18)[b]	During 85,000 cfs Day and 120,000 cfs Night Spill (7/2 to 7/18)[b]
Passage Survival (forebay, dam, and 81 km of tailwater; CR236 to CR153)	0.956 ($\widehat{SE}$ = 0.0054)	0.926 ($\widehat{SE}$ = 0.0089)	0.9030 ($\widehat{SE}$ = 0.0111)
Spillway Passage Survival and 81 km of Tailwater (CR234 to CR153)	0.930 ($\widehat{SE}$ = 0.0062)	0.9241 ($\widehat{SE}$ = 0.0121)	0.8774 ($\widehat{SE}$ = 0.0169)
Forebay Residence Time	0.69; 1.14 ($\widehat{SE}$ = 0.042)	0.80; 1.23 ($\widehat{SE}$ = 0.061)	0.94; 1.66 ($\widehat{SE}$ = 0.166)
100 m Forebay Residence Time (Median; Mean)	0.13; 1.00 ($\widehat{SE}$ = 0.164)	0.28; 1.32 ($\widehat{SE}$ = 0.265)	0.47; 2.37 ($\widehat{SE}$ = 0.907)
Tailrace Egress Time (Median; Mean)	0.42; 1.45 ($\widehat{SE}$ = 0.259)	0.48; 0.88 ($\widehat{SE}$ = 0.101)	0.48; 0.89 ($\widehat{SE}$ = 0.093)
Project passage time (Median; Mean)	1.26; 2.58 ($\widehat{SE}$ = 0.245)	1.37; 2.12 ($\widehat{SE}$ = 0.120)	1.54; 2.59 ($\widehat{SE}$ = 0.199)
Spill passage efficiency (SPE)[c]	0.524 ($\widehat{SE}$ = 0.009)	0.561 ($\widehat{SE}$ = 0.017)	0.5299 ($\widehat{SE}$ = 0.019)
Spill + B2CC passage efficiency[d]	0.615 ($\widehat{SE}$ = 0.008)	0.676 ($\widehat{SE}$ = 0.016)	0.6579 ($\widehat{SE}$ = 0.018)

(a) The survival estimate for the entire summer study was based on virtual releases of fish regrouped from The Dalles tailrace and Hood River, Oregon, releases only. Other performance measures were based on fish from all upstream releases.
(b) Survival estimates for the two spill treatment were based on virtual releases of fish regrouped from all upstream release sites to maximize power to detect differences.
(c) SPE is the number of fish passing the spillway divided by the number passing the entire dam.
(d) Spill + B2CC passage efficiency is a metric specified by the 2008 Fish Accords.

Table ES.3. Survival Study Summary

Year: 2010

Study site(s): Bonneville Dam

Objective(s) of study: Estimate passage survival for subyearling Chinook salmon and associated performance measures; evaluate effects of two spill treatment effects; evaluate whether the behavioral guidance structure (BGS) in the B2 forebay improved B2CC passage efficiency.

Fish species-race: subyearling Chinook salmon (CH0) Source: John Day Dam fish collection facility	Implant procedure: Surgical: Yes; Injected: No

Size (median):	CH0	Sample size:	CH0
Weight:	12.4 g	# release sites:	3
Length:	110 mm	# releases	32
		Total # released:	4449

Tag type/model: Advanced Telemetry Systems (ATS)-156dB Weight (g): 0.438 g (air)	Analytical model: single release	Characteristics of estimate: single release survival estimates reflecting relative effects

Environmental/operating conditions (daily from 13 June – 17 July):
Discharge (kcfs): Mean 261, Min 165, Max 347
Temperature (deg C): Mean 17.08°, Min 15.0°, Max 19.4°
Total dissolved gas (tailrace): Mean 112%, Min 106%, Max 117%
Treatment(s): 24-h 95-kcfs spill versus 85-kcfs day spill and 120-kcfs night spill in 2-day blocks (07/02–7/18).
Unique study characteristics: Turbine Unit 11 was offline all year; first year B1 sluiceway was widened for increased discharge; the B2 BGS was installed in the B2 forebay; turbine intake extensions were installed at every other intake on north half of B2 (15A, 15C, 16B, 17A, 17C, 18B).

Subyearling Chinook Survival and Passage Estimates	All Summer (6/13 to 7/20) [a]	24-h 95-kcfs Spill (7/2 to 7/18) [b]	85-kcfs Day / 120-kcfs Night (7/2 to 7/18) [b]
Passage Survival (forebay, dam, and 81 km of tailwater; CR236 to CR153)	0.956 ($\widehat{SE}$ = 0.0054)	0.926 ($\widehat{SE}$ = 0.0089)	0.903 ($\widehat{SE}$ = 0.0111)
Passage Survival (dam + 81 km of tailwater)	0.958 ($\widehat{SE}$ = 0.0055)	0.926 ($\widehat{SE}$ = 0.0089)	0.903 ($\widehat{SE}$ = 0.0111)
Spillway Passage Survival and 81 km of Tailwater (CR234 to CR153)	0.930 ($\widehat{SE}$ = 0.0062)	0.924 ($\widehat{SE}$ = 0.0121)	0.877 ($\widehat{SE}$ = 0.0169)
Forebay Residence Time	0.69; 1.14 ($\widehat{SE}$ = 0.042)	0.80; 1.23 ($\widehat{SE}$ = 0.061)	0.94; 1.66 ($\widehat{SE}$ = 0.166)
100-m Forebay Residence Time (Median; Mean)	0.13; 1.00 ($\widehat{SE}$ = 0.164)	0.28; 1.32 ($\widehat{SE}$ = 0.265)	0.47; 2.37 ($\widehat{SE}$ = 0.907)
Tailrace Egress Time (Median; Mean)	0.42; 1.45 ($\widehat{SE}$ = 0.259)	0.48; 0.88 ($\widehat{SE}$ = 0.101)	0.48; 0.89 ($\widehat{SE}$ = 0.093)
Project Passage Time (Median; Mean)	1.26; 2.58 ($\widehat{SE}$ = 0.245)	1.37; 2.12 ($\widehat{SE}$ = 0.120)	1.54; 2.59 ($\widehat{SE}$ = 0.199)
Spill Passage Efficiency (SPE) [c]	0.524 ($\widehat{SE}$ = 0.009)	0.561 ($\widehat{SE}$ = 0.017)	0.5299 ($\widehat{SE}$ = 0.019)
Spill + B2CC Passage Efficiency [d]	0.615 ($\widehat{SE}$ = 0.008)	0.676 ($\widehat{SE}$ = 0.016)	0.6579 ($\widehat{SE}$ = 0.018)

(a) The survival estimate for the entire summer study was based on virtual releases of fish regrouped from The Dalles tailrace and Hood River, Oregon, releases only. Other performance measures were based on fish from all upstream releases.
(b) Survival estimates for the two spill treatments were based on virtual releases of fish regrouped from all upstream release sites to maximize power to detect differences.

Table ES.3. (contd)

(c) SPE is the number of fish passing the spillway divided by the number passing the entire dam.
(d) Spill + B2CC passage efficiency is a metric specified by the 2008 Fish Accords.

Results: This was not an official compliance test requiring paired reference releases, but single-release estimates for subyearling Chinook salmon still exceeded the 2008 Biological Opinion requirement of 0.93. SPE was as high as or higher than previously reported based on previous radio-telemetry and fixed aspect hydroacoustic studies. There were no significant differences between performance metrics under the two 1-day spill treatments tested, although SPE and spill + B2CC passage efficiency differed among some spill and day/night treatment combinations.

Table ES.4. Survival Study Summary Statistics by Spill Treatment During Day and Night Periods

Spill Treatment (7/2 to 7/18)	Survival Dam Passage + 81 km of Tailwater	Survival Spillway Passage + 81 km of Tailwater	Median Forebay Residence Time	Median 100 m Forebay Residence Time	Median Egress Time	Median Project Passage Time	Spill Passage Efficiency ‖ Dam	Spill + B2CC Passage Efficiency ‖ Dam
95-kcfs Day Spill	0.9241	0.9217	0.7674	0.4758	0.4775	1.3200	0.6262	0.7721
SE	0.0109	0.0140	0.0825	0.5173	0.0775	0.1166	0.0196	0.0170
n	621	382	614	58	590	595	610	610
95-kcfs Night Spill	0.9306	0.9323	0.8960	0.1672	0.5314	1.4732	0.4173	0.4640
SE	0.0154	0.0236	0.0732	0.1441	0.2757	0.2843	0.0296	0.0299
n	285	116	280	63	265	270	278	278
85-kcfs Day Spill	0.9077	0.8893	0.9949	0.6661	0.5047	1.6035	0.5092	0.6630
SE	0.0125	0.0189	0.2120	1.2116	0.1193	0.2553	0.0214	0.0202
n	553	278	552	93	519	520	546	546
120-kcfs Night Spill	0.8884	0.8454	0.7839	0.1851	0.4008	1.3338	0.5954	0.6416
SE	0.0237	0.0357	0.1623	0.3174	0.0790	0.1949	0.0373	0.0365
n	178	103	173	32	161	166	173	173
Difference in 95-kcfs Day & 95-kcfs Night?	No	No	No	No	No	No	**Yes**	**Yes**
Difference in 95-kcfs Day & 85-kcfs Day?	No	No	No	No	No	No	**Yes**	**Yes**
Difference in 95-kcfs Day & 120-kcfs Night?	No	No	No	No	No	No	No	**Yes**
Difference in 95-kcfs Night & 85-kcfs Day?	No	No	No	No	No	No	No	**Yes**
Difference in 95-kcfs Night & 120-kcfs Night?	No	No	No	No	No	No	**Yes**	**Yes**
Difference in 85-kcfs Day & 120-kcfs Night?	No	No	No	No	No	No	No	No

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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 (USACE) Portland District, 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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Acronyms and Abbreviations

°C	degree(s) Celsius
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
3D	three dimensional
B1	Bonneville Powerhouse 1
B2	Bonneville Powerhouse 2
B2CC	Bonneville Powerhouse 2 Corner Collector
BGS	behavioral guidance structure
BiOp	Biological Opinion
BON	Bonneville Dam
BRZ	boat-restricted zone
FCRPS	Federal Columbia River Power System
g	gram(s)
h	hour(s)
JDA	John Day Dam
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
PSMFC	Pacific States Marine Fisheries Commission
Rkm or rkm	river kilometer(s)
RME	research, monitoring, and evaluation
ROR	run-of-river
RPA	Reasonable and Prudent Alternative
SE	standard error
SPE	spill passage efficiency
TDA	The Dalles Dam
TR	tailrace
USACE	U.S. Army Corps of Engineers
UW	University of Washington

Contents

Figures

Tables

1.0 Introduction

The 2010 study documented in this report was conducted by researchers at the Pacific Northwest National Laboratory (PNNL) in collaboration with the Pacific States Marine Fisheries Commission (PSMFC), U.S. Army Corps of Engineers (USACE) Portland District, and the University of Washington (UW). The study was primarily designed to estimate the survival rates of subyearling Chinook salmon smolts passing through 1) the forebay, dam, and 81 km of tailwater; and 2) the dam and its various routes and 81 km of tailwater. The study also estimated additional passage performance measures (most of which were stipulated in the Columbia Basin Fish Accords), evaluated the effects of two spill treatments on passage and survival metrics, and evaluated the performance of the behavioral guidance structure (BGS) in the Powerhouse 2 (B2) forebay. After a Studies Review Work Group Meeting in January 2011, the two spill treatments also were split into day and night periods for additional testing.

The 2010 study was not an official compliance test as described in the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp; NOAA 2008), because passage conditions for the dam had not been finalized. The Powerhouse 1 (B1) sluiceway was expanded for 2010 to roughly triple the amount of flow passing through surface flow outlets from the B1 forebay, but flow was not accurately measured in 2010 and some of the floating sluiceway gates were sticking during the fish passage season. Both should be remedied for 2011. In addition, regional fishery managers wanted to add one more year of evaluation of the BGS installed in B2 forebay. Managers also wanted to evaluate the effects of two spill treatments on fish-passage metrics and survival in summer 2010. One spill treatment consisted of 24-h 95,000-cfs spill and the other consisted of 85,000-cfs day and 120,000-cfs night spill. Unit 11, which is adjacent to the B2 Corner Collector (B2CC) and critical for proper functioning of that surface flow outlet, was out of service throughout 2010. The USACE Portland District also wanted researchers to evaluate the performance of two independent cabled arrays deployed on every dam face (B1, the spillway, and B2) to make certain that the arrays would be ready for an official compliance test in 2011.

Acoustically tagged subyearling Chinook salmon smolts released in the Columbia River upstream of John Day Dam (near Roosevelt, Washington and Arlington, Oregon), in The Dalles tailrace, and in the tailwater near Hood River, Oregon, that were detected either at the Bonneville Dam forebay entrance array or at the face of the dam were available to form virtual releases. Single-release passage-survival estimates were made for fish passing through two river reaches: 1) the dam and 81 km of tailwater and 2) the forebay, dam, and 81 km of tailwater. A total of 4449 subyearling Chinook salmon smolts were tagged and released to support survival studies at John Day Dam, The Dalles Dam, and Bonneville Dam in summer 2010. The Juvenile Salmon Acoustic Telemetry System (JSATS) tag model number ATS-156dB, weighing 0.438 g in air, was used in this investigation.

1.1 Background

The 2008 FCRPS BiOp contains a Reasonable and Prudent Alternative (RPA) that includes actions calling for measurements of juvenile salmonid survival (RPAs 52.1 and 58.1). These RPAs are being addressed as part of the federal research, monitoring, and evaluation (RME) effort for the FCRPS BiOp. Most importantly, the FCRPS BiOp includes performance standards for juvenile salmonid survival in the

FCRPS against which the Action Agencies (Bonneville Power Administration, Bureau of Reclamation, and USACE) must compare their estimates, as follows (after the RME Strategy 2 of the RPA):

> Juvenile Dam-Passage Performance Standards – The Action Agencies juvenile performance standards are an average across Snake River and lower Columbia River dams of 96% 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 *2008 Columbia Basin Fish Accords Memorandum of Agreement [MOA] between the Three Treaty Tribes and FCRPS Action Agencies (3 Treaty Tribes and Action Agencies 2008)*, known informally as the Fish Accords,[1] 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.

1.2 Study Objectives and Scope

The purpose of summer 2010 monitoring at Bonneville Dam was to estimate performance measures outlined in the 2008 FCRPS BiOp and the Fish Accords for subyearling Chinook salmon using a single-release passage and survival model, evaluate B2 BGS performance, and evaluate the effects of two spill treatments in summer. The following metrics were estimated using the JSATS technology:

- In this report, dam-passage survival is defined as survival from the upstream face of the dam to the first survival array located 81 km downstream of Bonneville Dam. The survival estimate includes the mortality of fish in this 81-km river reach in addition to mortalities associated with dam passage. A single-release point estimate >93% also would exceed the BiOp standard for a paired-release estimate, because the single-release estimate is more conservative than the paired-release estimate.
- In this report, we present two estimates fish-passage efficiency estimates. SPE is defined as the number of fish passing through the spillway divided by the number passing the dam. We also provide an estimate of spill + B2CC passage efficiency, as specified in the 2008 Fish Accords.

[1] Available at http://www.salmonrecovery.gov/Files/BiologicalOpinions/MOA_ROD.pdf

- 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 time smolts take to travel from the dam to the downstream tailrace boundary.
- Survival from the forebay entrance array to the primary array 81 km downstream of the dam was estimated instead of forebay-to-tailrace survival, which was specified as BRZ-to-BRZ survival in the Fish Accords. Forebay to tailrace survival estimates require tailrace and tailwater reference releases that were not part of the 2010 study. We did provide a single-release estimate of survival from the forebay entrance array to the dam face.

This report is designed to provide a succinct and timely summary of BiOp/Fish Accords performance measures. A subsequent, comprehensive technical report scheduled for 2011 will provide more detailed data about route-specific passage and survival rates at Bonneville Dam in summer 2010. Dam-passage survival to the Bonneville tailrace could not be estimated in 2010 because there were no reference releases of fish in the Bonneville tailrace. Forebay to tailrace survival could not be estimated for the same reason. Therefore BiOp performance standards were not explicitly tested.

This report summarizes the results of the 2010 summer acoustic-telemetry study of subyearling Chinook salmon passage and survival at Bonneville Dam. This study is a precursor to a full-scale compliance study to be performed in 2011.

The study methods and results described in the ensuing sections of this report are reported by performance measure.

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 Bonneville Dam consisted of a combination of a virtual release of fish at the forebay entrance array or at the face of the dam and the detection of the same fish below the dam (Figure 2.1). Releases of tagged fish near Roosevelt, Washington, The Dalles tailrace, and Hood River, Oregon, supplied a source of fish known to have arrived alive at the forebay entrance array or at the face of Bonneville 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 to 81 km downstream of the dam (Figure 2.1). We were unable to account and adjust for this extra mortality in the tailwater because there were no paired releases of fish below Bonneville Dam. The sizes of the releases of the acoustic-tagged fish used in the dam-passage survival estimates are summarized in Table 2.1.

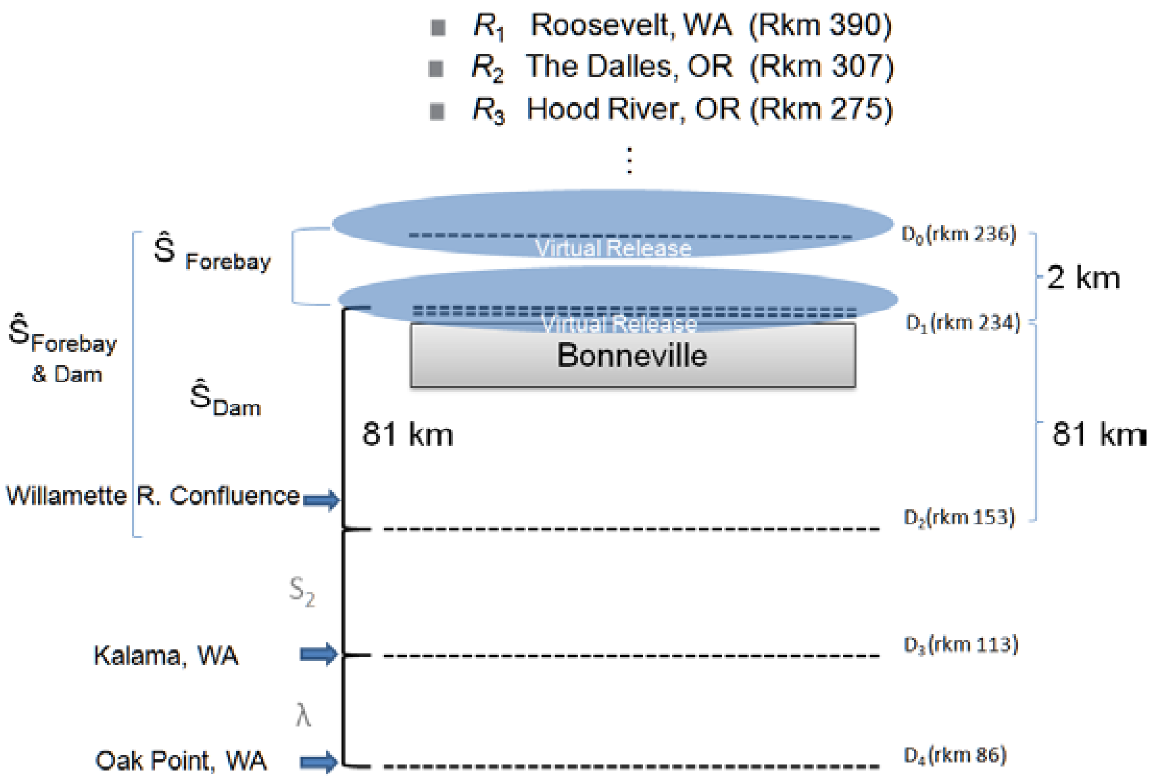

Figure 2.1. Schematic of the 2010 Study Design. The diagram shows the three releases of fish that could be regrouped to form virtual releases at the forebay entrance array (D_0) or dam-face array (D_1) and subsequent detections or non-detections on three downstream arrays (D_2, D_3, and D_4) that were used to create capture histories for estimating single-release survival rates down to the primary array (D_2).

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

Release Location	Released
Above John Day near Arlington, Oregon (R_1)	2849
The Dalles Dam Tailrace (R_2)	800
Bonneville Reservoir (R_3)	800

The three-dimensional (3D) double-detection array at the face of Bonneville Dam used to compose 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 and spill + B2CC passage efficiency. 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.

A total of 50 acoustic tags were randomly sampled from the tags used in the summer season for a tag-life assessment. The tags were activated, held in river water, and monitored continuously until they failed. The results of the tag-life study were available 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 (JBS) 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 summer 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 subyearling Chinook salmon smolts used in the study were all obtained from the John Day Dam JBS. The PSMCF diverted fish from the JBS into an examination trough, as described by Martinson et al. (2006). Fish ≥95 mm in length without malformations or excessive descaling (>20% total body surface) were selected for tagging.

2.2.3 Fish Collection

Juvenile salmonids were diverted from the JBS and then routed into a 1795-gal holding tank in the Smolt Monitoring Facility (SMF). About 150 to 200 smolts and other fishes were crowded with a panel net into a 20- by 24-in. pre-anesthetic chamber. The water level in the chamber was lowered to about 8 in. (48 L) at which point fish were anesthetized with 60 mL of a stock tricaine methanesulfonate (MS-222) solution prepared at a concentration of 50 g/L. Once they were anesthetized, the fish were routed into the examination trough. Technicians added MS-222 as needed to maintain sedation, and 5 to 10 mL of PolyAquaTM to reduce fish stress. Water temperatures were monitored in the main holding tank and in the examination trough, and water in the trough was refreshed before temperatures there increased more than 2°C above those observed in the main holding tank.

Once fish were in the examination trough, smolts targeted for surgical procedures were evaluated in accordance with the following criteria:

- Qualifying (Acceptable) Conditions
  - size ≥95 mm
  - visible elastomer tag(s) present or absent
  - adipose-fin clipped or unclipped
  - presence of trematodes, copepods, leeches
  - short operculum
  - healed (moderate) injuries (e.g., bird strikes)
  - ≤3% fungal patch
  - minor fin blood
  - partial descaling (3–19%)
  - steelhead (STH) with eroded pectoral or ventral fins (likely hatchery STH).
- Disqualifying Conditions
  - ≥20% descaling
  - body punctures (showing blood; e.g., predator marks, bird strikes, head wounds, nose/snout injuries)
  - obvious signs of bacterial kidney disease
  - eye hemorrhage or pop eye
  - >3% coverage with fungus
  - deformed or emaciated
  - holdovers (fish not "spring" yearling Chinook salmon [CH1] or "summer" subyearling Chinook salmon [CH0])
  - passive integrated transponder (PIT)- or radio-tagged or other post-surgical fishes
  - notable operculum damage (except short operculum)
  - presence of columnaris, furuncles
  - injured caudal peduncles
  - injured caudal fins
  - fin hemorrhage.

We summarized the number and percent of fish collected for tagging according to their fate (Table 2.2). Excluded fish were released to the river through the SMF holding system after a 30-minute recovery period. Accepted fish were counted and moved in approximately equal proportions to six 80-gal pre-surgery holding tanks, where they were held for 18 to 30 hours before surgery. The pre-surgery holding duration depended on the time of collection and the time of tagging on the next day. Fish that were rejected during the tagging process were placed in a recovery tank to allow anesthesia to wear off and then they were released back to the river through the bypass system. Most fish were tagged and released alive. We also tallied the number and percent of fish rejected from tagging because of maladies (Table 2.3) and excluded for other reasons (Table 2.4).

Table 2.2. Summary of the Number and Percent of Fish that Were Rejected, Excluded, Tagged and Released Alive, Tagged and Released Dead, or Exceeded the Daily Tagging Quota in 2010

Fate	CH0	
Statistics	n	%
Rejected[(a)]	430	7.6
Excluded[(b)]	330	5.8
Tagged and Released Live	4449	78.8
Tagged and Released Dead[(c)]	67	1.2
Extra Fish[(d)]	369	6.5
Collected	5645	100.0

(a) Because of maladies.
(b) Too short, too long, previously tagged, dead, wrong species, dropped, or jumped.
(c) Beyond overnight mortalities, others were sacrificed.
(d) Collected but not evaluated before the tagging quota was met.

Table 2.3. Number and Percent Rejected Because of Maladies

	CH0	
Malady Description	n	%
BKD	2	0.5
Descaling (≥20%)	226	52.6
Emaciated	1	0.2
Exophthalmia	5	1.2
Fin Rot	5	1.2
Fungus	9	2.1
Hemorrhaging	5	1.2
Lacerations	69	16.0
Lesions	26	6.0
Operculum Damage	33	7.7
Other	4	0.9
Parasites	34	7.9
Skeletal Deformities	11	2.6
Total	430	100.0

Table 2.4. Number and Percent Excluded from Tagging for Other Reasons

	CH0	
Reason for Exclusion	n	%
Moribund	2	0.6
Previously tagged	120	36.4
< 95 or > 260 mm	202	61.2
Wrong species	5	1.5
Dropped/Jumped	1	0.3
Total	330	100.0

2.2.4 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 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 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 18 to 24 h before being transported for release into the river. The loading rate was five fish per bucket.

2.2.5 Release Procedures

All fish were tagged at John Day Dam and transported by truck to the three release locations (Table 2.5). 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 35 consecutive days (from June 13 to July 17, 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 for The Dalles Dam study (Table 2.5).

Table 2.5. Relative Release Times for the Acoustic-Tagged Fish to Accommodate Downstream Mixing for The Dalles Dam Study. Releases were timed to accommodate the approximately 60-h travel time between R_1 and R_2 and the 13-h travel time between R_2 and R_3.

	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: 2000 h	Day 5: 0900 h
R_3 (rkm 275)	Day 4: 0900 h	Day 5: 2200 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 offices in North Bonneville and Richland, Washington, 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 data set 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 used during processing of autonomous node data:

- Multipath filter: Same as for the cabled-array data.
- 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 preceded passage at a dam based on spatial tracking of tagged fish movements to a location of last detection. Multiple receptions of messages within an event can be used to triangulate successive tag positions relative to hydrophone locations.

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 deviated 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.

Tagged fish in the immediate forebay of Bonneville Dam were tracked in three dimensions to determine routes of passage to estimate SPE and spill + B2CC 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. (2009) for John Day Dam.

2.4 Statistical Methods

The estimation of passage survival; tag-life analysis; need for tests of assumptions; and the estimation of travel times, B2CC passage efficiency, SPE, and spill + B2 passage efficiency are described below.

2.4.1 Estimation of Passage Survival

A joint likelihood model was used to estimate passage survival for two river reaches: 1) from the forebay entrance array, through the forebay, the dam, and tailwater downstream to CR153, and 2) from dam face, through the dam and tailwater downstream to CR153. Capture histories from all virtual releases through three downstream arrays (Figure 2.1), both daytime and nighttime, were pooled for the analysis to produce a single season-wide estimate of survival for each river reach of interest. Virtual releases also were formed from fish arriving at the forebay or dam-face array during one of two spill treatments consisting of either 24-h 95-kcfs spill or 85-kcfs day/120-kcfs night spill. All single-release survival calculations and tag-life corrections were performed using Program ATLAS (http://www.cbr.washington.edu/paramest/atlas/).

2.4.2 Tag-Life Analysis

The 50 acoustic tags systematically sampled from the tags used in the subyearling Chinook salmon study 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 written as

$$f(t) = 1 - \left[\Phi\left(\frac{1 - rt}{\sqrt{u^2 + s^2 t}} \right) - e^{\left(\frac{2u^2 r^2}{s^4} + \frac{2r}{s^2} \right)} \Phi\left(\frac{2u^2 r + rt + 1}{\sqrt{u^2 + s^2 t}} \right) \right]^{e^{-kt}} \quad (2.1)$$

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 234, 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 following quotient:

$$P\left(t_1 \middle| t_0\right) = \frac{S(t_1)}{S(t_0)}. \quad (2.2)$$

2.4.3 Tests of Assumptions

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 of 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

There were no downstream reference releases of fish downstream of Bonneville Dam and therefore there was no need to test for mixing in the common tailwater.

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 on the survival of subyearling Chinook salmon were evaluated as part of the compliance study at The Dalles Dam (Skalski et al. 2010a).

2.4.4 Estimation of Travel Times

Travel times associated with forebay residence, tailrace egress, and project passage were estimated using medians and arithmetic averages. A few fish with high travel times tended to bias means upward relative to median estimates. The variance of $\bar{t}$ was estimated by

$$\widehat{\text{Var}}(\bar{t}) = \frac{\sum_{i=1}^{n}(t_i - \bar{t})^2}{n(n-1)} \tag{2.3}$$

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

Methods for estimating travel times were as follows:

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

2.4.5 Estimation of B2CC Passage Efficiency

The passage efficiency of the B2CC for each run was estimated relative to absolute numbers passing B2, as follows:

$$\widehat{\text{B2CCE}}_{B2} = \frac{\hat{N}_{B2CC}}{\hat{N}_{B2CC} + \hat{N}_{B2\_JBS} + \hat{N}_{B2\_Turbine}} \tag{2.4}$$

where $\hat{N}_{B2CC}$ is the estimated abundance of acoustic-tagged fish passing through the B2CC; $\hat{N}_{B2\_JBS}$ is the estimated abundance of fish passing through the B2 JBS; and $\hat{N}_{B2\_Turbine}$ is the estimated abundance of fish passing through B2 turbines. A 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 B2CCE relative to B2 was estimated as

$$\text{Var}\left(\widehat{\text{B2CCE}}\right) = \frac{\widehat{\text{B2CCE}}\left(1-\widehat{\text{B2CCE}}\right)}{\sum_{i=1}^{3}\hat{N}_i} + \widehat{\text{B2CCE}}^2\left(1-\widehat{\text{B2CCE}}\right)^2 \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{B2CC}\right)}{\left(\hat{N}_{B2CC}\right)^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{B2\_JBS}\right)}{\hat{N}_{JBS}^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{B2\_Turbine}\right)}{\hat{N}_{B2\_Turbine}^2}\right]. \tag{2.5}$$

2.4.6 Estimation of Spill Passage Efficiency

Traditionally, SPE is the number of fish passing the spillway divided by the number passing the entire dam. SPE was estimated by the fraction

$$\widehat{\text{SPE}} = \frac{\hat{N}_{SP}}{\hat{N}_{SP} + \hat{N}_{PH}} \tag{2.6}$$

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

$$\text{Var}\left(\widehat{\text{SPE}}\right) = \frac{\widehat{\text{SPE}}\left(1-\widehat{\text{SPE}}\right)}{\sum_{i=1}^{3}\hat{N}_i} + \widehat{\text{SPE}}^2\left(1-\widehat{\text{SPE}}\right)^2 \cdot \left[\frac{\widehat{\text{Var}}\left(\hat{N}_{SP}\right)}{\left(\hat{N}_{SP}\right)^2} + \frac{\widehat{\text{Var}}\left(\hat{N}_{PH}\right)}{\hat{N}_{PH}^2}\right]. \tag{2.7}$$

2.4.7 Estimation of Spill + B2CC Passage Efficiency

By definition in the Fish Accords, another metric is required and that is the number of fish passing the spillway and the B2CC divided by the number passing the dam. It is estimated as follows:

$$\widehat{\text{SPE}}_{Spill+B2CC} = \frac{(\hat{N}_{SP} + \hat{N}_{B2CC})}{\hat{N}_{SP} + \hat{N}_{PH}} \tag{2.8}$$

where $\hat{N}_i$ is the estimated abundance of acoustic-tagged fish through the *i*th route (i = spillway [SP], the B2CC, or powerhouse 1 and 2 combined [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 SPE was estimated as follows:

$$\mathrm{Var}\left(\mathrm{SPE}_{Spill+B2CC}\right) = \frac{\mathrm{SPE}_{Spill+B2CC}\left(1 - \mathrm{SPE}_{Spill+B2CC}\right)}{\sum_{i=1}^{3}\hat{N}_i} + \mathrm{SPE}_{Spill+B2CC}{}^{2}\left(1 - \mathrm{SPE}_{Spill+B2CC}\right)^{2}$$

$$\cdot \left[\frac{\mathrm{Var}\left(\hat{N}_{SP} + \hat{N}_{B2CC}\right)}{\left(\hat{N}_{SP} + \hat{N}_{B2CC}\right)^{2}} + \frac{\mathrm{Var}\left(\hat{N}_{PH}\right)}{\hat{N}_{PH}^{2}}\right]. \qquad (2.9)$$

3.0 Results

Results are described for discharge and spill conditions, assessed assumptions, passage survival estimates, spill treatment effects on survival rates, estimated travel times, SPE and spill + B2CC passage efficiency, and the effects of spill treatments during day and night periods.

3.1 Discharge and Spill Conditions

Before July 4th, daily project discharge was much higher than the average of daily estimates for the previous 10-year period and close to the 10-year average between July 5 and July 30 (Figure 3.1). Daily spill discharge was above daily averages for the previous 10-year period on all but 1 day of the summer study.

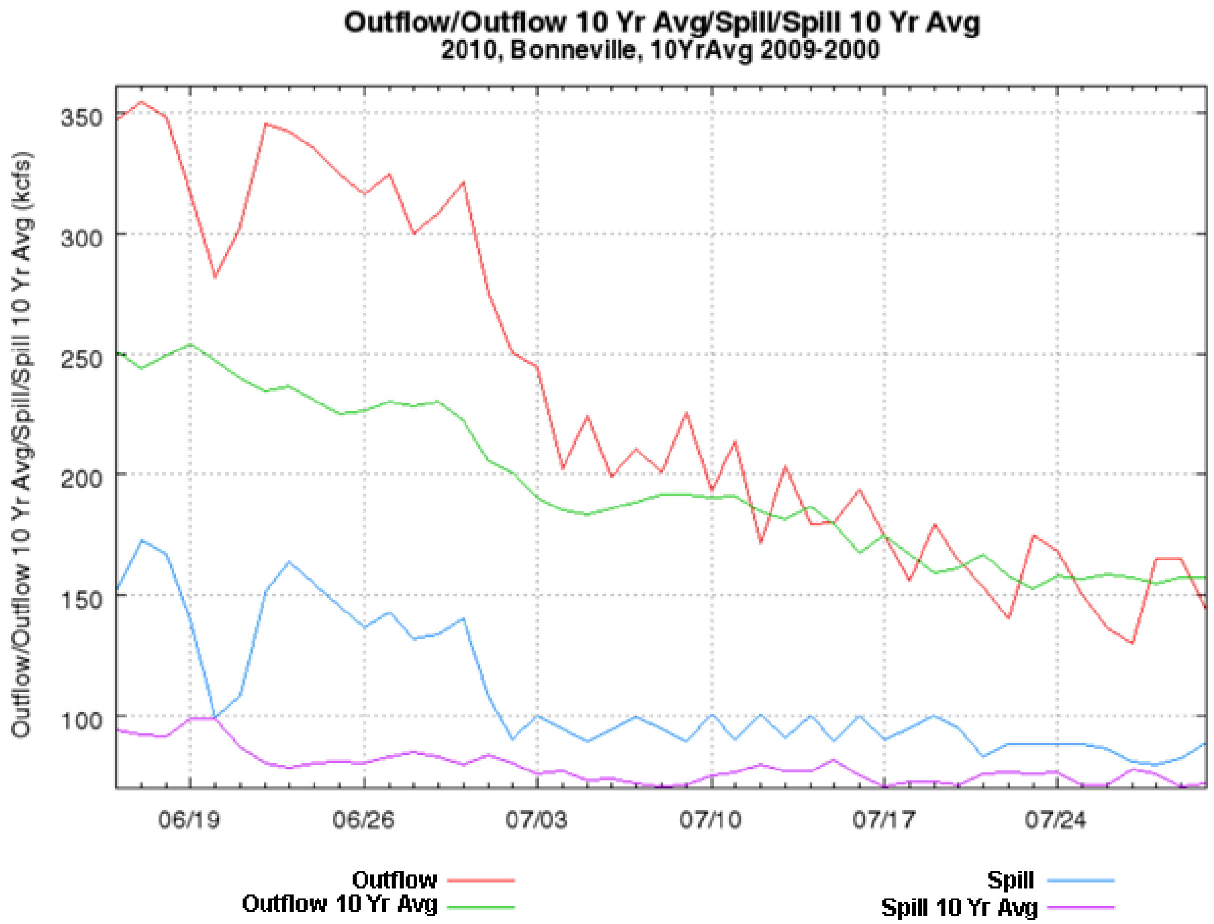

Figure 3.1. Daily Outflow and Spill Discharge of Water from Bonneville Dam for the Period from June 16 through July 30, 2010 (Outflow and Spill) and the 10-Year Averages from 2000 Through 2009

Prescribed spill treatments were only realized after river discharge declined to levels where dam operators had sufficient control to deliver eight 2-day blocks of spill treatments (Figure 3.2). Each 2-day treatment block consisted of one randomly selected 1-day spill treatment followed by another day with the alternative treatment. Spill treatments consisted of either 24 h of 95-kcfs spill or 85-kcfs day and 120-kcfs night spill.

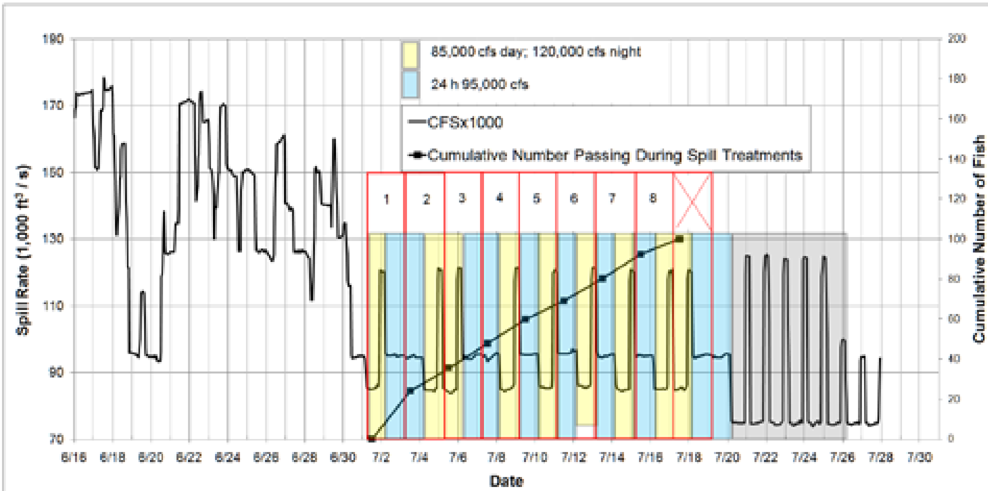

Figure 3.2. Plot of Spill Discharge Rate During Summer 2010 Showing Eight Successfully Realized Spill Treatment Blocks. Each block consisted of one randomly selected 1-day treatment followed by the alternative treatment.

3.2 Assessment of Assumptions

The assessment of assumptions covers fish size distribution, tag-life-corrections, handling mortality, tag shedding, tagger effects, and arrival distributions relative to tag life. Mixing of fish releases was not a consideration in 2010 because there were no reference releases of fish downstream of the dam.

3.2.1 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 subyearling Chinook salmon (Figure 3.3). The tagged fish had less representation in the 95- to 100–mm and 105- to 110-mm categories than the ROR fish. No fish less than 95 mm were tagged. The length distributions for the three subyearling Chinook salmon releases were quite similar, and the median length of tagged fish across the course of the study remained stable (Skalski et al. 2010a).

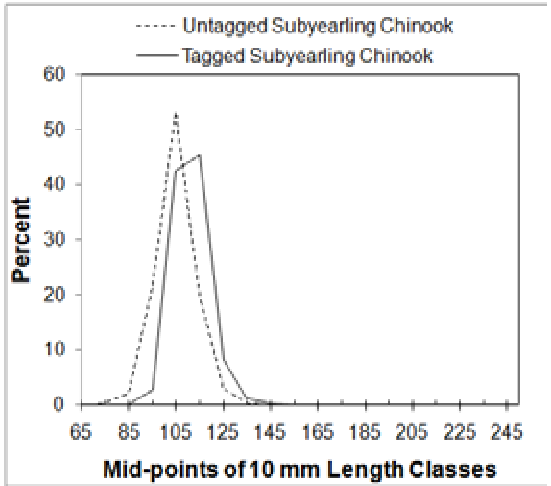

Figure 3.3. Relative Length Frequency Distributions of Tagged and Untagged Subyearling Chinook in John Day Smolt Monitoring Facility Samples in Summer 2010

3.2.2 Tag-Life Corrections

In summer, mean tag life (n = 50) was 35.54 days. The earliest tag failure was at 31.27 days and the latest at 40.13 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 $\hat{r}$ = 0.028261, $\hat{s}$ = - 2.91111×10^{-9}, $\hat{k}$ = 0, and $\hat{u}$ = 0.058789. This tag-life survivorship model (Figure 3.4) could have been used to estimate the probabilities of tag failure and provide tag-life-adjusted estimates of smolt survival but no correction was required for summer 2010 data. All subyearlings passed survival-detection arrays before there was any tag failure, and consequently, uncorrected Cormack-Jolly-Seber point estimates were identical to tag-life-corrected point estimates.

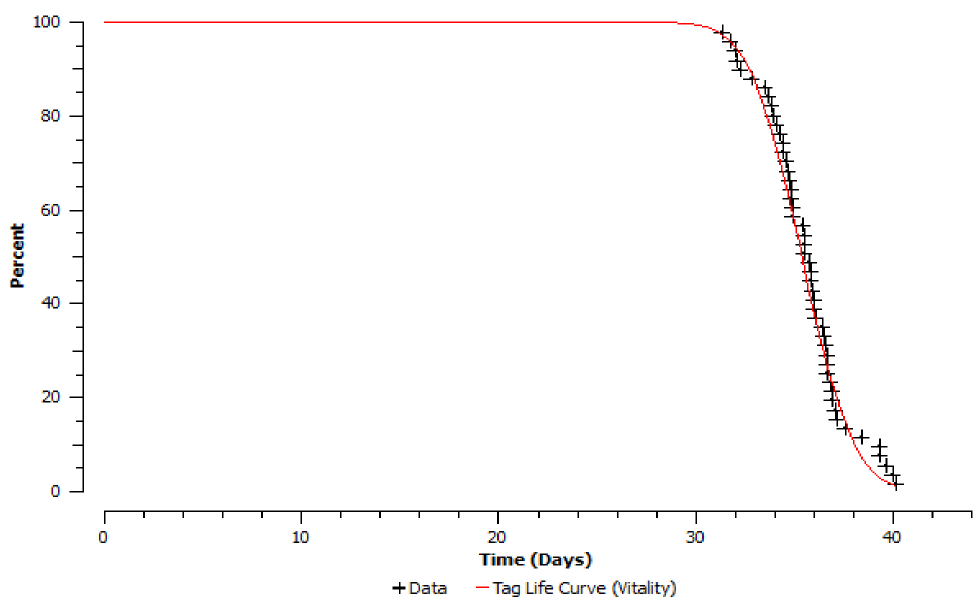

Figure 3.4. Individual Failure Times for the n = 50 Acoustic Tags Used in the Summer Tag-Life Study, Along with the Fitted Four-Parameter Vitality Model of Li and Anderson (2009)

3.2.3 Handling Mortality and Tag Shedding

Fish were held for 24 h prior to release. The 24-h tagging mortality in summer was 0.22%. No tags were shed during the 24-h holding period.

3.2.4 Tagger Effects

Having various fish handlers tag the same proportions of fish for release at each of the release sites can help minimize, but did not necessarily eliminate, handling effects in the estimate of dam-passage survival. The study was therefore designed to balance tagger effort across locations. Implementation produced near-perfect balance for the tagged subyearling Chinook salmon (Skalski et al. 2010a). 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. Significant (P<0.05.) heterogeneity was detected. However, further examination indicated that seasonal trends in survival were confounding attempts to assess the presence of tagger effects using the F-tests because the effect of the various taggers was not evenly distributed across the course of the study (Skalski et al. 2010a). Furthermore, when fish tagged by different staff during the same time periods were examined, survivals rates were homogeneous with no obvious evidence of any tagger effect. Therefore, fish tagged by all taggers were included in the analysis for this report.

3.2.5 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). The estimated probability of a tag in fish from the various release groups being functional when detected at the different survival detection arrays was 100%. Therefore, no tag-life corrections to survival rates were applied to summer 2010 data.

The last distinct detection array used in the survival analysis was rkm 86.2 (Figure 3.5). Plots of the arrival distributions of the three release groups (i.e., V_1, R_2, and R_3) to that array indicate that all subyearling Chinook salmon arrived well before tag failure became problematic. Tag-life adjustments to survival estimates would be incomplete if fish had arrival times beyond the range of observed tag lives.

3.3 Passage Survival Estimates

As described in this section, we first compared single-release survival estimates from the dam face (CR234) to the primary array (CR153) for fish from each of the three upstream release sites. The objective was to determine whether we could reasonably pool fish from different release sites to estimate survival. Second, for releases that could be pooled into virtual releases, we estimated single-release survival rates for fish passing through two reaches of river: 1) from the forebay entrance array (CR236) through the dam and 81 km of tailwater to the primary array (CR153), and 2) from the dam face through the dam and 81 km of tailwater to the primary array (CR153). All capture histories, passage-survival estimates, and capture probabilities for the reach-specific estimates are presented in the appendix and are summarized in the following sections.

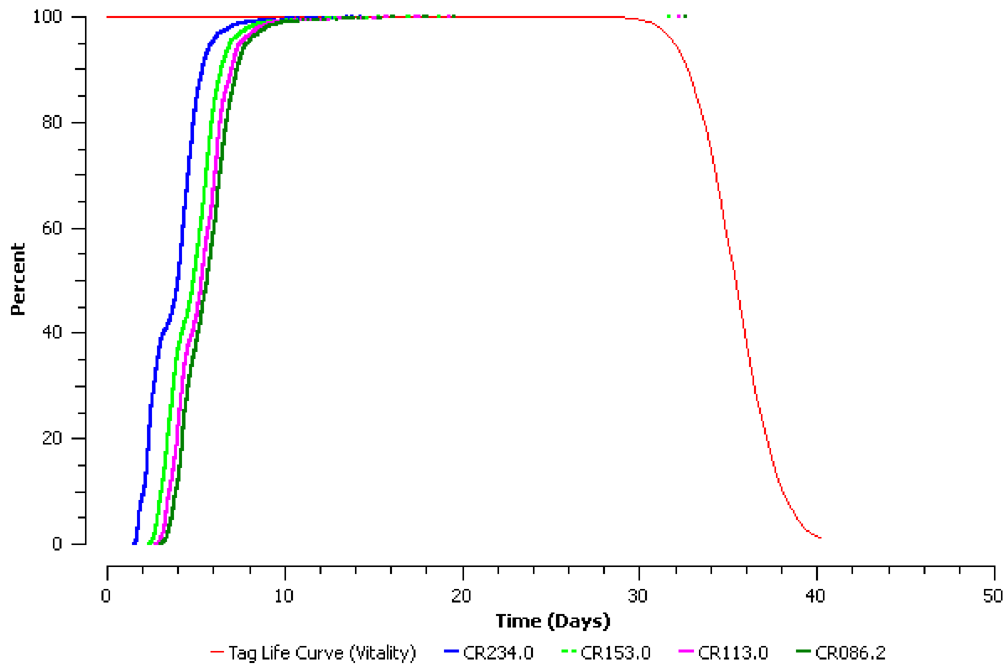

Figure 3.5. Plot of the Fitted Tag-Life Survivorship Curve and the Arrival-Time Distributions of Subyearling Chinook Salmon Smolts for Releases V_1, R_2, and R_3 at the Acoustic-Detection Array Located at rkm 86.0 (Figure 2.1)

3.3.1 Effect of Fish Release Site on Survival Estimates

For each of the upstream fish release sites, we compared dam-face (CR234) virtual release survival estimates downstream through 81 km of tailwater to array CR153. We found that the survival of fish released in the Bonneville pool (i.e., in The Dalles Dam (TDA) tailrace or at Hood River, Oregon) was 2.3 to 2.6% higher than that of fish released above John Day Dam (JDA) (Table 3.1; Figure 3.6). We did not pool fish released above JDA near Roosevelt, Washington (Arlington, Oregon) with fish released in the pool just upstream of Bonneville Dam (BON) to evaluate survival for the entire summer study, because of the appearance of a tag-effect for subyearlings traveling from Roosevelt through two dams to reach BON. However, we did pool fish from all upstream releases to evaluate the effects of spill or day and night treatments because those estimates are relative to one another.

Table 3.1. Estimates of Single Release Survival and Standard Errors for Subyearlings Released at Three Sites Upstream of Bonneville Dam and Regrouped at the Dam Face to Form Virtual Releases for Estimating Passage Survival Through the Dam and 81 km of Tailwater

Release Location	Survival from CR234 (BON) to CR153	Standard Error
Roosevelt, Washington/Arlington, Oregon (CR390)	0.933	0.0058
The Dalles Tailrace (CR307)	0.956	0.00783
Hood River, Oregon (CR275	0.959	0.00758

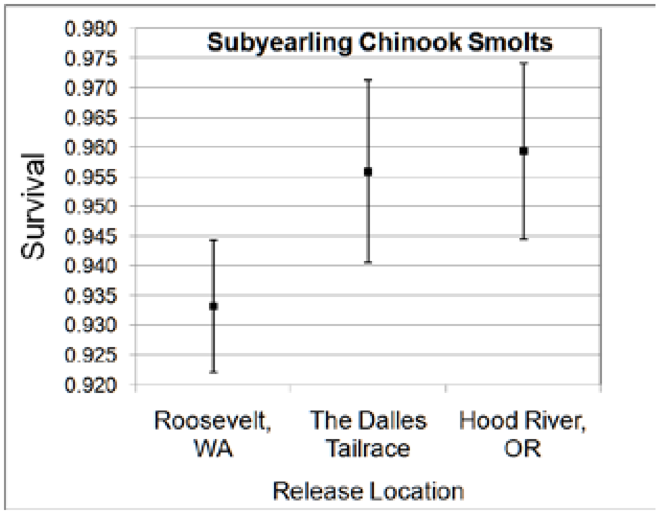

Figure 3.6. Plot of Single-Release Survival Estimates and 95% Confidence Intervals for Subyearlings Released at Three Sites Upstream of Bonneville Dam and Regrouped at the Dam Face to Form Virtual Releases for Estimating Survival from the Dam to a Tailwater Array Located 81 km Downstream of the Dam (Figure 2.1)

3.3.2 Passage Survival Through BON and 81 km of Tailwater

The dam-face virtual release survival estimate for subyearlings passing through the dam (CR234) and 81 km of tailwater to array CR153 was (0.958; $\widehat{SE}$ = 0.0055) for summer 2010, and there was no obvious difference in survival between the two spill treatments based on virtual releases of fish from all upstream release sites. Survival under the 95-kcfs spill treatment was 0.9262 ($\widehat{SE}$ = 0.0089), and survival under the 85-kcfs day and 120-kcfs night spill treatment was 0.9030 ($\widehat{SE}$ = 0.0111). The summer estimate for passage of subyearlings through the dam and 81 km of tailwater exceeded the BiOp requirement for dam to tailrace passage using a paired-release model.

3.3.3 Passage Survival Through the Forebay, Dam, and 81 km of Tailwater

Forebay virtual release survival estimates from CR236 to an array located 81 km downstream of BON (CR153) was 0.956 ($\widehat{SE}$ = 0.0054) for summer 2010. The point estimate under the 95-kcfs spill treatment based on regrouping fish from all upstream releases (0.926; $\widehat{SE}$ = 0.0089) was 2.32% higher than the estimate under the 85-kcfs day/120-kcfs night spill treatment (0.903; $\widehat{SE}$ = 0.0111), although overlapping 95% confidence intervals suggest that this difference was not significant.

3.4 Spill Treatment Effects on Survival Rates

None of the survival estimates differed significantly between the two 24-h spill treatments tested in summer 2010 based upon overlap of 95% confidence intervals (Table 3.2). In addition, none of the travel time estimates differed significantly among spill treatments during day and night periods (i.e., 95-kcfs day spill, 95-kcfs night spill, 85-kcfs day spill, and 120-kcfs night spill).

Table 3.2. Passage Survival and 95% Confidence Interval Estimates for Two River Reaches During Two Spill Treatments

	24-h 95-kcfs Spill			85-kcfs Day/120-kcfs Night Spill		
Survival Metric	Point Estimate	Lower 95% CI	Upper 95% CI	Point Estimate	Lower 95% CI	Upper 95% CI
Virtual releases formed from fish from all upstream releases						
Forebay Entrance to CR153	0.9261	0.9087	0.9435	0.9030	0.8813	0.9247
Dam Face to CR153	0.9262	0.9088	0.9436	0.9030	0.8813	0.9247
Spillway to CR153	0.9241	0.9004	0.9478	0.8774	0.8443	0.9105
Virtual releases formed from fish from Roosevelt, Washington, only (CR390)						
Dam to CR153	0.8956	0.8675	0.9237	0.8766	0.8430	0.9102

3.5 Travel Time Estimates

We estimated median, mean, and standard error of the mean travel times for subyearlings passing through four river reaches around BON (Table 3.3). None of the travel time metrics differed significantly between the two spill treatments, based upon overlap of 95% confidence intervals.

Table 3.3. Travel Time Estimates for Subyearlings Passing Through Three Reaches near Bonneville Dam

Subyearling Chinook Survival and Passage Estimates	All Summer	24-h 95-kcfs Spill	85-kcfs Day/120-kcfs Night Spill
Median forebay residence time	0.69 ($\widehat{SE}$ = 0.042)	0.80 ($\widehat{SE}$ = 0.062)	0.94 ($\widehat{SE}$ = 0.167)
Median100-m forebay residence time	0.13 ($\widehat{SE}$ = 0.164)	0.27 ($\widehat{SE}$ = 0.267)	0.47 ($\widehat{SE}$ = 0.914)
Median tailrace egress time	0.42 ($\widehat{SE}$ = 0.259)	0.48 ($\widehat{SE}$ = 0.089)	0.48 ($\widehat{SE}$ = 0.064)
Median project passage time	1.26 ($\widehat{SE}$ = 0.245)	1.37 ($\widehat{SE}$ = 0.110)	1.53 ($\widehat{SE}$ = 0.189)

3.6 Spill Passage Efficiency

In summer 2010, SPE was 0.524 ($\widehat{SE}$ = 0.0085), and there was no significant difference in SPE between the two spill treatments based on overlapping 95% confidence intervals. The SPE during the 95-kcfs spill treatment was 0.567 ($\widehat{SE}$ = 0.0167), and the estimate during the 85-kcfs day/120-kcfs night treatment was 0.534 ($\widehat{SE}$ = 0.0187). A ½ 95% confidence interval above or below a point estimate would be $\widehat{SE} \cdot 1.96$.

3.7 Spill + B2CC Passage Efficiency

Spill + B2CC passage efficiency in summer 2010 was 0.615 ($\widehat{SE}$ = 0.0083), and there was no significant difference in SPE between the two spill treatments based on overlapping 95% confidence intervals. The spill + B2CC passage efficiency during the 24-h 95-kcfs spill treatment was 0.683 ($\widehat{SE}$ = 0.0157), and the estimate during the 85-kcfs day/120-kcfs night treatment was 0.662

($\widehat{SE}$ = 0.0177). Again, a ½ 95% confidence interval above or below either point estimate would be $\widehat{SE} \cdot 1.96$.

3.8 Spill Treatment Effects During Day and Night Periods

Dam and spillway passage survival estimates and travel time estimates through four reaches near the dam did not differ significantly among spill treatments during day and night time periods, but there were significant differences observed for SPE and for spill + B2CC passage efficiency among treatments (Table 3.4). Estimates of SPE were higher during the 95-kcfs day treatment than during the 95-kcfs night treatment or during the 85-kcfs day treatment. SPE also was higher during the 120-kcfs night treatment than during the 95-kcfs night treatment. For spill + B2CC passage efficiency, the 95-kcfs day treatment was higher than the 95-kcfs night, 85-kcfs day, and 120-kcfs night treatments. The 95-kcfs night spill treatment provided lower spill + B2CC passage efficiency than the 85-kcfs day treatment and the 120-kcfs night treatment, but that efficiency was similar for the 85-kcfs day treatment and the 120-kcfs night treatment.

Table 3.4. Survival Study Summary Statistics by Spill Treatment During Day and Night Periods

Spill Treatment (7/2 to 7/18)	Survival Dam Passage + 81 km of Tailwater	Survival Spillway Passage + 81 km of Tailwater	Median Forebay Residence Time	Median 100 m Forebay Residence Time	Median Egress Time	Median Project Passage Time	Spill Passage Efficiency || Dam	Spill + B2CC Passage Efficiency || Dam
95-kcfs Day Spill	0.9241	0.9217	0.7674	0.4758	0.4775	1.3200	0.6262	0.7721
SE	0.0109	0.0140	0.0825	0.5173	0.0775	0.1166	0.0196	0.0170
n	621	382	614	58	590	595	610	610
95-kcfs Night Spill	0.9306	0.9323	0.8960	0.1672	0.5314	1.4732	0.4173	0.4640
SE	0.0154	0.0236	0.0732	0.1441	0.2757	0.2843	0.0296	0.0299
n	285	116	280	63	265	270	278	278
85-kcfs Day Spill	0.9077	0.8893	0.9949	0.6661	0.5047	1.6035	0.5092	0.6630
SE	0.0125	0.0189	0.2120	1.2116	0.1193	0.2553	0.0214	0.0202
n	553	278	552	93	519	520	546	546
120-kcfs Night Spill	0.8884	0.8454	0.7839	0.1851	0.4008	1.3338	0.5954	0.6416
SE	0.0237	0.0357	0.1623	0.3174	0.0790	0.1949	0.0373	0.0365
n	178	103	173	32	161	166	173	173
95-kcfs Day & 95 kcfs Night Different?	No	No	No	No	No	No	**Yes**	**Yes**
95-kcfs Day & 85 kcfs Day Different?	No	No	No	No	No	No	**Yes**	**Yes**
95-kcfs Day and 120-kcfs Night Different?	No	No	No	No	No	No	No	**Yes**

Table 3.4. (contd)

Spill Treatment (7/2 to 7/18)	Survival Dam Passage + 81 km of Tailwater	Survival Spillway Passage + 81 km of Tailwater	Median Forebay Residence Time	Median 100 m Forebay Residence Time	Median Egress Time	Median Project Passage Time	Spill Passage Efficiency ‖ Dam	Spill + B2CC Passage Efficiency ‖ Dam
95-kcfs Night and 85-kcfs Day Different?	No	No	No	No	No	No	No	**Yes**
95-kcfs Night and 120-kcfs Night Different?	No	No	No	No	No	No	**Yes**	**Yes**
85-kcfs Day and 120-kcfs Night Different?	No	No	No	No	No	No	No	No

4.0 Discussion

This section briefly discusses the reasonableness of primary survival model assumptions, the historical context for estimates, and the statistical performance of the double array and spill-treatment comparisons.

4.1 Reasonableness of Model Assumptions

The survival study at BON was a precursor to a full-scale application of the virtual/paired-release design of Skalski et al. (2010b) in the FCRPS in 2011, but the single-release survival model used in this study has some of the same assumptions as the virtual/paired-release design.

Overall, the primary assumptions of the single-release survival model used for this study were reasonable. Auxiliary analyses found no tagger effects that might confound estimation of dam-passage survival (Skalski et al. 2010a). Travel times were also sufficiently short relative to tag life in summer that no tag-life corrections were required to adjust the release-recapture data for tag failure. In all cases, the probability that an acoustic tag was active at a downstream detection location was 100%. The median mean length of subyearling Chinook salmon smolts used in the tagging study was only about 5 mm longer than the median length of ROR subyearlings sampled at John Day Dam by the Fish Passage Center. No tagger effects on survival were observed in summer 2010. Overall, the summer 2010 acoustic-tag studies at BON appear to have been well executed and lacked flaws that could negate study results.

4.2 Historical Context

No historical survival rates are exactly comparable to the estimates made for 2010. Historical estimates cover different river reaches than those used in 2010 and often were based on fish with different tag burdens being released at different locations upstream of the dam. This is not to say that comparisons to historical estimates would be meaningless or lack instructional value; it is just to say that every comparison differs in precision. Another problem in comparing estimates for subyearlings is that the timing and magnitude of a decrease in survival rate during summer varies among years. The falloff itself is partly related to increased mortality and partly to some individuals ceasing to migrate and being incorrectly counted as mortalities. The survival model assumes that all tagged individuals are actively migrating downstream, and this assumption is less valid for the second half of the summer migration than it is for the first half. The best way to eliminate bias due to residualization is to standardize each survival estimate by dividing by the survival of a reference release or reference virtual release, because fish in the upstream virtual release and the reference release (downstream release or a virtual release through the B2CC) both should exhibit the same temporal trends in mortality and residualization in the same year. Tag burdens (tag weight/fish weight) on subyearlings were much higher before 2008 than they were after 2008, so we did not compare 2010 estimates with estimates made before 2008.

A paired-release survival estimate for subyearlings passing the forebay, dam, and 81 km of tailwater in 2010 was only 1.6% higher than a paired-release estimate for 2008 and 2.6% higher than in 2009 (Table 4.1), where paired estimates were calculated by dividing the survival rates for subyearlings that passed through BON by the rates for subyearlings in reference releases in the tailrace (2008) or for subyearlings that passed through the B2CC (2009 and 2010; Table 4.1). Survival rates for subyearlings passing through the B2CC typically are so high that virtual releases passing through the B2CC make good virtual reference releases for the dam.

Historically, forebay residence times were calculated for each dam structure at BON as the time from first detection by radio telemetry (presumably about 100 m from antennas) until the time of passage through the dam. Average estimates summarized by Ploskey et al. (2007), were 4.4 h at B1, 0.4 h at the spillway, and 0.2 h at B2. The average of the historical means for the three locations (1.67 h) was reasonably close to the mean estimate for the dam in summer 2010 (1.57 h).

Table 4.1. Comparison of Virtual Paired-Release Passage Survival Estimates in 2008, 2009, and 2010. Treatment refers to virtual releases of fish known to have passed through the forebay, dam, and tailwater, and reference refers to fish released either in the tailrace or that were regrouped to form a virtual release of fish known to have passed through the B2CC.

Year	Paired-Release Estimate	Virtual Single Release Estimate	Reference Release or Virtual Reference Release Estimate
2008[a]	0.970	0.953	0.982
2009[b]	0.960	0.904	0.942
2010[c]	0.986	0.956	0.970

(a) Faber et al. (2010): Pooled estimates from a virtual single release from CR237 and a release in the tailrace.
(b) Faber et al. (2011): Pooled estimates from a virtual single releases from CR236 and the B2CC
(c) This study: Pooled estimates from virtual single releases from CR236 & B2CC

Holmberg et al. (2001) estimated median egress times from the forebay to the B2 outfall vicinity for subyearling Chinook that passed B1 (0.40 h) and the spillway (0.41) and those egress times were close to our median estimate of 0.42 h.

Historical estimates of SPE for non-drought summers ranged from 0.35 to 0.65 (summarized by Ploskey et al. 2007). The summer 2010 estimate of SPE (0.519) is near the middle of the historical range for subyearlings in non-drought years.

4.3 Statistical Performance

The full-dam single-release survival study at BON in 2010 was a precursor to a full-scale application of the virtual/paired-release design planned for BON in 2011. The double array at each dam face provided a combined detection probability of 1.0, and this indicates that dam-face deployments are ready for a full BiOp study. We found no significant difference in any performance metrics between the two 1-day spill treatments tested in summer 2010, although SPE and spill + B2CC efficiency differed among some spill and day/night treatment combinations. Numbers of tagged fish released upstream of the dam provided sufficient precision for survival estimates even though we did not use fish released upstream of TDA to survival for the entire summer study.

5.0 References

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Appendix A

Capture Histories, Survival, and Detection Probabilities

Appendix A - Capture Histories, Survival, and Detection Probabilities

This appendix contains detailed capture histories for each of the three runs of fish studied at Bonneville Dam in 2010. In capture history tables, the headings of columns 2 through 9 have three digits and each digit represents a detection (1) or non-detection (0) at three successive survival arrays (CR153, CR113, and CR086).

Table A.1. Bonneville Dam Passage Capture History for Subyearling Chinook Salmon

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish[(a)]	1044	160	52	8	0	0	86	10

(a) After BON dam-face virtual release of subyearlings from TDA tailrace and Hood River releases only.

Table A.2. Bonneville Dam Passage Survival and Capture Detail for Subyearling Chinook Salmon

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - TDA TR and Hood River	0.9576	0.005475	0.9876	0.003658

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - TDA TR and Hood River	0.8691	0.009146	0.9525	0.005981	0.9262	0.007253

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

Table A.3. Bonneville Dam Passage Capture History for Subyearling Chinook Salmon During the 24-h, 95-kcfs Spill Treatment (Figure 3.2)

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish[(a)]	700	49	28	1	0	0	22	1

(a) After Bonneville dam-face virtual release of subyearlings from all upstream releases (Roosevelt, The Dalles Dam tailrace, and Hood River).

Table A.4. Bonneville Dam Passage Detection and Survival Rates for Subyearling Chinook Salmon During the 24-h, 95-kcfs Spill Treatment (Figure 3.2)

Survival Detail:

	CR234.0 to CR153.0	CR153.0 to CR113.0

	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.9262	0.008931	0.9663	0.006584

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9363	0.008627	0.9627	0.006792	0.9702	0.006119

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

Table A.5. Bonneville Dam Passage Capture History for Subyearling Chinook Salmon During the 85- kcfs Day and 120-kcfs Night Spill Treatment (Figure 3.2)

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish[(a)]	572	27	19	1	0	0	19	2

(a) After BON dam-face virtual release of subyearlings from all upstream releases (Roosevelt, The Dalles Dam tailrace, and Hood River).

Table A.6. Bonneville Dam Passage Detection and Survival Rates for Subyearling Chinook Salmon During the 85 kcfs Day and 120 kcfs Night Spill Treatment (Figure 3.2)

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.9030	0.011085	0.9786	0.005945

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9531	0.008355	0.9677	0.007107	0.9661	0.007265

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

Table A.7. Capture-History Data for Virtual Releases of Subyearling Chinook Salmon Passing Bonneville Dam in Summer 2010. These data are for fish passing the dam during day 95-kcfs spill (Figure 3.2).

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	479	37	15	1	17	0	18	48

Table A.8. Single-Release-Survival Estimates and Capture Probabilities for Subyearling Chinook Salmon Passing the Dam During Day 95-kcfs Spill (Figure 3.2). These data are based on all upstream releases of fish traveling from release sites to the dam array (CR234), from the dam to the primary array (CR153), and from the primary to the secondary array (CR113.0).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstrea	0.9217	0.014076	0.9580	0.011210

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstrea	0.9288	0.014010	0.9666	0.009911	0.9755	0.008569

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

Table A.9. Capture-History Data for Virtual Releases of Subyearling Chinook Salmon at the Bonneville Dam Spillway in Summer 2010. These data are for fish passing the dam during night 95-kcfs spill treatment (Figure 3.2).

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	221	12	13	0	5	1	9	20

Table A.10. Single-Release-Survival Estimates and Capture Probabilities for Subyearling Chinook Salmon Passing the Dam During Night 95-kcfs Spill (Figure 3.2). These data are based on all upstream releases of fish traveling from release sites to the dam array (CR234), from the dam to the primary array (CR153), and from the primary to the secondary array (CR113.0).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.9306	0.015419	0.9650	0.011908

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9484	0.013934	0.9472	0.014264	0.9749	0.010119

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

Table A.11. Capture-History Data for Virtual Releases of Subyearling Chinook Salmon Passing Bonneville Dam in Summer 2010. These data are for fish passing the dam during day 85-kcfs spill (Figure 3.2).

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0

Number of Fish	429	19	18	0	17	1	12	51

Table A.12. Single-Release-Survival Estimates and Capture Probabilities for Subyearling Chinook Salmon Passing the Dam During Day 85-kcfs Spill (Figure 3.2). These data are based on all upstream releases of fish traveling from release sites to the dam array (CR234), from the dam to the primary array (CR153), and from the primary to the secondary array (CR113.0).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.8893	0.018919	0.9850	0.008543

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9465	0.014435	0.9609	0.012786	0.9444	0.014974

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

Table A.13. Capture-History Data for Virtual Releases of Subyearling Chinook Salmon Passing Bonneville Dam in Summer 2010. These data are for fish passing the dam during night 120-kcfs spill (Figure 3.2).

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	143	8	1	1	2	1	2	20

Table A.14. Single-Release-Survival Estimates and Capture Probabilities for Subyearling Chinook Salmon Passing the Dam During Night 120-kcfs Spill (Figure 3.2). These data are based on all upstream releases of fish traveling from release sites to the dam (CR234), from the spillway to the primary array (CR153), and from the primary to the secondary array (CR113.0).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.8454	0.035749	0.9877	0.012269

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9302	0.027471	1.0000	0.000000	0.9767	0.016252

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

Table A.15. Forebay Virtual Release Capture History for Subyearling Chinook Salmon.

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish[(a)]	1132	175	58	10	90	13	20	73

(a) After Bonneville Dam forebay virtual release of subyearlings from The Dalles Dam tailrace and Hood River releases only.

Table A.16. Forebay Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon

Survival Detail:

	CR236.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - TDA TR and Hood River	0.9555	0.005379	0.9882	0.003471

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - TDA TR and Hood River	0.8660	0.008860	0.9505	0.005847	0.9270	0.006930

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

Table A.17. Bonneville Spillway Virtual Release Capture History for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River).

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	1238	188	66	11	109	16	30	129

Table A.18. Bonneville Spillway Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.9304	0.006196	0.9833	0.003817

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.8679	0.008391	0.9488	0.005687	0.9194	0.006912

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

Table A.19. Bonneville Spillway Virtual Release Capture History for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for fish passing the spillway during the 24-h 95-kcfs spill treatment (Figure 3.2).

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	387	27	15	1	11	1	17	39

Table A.20. Bonneville Spillway Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during the 24-h 95-kcfs spill treatment (Figure 3.2).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.9241	0.012114	0.9615	0.009415

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9344	0.011777	0.9628	0.009128	0.9718	0.008016

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

Table A.21. Bonneville Spillway Virtual Release Capture History for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during the 85-kcfs day/120-kcfs night spill treatment.

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	287	18	9	0	14	1	5	47

Table A.22. Bonneville Spillway Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during the 85-kcfs day/120-kcfs night spill treatment (Figure 3.2).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.8774	0.016885	0.9855	0.007074

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9422	0.012861	0.9713	0.009416	0.9531	0.011816

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

Table A.23. Bonneville Spillway Virtual Release Capture History for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during day 95-kcfs spill.

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	295	23	10	1	8	0	14	31

Table A.24. Bonneville Spillway Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during day 95-kcfs spill (Figure 3.2).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.9217	0.014076	0.9580	0.011210

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9288	0.014010	0.9666	0.009911	0.9755	0.008569

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

A.1.1 Spillway Passage during the Night Under 24-h 95-kcfs Spill

Table A.25. Bonneville Spillway Virtual Release Capture History for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during night 95-kcfs spill.

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	92	4	5	0	3	1	3	8

Table A.26. Bonneville Spillway Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during night 95-kcfs spill (Figure 3.2).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.9323	0.023606	0.9728	0.016653

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*

Summer - All Releases Upstream	0.9524	0.020783	0.9505	0.021584	0.9600	0.019596

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

Table A.27. Bonneville Spillway Virtual Release Capture History for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for spillway passage during day 85-kcfs spill.

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	209	12	9	0	12	1	4	31

Table A.28. Bonneville Spillway Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during day 85-kcfs spill (Figure 3.2).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.8893	0.018919	0.9850	0.008543

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9465	0.014435	0.9609	0.012786	0.9444	0.014974

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

Table A.29. Bonneville Spillway Virtual Release Capture History for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for spillway passage during night 120-kcfs spill.

	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0
Number of Fish	78	6	0	0	2	0	1	16

Table A.30. Bonneville Spillway Virtual Release Detection and Survival Rates for Subyearling Chinook Salmon Regrouped from All Upstream Releases (Roosevelt, TDA tailrace, and Hood River). These data are for passage during night 120-kcfs spill (Figure 3.2).

Survival Detail:

	CR234.0 to CR153.0		CR153.0 to CR113.0	
	Estimate	s.e.†	Estimate	s.e.*
Summer - All Releases Upstream	0.8454	0.035749	0.9877	0.012269

Capture Detail:

	CR153.0		CR113.0		CR086.2 Survival*Capture	
	Estimate	s.e.*	Estimate	s.e.*	Estimate	s.e.*
Summer - All Releases Upstream	0.9302	0.027471	1.0000	0.000000	0.9767	0.016252

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

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