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Evaluation of a Behavioral Guidance Structure at Bonneville Dam Second Powerhouse including Passage Survival of Juvenile Salmon and Steelhead using Acoustic Telemetry, 2008

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FINAL REPORT

February 2010

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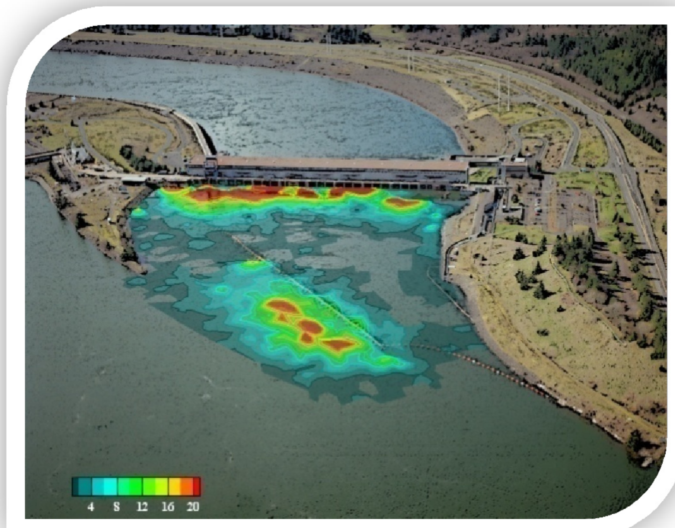

1 – NOAA Fisheries
2 – Pacific States Marine Fisheries Commission
3 – Columbia Basin Research

February 2010

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

Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

In 2008, the Portland District of the U.S. Army Corps of Engineers contracted with the Pacific Northwest National Laboratory (PNNL) to conduct an acoustic telemetry study to evaluate a newly deployed 700-ft-long and 10-ft-deep behavioral guidance structure (BGS) located in the forebay of the Bonneville Dam second powerhouse (B2) and to estimate the survival of yearling Chinook salmon, subyearling Chinook salmon, and juvenile steelhead passing downstream through this powerhouse. The BGS was deployed to increase the survival of fish passing B2 by increasing the percentage of outmigrating smolts entering the B2 Corner Collector, a surface flow outlet known to be a relatively benign route for downstream passage at this dam. Fish longer than 95 mm were surgically implanted with Juvenile Salmon Acoustic Telemetry System (JSATS) and passive integrated transponder (PIT) tags, held overnight in tanks supplied with continuous flow of river water to allow time for recovery from surgery and released upstream as part of two concurrent survival studies that were evaluating survival at John Day Dam and the Bonneville spillway. Tagged fish were released at or downstream of Arlington, Oregon, approximately 156 km upstream on the Columbia River. Additional release points included the tailwaters of John Day Dam and The Dalles Dam. The volitional movements of the tagged migrants were subsequently tracked through the B2 forebay to their eventual route of passage. Passage location was recorded and incorporated with detections from three downstream survival arrays to produce survival estimates. The tracked positions of fish in the forebay and passage distribution at B2 were evaluated to determine behavior relative to the BGS location.

Major Findings

The BGS increased passage percentage into the B2 Corner Collector (B2CC) for yearling Chinook salmon by up to 9%, but no improvements were observed for subyearling Chinook or juvenile steelhead when comparing 2008 results to passage distributions observed in 2004 and 2005 radio-telemetry studies. The majority of steelhead and yearling Chinook salmon were found to navigate past the BGS and through the south gap (area between the downstream tip of the BGS and Cascade Island), which was closest to the Corner Collector. Whereas equal proportions of subyearling Chinook salmon navigated through the south and north gaps between the BGS and shorelines. The corner collector efficiency was always higher for fish passing through the south gap compared to fish passing the north gap or under the BGS. Overall, the B2 corner collector efficiency was very high for juvenile steelhead (75%) followed by yearling Chinook salmon (49%) and then subyearling Chinook salmon (40%). Downstream migrants appeared to navigate downstream proportionally to water velocities in the thalweg when their downstream pathways were plotted in relation to the BGS and the B2 forebay. There were significant operational differences at B2 between spring and summer. During spring, turbine unit 15 (in the center of the powerhouse) was offline, and during summer turbine unit 11 (adjacent to the corner collector) was not operational. Because of the operational differences, it was difficult to compare passage percentages when the BGS was not present but all units were operating, which was the case in 2004 and 2005. The BGS design was based on total powerhouse operation. The outage of these units may have altered flow along the upstream side of the BGS and around the BGS enough to influence the discovery of the B2CC for smolts, thereby affecting the efficiency of the B2CC.

In the relatively high flow year of 2008, there was a high survival rate of outmigrating smolts passing all routes of B2. Paired and triple release survival estimates for yearling Chinook salmon were at or near

100% for the B2CC and the JBS, and slightly lower for turbine routes (97% – 98%). Similarly, subyearling Chinook salmon had paired and triple release survival estimates near 100% for the B2CC and JBS, but had comparatively lower turbine survival rates (95% – 97%). These estimates and corresponding confidence limits would have met the current Biological Opinion (BiOp) standards set in 2008 for survival past Columbia and Snake River dams. Because there were no control releases, Juvenile steelhead survival was evaluated using single-release Cormack-Jolly-Seber models. These estimates include mortality between the dam and the downstream survival arrays, where we found estimates near 98% survival for all routes at B2 through the tailrace. We found that there were no obvious seasonal survival trends in the spring for yearling Chinook salmon or juvenile steelhead, but there was a very significant trend in the summer. Subyearling Chinook showed a strong decline in survival for all routes passing B2 as the summer progressed. It is possible that residualization (reverse smoltification) decreased flow, and increasing temperatures may have contributed to this trend because these variables were all significantly correlated with the decreasing survival. Nevertheless, the survival of subyearling Chinook was still above the 93% standard set by the 2008 BiOp.

In summary, the BGS benefitted the collection efficiency and effectiveness for yearling Chinook passing the B2CC, but did not change juvenile steelhead or subyearling Chinook collection efficiency compared to prior study years. The B2CC passage efficiency for steelhead is very high with or without the BGS. Survival estimates for all smolts passing downstream through B2 were very high using triple, paired, and single-release Cormack-Jolly-Seber modeling methods and would meet current BiOp standards. Turbine unit 11 provides flow into the south of the powerhouse where the B2CC is located; thus, the fact that this unit was off during summer may have reduced B2CC efficiency for subyearling Chinook salmon. To satisfactorily test the affect the BGS has on improving the B2CC efficiency for subyearling Chinook, turbine unit 11 should be operational. Detailed survival and passage metrics are summarized below in Tables ES1.1 through ES1.5.

Summary of Survival Estimates

Table ES.1. Summary of Survival Estimates for Yearling Chinook Salmon Released into the Lower Columbia River and Regrouped Passing Routes at Bonneville Dam[(a)]

	Bonneville Corner Collector	Juvenile Bypass System	B2 Turbines	Bonneville 2nd Powerhouse	B2CC Direct Release
Single Release Survival	0.987 (0.012)	0.983 (0.022)	0.946 (0.030)	0.970 (0.017)	0.976 (0.014)
Paired Release Survival	1.021 (0.034)	1.017 (0.045)	0.979(0.037)	1.005 (0.030)	1.011 (0.027)
Triple Release Survival		1.007 (0.037)	0.969 (0.042)	0.994 (0.034)	

(a) Cormack-Jolly-Seber single-release, paired-release, and triple-release survival estimates are shown. Survival estimates were variance or sample-weighted (N-weighted) as appropriate based on chi-square results and sample size. One-half 95% confidence intervals are reported in parentheses.

Table ES.2. Summary of Survival Estimates for Juvenile Steelhead Released into the Lower Columbia River and Regrouped Passing Routes at Bonneville Dam[(a)]

	Bonneville Corner Collector	Juvenile Bypass System	B2 Turbines	Bonneville 2nd Powerhouse
Single Release Survival	0.984 (0.027)	0.984 (0.039)	0.982 (0.024)	0.982 (0.019)

(a) Cormack-Jolly-Seber single-release estimates are shown. Survival estimates were sample-weighted (N-weighted) as appropriate based on chi-square results and sample size. One-half 95% confidence intervals are reported in parentheses.

Table ES.3. Summary of Survival Estimates for Subyearling Chinook Salmon Released into the Lower Columbia River and Regrouped Passing Routes at Bonneville Dam[(a)]

	Bonneville Corner Collector	Juvenile Bypass System	B2 Turbines	Bonneville 2nd Powerhouse	B2CC Direct Release
Single Release Survival	0.978 (0.014)	0.975 (0.021)	0.937 (0.018)	0.964 (0.014)	0.991 (0.010)
Paired Release Survival	0.996 (0.016)	0.991 (0.024)	0.954(0.020)	0.981 (0.016)	1.009 (0.01)
Triple Release Survival		1.006 (0.028)	0.967 (0.025)	0.990 (0.022)	

(a) Cormack-Jolly-Seber single-release, paired–release, and triple-release survival estimates are shown. Survival estimates sample-weighted (N-weighted) as appropriate based on chi-square results and sample size. One-half 95% confidence intervals are reported in parentheses.

Passage Distribution Summary

Table ES.4. Passage Numbers and Associated Percentage for Tagged Juvenile Salmon and Steelhead Migrating Downstream Through B2 Routes

Species	Unit	Number	Passage (%)
Yearling Chinook Lower Granite Released	B2CC	291	47%
	TU11	23	4%
	TU12	46	7%
	TU13	3	0%
	TU14	107	17%
	TU15	2	0%
	TU16	72	12%
	TU17	48	8%
	TU18	14	2%

Table ES.4. (contd)

Species	Unit	Number	Passage (%)
Yearling Chinook Lower Granite Released	FU2	15	2%
	Unknown	1	0%
	Total	**622**	
Yearling Chinook Lower Columbia Released	B2CC	442	49%
	TU11	8	1%
	TU12	40	4%
	TU13	18	2%
	TU14	113	13%
	TU15	31	3%
	TU16	91	10%
	TU17	74	8%
	TU18	34	4%
	FU2	9	1%
	Unknown	41	5%
	Total	**901**	
Juvenile Steelhead	B2CC	693	75%
	TU11	2	0%
	TU12	26	3%
	TU13	18	2%
	TU14	79	9%
	TU15	13	1%
	TU16	24	3%
	TU17	20	2%
	TU18	12	1%
	FU2	1	0%
	Unknown	38	4%
	Total	**926**	
Subyearling Chinook	B2CC	741	40%
	TU11	5	0%
	TU12	136	7%
	TU13	119	6%
	TU14	137	7%
	TU15	201	11%
	TU16	233	13%
	TU17	120	6%
	TU18	108	6%
	FU2	39	2%
	Unknown	24	1%
	Total	**1863**	

Metrics

Table ES.5. Total Tagged Yearling Chinook, Juvenile Steelhead, and Subyearling Chinook that Passed Through B2 Routes, and Associated Fish Passage Efficiency (FPE) and Fish Guidance Efficiency (FGE) Values

Species	B2CC	JBS	Turbine	Guided Screens + B2CC	Unguided (Screens)	Total Passed B2	B2CC Effectiveness	Mean B2-Q (kcfs)	Mean B2CC Q (kcfs)	B2CC-E	FPE	FGE
Yearling Chinook LGR Released	291	63	268	354	268	622	10.5	111.2	4.95	47%	57%	19%
Yearling Chinook LGR Released	442	160	299	602	299	901	11.0	111.2	4.95	49%	67%	35%
Juvenile Steelhead	693	87	146	780	146	926	16.8	111.2	4.95	75%	84%	37%
Subyearling Chinook	741	328	794	1069	794	1863	9.0	111.5	4.97	40%	57%	29%

LGR = Lower Granite Dam

Preface

The U.S. Army Corps of Engineers (USACE) Portland District (CENWP), contracted with the Pacific Northwest National Laboratory (PNNL), Richland, Washington, to conduct an acoustic telemetry survival study at the Bonneville Dam in 2008. The project took place as a part of a call for proposals titled *SPE-P-08-1: Evaluation of a Behavioral Guidance Structure at Bonneville Dam Second Powerhouse*. PNNL assembled a study team consisting of staff from PNNL, the Pacific States Marine Fisheries Commission (PSMFC), the University of Washington, and the National Marine Fisheries Service. The Portland District provided all funding and oversight.

Acknowledgments

Many people made valuable contributions to this study and deserve acknowledgment. A team assembled by the National Oceanic and Atmospheric Administration (NOAA) Fisheries was responsible for tagging and releasing juvenile Chinook salmon smolts into the Bonneville Dam tailrace and Second Powerhouse Corner Collector during this study. They were led by Lynn McComas and Jason Everett (NOAA Fisheries) and came from NOAA Fisheries (Jeff Moser, Galan Wolf, and Steve Brewer) and the Pacific States Marine Fisheries Commission (PSMFC; – Dennis Quaempts, Caren Dittbrenner, Mike Jenkins, Linda McPhetridge). The PSMFC supervisors at the John Day Dam Smolt Monitoring Facility (Greg Kovalchuk) and at the Bonneville Dam Juvenile Monitoring Facility (Dean Ballinger) were helpful in coordinating fish collections with daily fish sampling at the respective locations.

Mr. Dennis Schwartz served as the USACE Contracting Officers Technical Representative and provided valuable coordination between researchers and Bonneville Dam personnel. Mr. Brad Eppard contributed many valuable suggestions on study design and implementation, and furnished dam operations data.

Jonathon Rerecich and Ben Hausman, Bonneville Lock and Dam Project, provided pre-work safety orientations and facilitated coordination between researchers and the Bonneville Project. The project supplied electricity to trailers on the north and south ends of the spillway, and set up clearances on the electric bus line supplying power to cranes on the spillway when researchers needed access to spillway piers. The rigging crew at Bonneville Dam was particularly helpful as well.

Many PNNL staff assisted in project management (Geoff McMichael and David Geist), surgery training (Rich Brown and Kate Deters), fish collection (Robin Durham), fish transport and release, tag-life monitoring (Rich Brown and Kathleen Carter), Juvenile Salmon Acoustic Telemetry System development (Eric Choi, Brian LaMarche, Daniel Deng, Thomas Seim, and Thomas Carlson), deployment and retrieval of spillway hydrophones (Fenton Khan), deployment and retrieval of autonomous nodes (Matthew Meyer, Gary Johnson, Aaron Cushing, and Matthew Wilberding), and database entry and management (Jessica Carter). Dr. Kenneth Ham was very helpful in implementing filters for autonomous node data. Dr. David Geist was the Ecology Group Manager within PNNL, and Dr. Dennis Dauble was the line manager during this study.

Sonic Concepts in Seattle, Washington, fabricated electronic tags for spring tagging and all receiving hydrophones and repaired broken hydrophones when needed. Advanced Telemetry Systems (ATS), Inc. made the acoustic tags used in summer. Precision Acoustic Systems, also in Seattle, conducted node acceptance tests for PNNL. Cascade Aquatics, Inc. in Ellensberg, Washington, activated and delivered the acoustic tags. Schlosser Machine Shop fabricated anchors for autonomous nodes.

Acronyms and Abbreviations

ATS	Advanced Telemetry Systems®
B1	Bonneville Powerhouse 1
B2	Bonneville Powerhouse 2
B2CC	Bonneville Powerhouse 2 Corner Collector
B2 JBS	Bonneville Powerhouse 2 Juvenile Bypass System
BiOp	Biological Opinion
BON	Bonneville Dam
BTW0	egress survival array
BTW1	primary survival array
BTW2	secondary survival array
BTW3	tertiary survival array
BPA	Bonneville Power Administration
BTW	Bonneville tailwater
°C	degree(s) Celsius or Centigrade
CENWP	Corps of Engineers, Northwest, Portland
CF	CompactFlash (card)
cfs	cubic feet per second
CI	confidence interval (95% unless specified otherwise)
CJS	Cormack-Jolly-Seber model
CL	confidence limit
cm	centimeter(s)
CSV	comma-separated variables
CV^2	coefficient of variation squared
D	dead-fish detection probability
p_1,p_2	mean detection probability
DART	Data Access in Real Time
FCRPS	Federal Columbia River Power System
FU	Fish Unit
ft	foot(feet)
g	gram(s)
gal	gallon(s)
GB	gigabyte(s)
GPS	global positioning system
hr	hour(s)
JBS	Juvenile Bypass System
JMF	Juvenile Monitoring Facility below the Second Powerhouse (B2)

JSATS	Juvenile Salmon Acoustic Telemetry System
km	kilometer(s)
L	liter(s)
LED	light-emitting diode
m	meter
mg/L	milligram(s) per liter
mL	milliliter(s)
mm	millimeter(s)
m/s	meter(s) per second
MS-222	tricaine methanesulfonate
MSL	mean sea level
NOAA	National Oceanic and Atmospheric Administration
O_2	oxygen
PAS	Precision Acoustic System
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
PSMFC	Pacific States Marine Fisheries Commission
PVC	polyvinyl chloride
rkm	river kilometer
RS	relative survival
s	second(s)
SAS	Statistical Analysis System
SE	standard error
SYC	subyearling Chinook salmon
TDG	total dissolved gas
TU	Turbine Unit
USACE	U.S. Army Corps of Engineers
UTM	Universal Transverse Mercator (a global positioning grid system)
YC	yearling Chinook salmon

Contents

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1.0 Introduction

In a continual effort to improve conditions for juvenile anadromous fish passing through Columbia River dams, the U.S. Army Corps of Engineers (USACE) Portland District (CENWP) has funded numerous evaluations of fish passage and survival. In 2008, the CENWP asked Pacific Northwest National Laboratory (PNNL) to conduct an acoustic telemetry study to evaluate a prototype behavioral guidance structure (BGS) that was installed in the forebay of Bonneville Dam's Washington shore powerhouse (the Powerhouse 2 or B2). The BGS was designed to increase the passage of juvenile salmon into the B2 Corner Collector (B2CC), a surface flow outlet passage route, thereby increasing the survival of juvenile salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) passing through B2. To evaluate the BGS, we studied the approach and passage distribution of juvenile salmon relative to the BGS location. In addition, we estimated route-specific survival of tagged juvenile salmon and steelhead passing downstream through B2.

1.1 2008 Study Objectives and Tasks

The primary objective of the acoustic telemetry study was to evaluate the performance of the BGS on influencing the passage and survival of juvenile salmon passing B2 routes in comparison to prior years. Tasks undertaken to accomplish the objectives included the following:

1. PNNL evaluated the performance of the BGS for guiding yearling Chinook salmon, steelhead, and subyearling Chinook salmon to the B2CC by calculating a variety of statistical metrics. These metrics were estimated by type of fish, season, and for day or night periods. We sought to estimate the following:
   a. BGS guidance efficiency = Number guided along the BGS/Number detected in the B2 forebay.
   b. B2 FPE = (Number passing in the B2CC + Number passing the B2 JBS)/B2 Passage.
   c. B2CC passage efficiency = Number passing into the B2CC/Number passing B2.
   d. B2CC passage effectiveness = B2CC passage efficiency/Proportion of B2 flow to the B2CC.
   e. B2 FGE = Number of PIT or acoustic tags detected in the B2 JBS/Number tracked passing into turbines.
   f. Turbine passage = Number entering turbines.
   g. Turbine passage efficiency = Number entering turbines/B2 passage.
2. A PNNL team collected juvenile salmonids at the JDA SMF and surgically implant 3425 yearling Chinook salmon and 3427 steelhead in spring and 5909 subyearling Chinook salmon in summer with JSATS acoustic and PIT tags and released them three times per day over a period of 28 consecutive days at in two sites in spring and over a period of 29 consecutive days at three sites in summer. These releases of treatment fish above BON provided the opportunity for tagged fish to be detected on a B2 forebay array and regrouped into virtual releases passing B2 routes.
3. A NOAA Fisheries team collected juvenile Chinook salmon smolts at the BON Juvenile Monitoring Facility (JMF) and surgically implanted 1654 yearling and subyearling Chinook Salmon with JSATS and PIT tags. Fish were released into the tailrace of Bonneville Dam three times per day over a 34-day period in spring (826 YC) and over a 37-day period in summer (1020 SYC) to serve as

reference release groups for treatment fish under Task 2 above. The team also released fish (826 YC and 1020 SYC) directly into the B2CC on a similar schedule so that B2CC and tailwater releases could be used to scale paired-release estimates of dam (concrete) survival.

4. A PNNL team deployed and maintained a cabled system of 44 hydrophones on nine turbine piers and throughout the forebay to detect the passage of tagged fish migrating downstream. Hydrophone detections were used to assign a route of passage for fish based upon the location of the last of at least four detections within 60 seconds. Detections of PIT tags in the B2 JBS and the B2CC and of acoustic detections on hydrophones in a B2 dam-face array were used to assign the route of passage at B2.
5. Twenty-two hydrophones were maintained and deployed in the area adjacent to the BGS to establish approach patterns of outmigrating smolts in relation to the BGS deployment. Tagged fish were categorized as either passing through the north gap (not guided), under the BGS (not guided) or passing through the south gap toward the corner collector (guided). Due to equipment failures during the season, the detailed BGS approach distribution was evaluated from May 1 to 8 for the spring season, and from June 27 to July 17 for the summer season. The last detection of a tag that had four or more detections within 60 seconds was used to assign routes for the entirety of the spring and summer seasons.
6. A PNNL team deployed and maintained a primary survival array with nine autonomous underwater nodes near Reed Island, which is located about 34.4 km downstream of the dam and a secondary array with six autonomous nodes near Lady Island located about 42.4 km downstream. Detections of coded acoustic tag signals on these arrays and a third array deployed by a post-FCRPS study team were used to complete detection histories for route-specific survival estimates using single- and paired-release survival models.
7. Estimate distribution statistics associated with the time required for fish to pass from a forebay entrance array located two km upstream of B2 to the final passage at the powerhouse.
8. Estimate survival by route of passage based upon detection histories of treatment and reference fish at the primary, secondary, and tertiary tailwater arrays, using paired- and triple-release survival models. Routes were pooled by type (e.g., JBS, B2CC, or turbines). All survival estimates were accompanied by an estimate of the one-half 95% confidence interval (1/2 95% CI).
9. We tested a hypotheses comparing the 2008 passage metrics with the BGS installed to mean estimates for 2004 and 2005 before the BGS was deployed (by fish type), including:
   a. H_o: Survival in 2008 when the BGS is installed is not significantly higher than mean survival for 2004 and 2005.
10. We also tested the efficiency of the B2CC PIT-tag reader from the direct release and virtual release of dual tagged (PIT/acoustic) fish released into the mouth of B2CC by the post-FCRPS study.

1.2 Definitions

In this report, we define estimates of single-release, paired- and triple-release survival by the upstream and downstream boundaries of the reach of interest. The following additional definitions are needed to clarify paired-release survival metrics.

Forebay is the reach of river immediately upstream of the dam where operations at the dam are the primary contributing factor to the velocity and direction of water flow. The upstream boundary of a forebay is where a significant alteration in water-flow allocation through dam operational changes affects water velocity or direction. The downstream boundary is the upstream face of the dam. The BON forebay entrance array was located 2 km upstream of B2.

Tailrace is the reach of river immediately downstream of the dam where dam operations are the primary factor affecting the velocity and direction of water flow. The upstream boundary of the tailrace is the downstream face of the dam and the downstream boundary is where operational changes at the dam no longer affect the direction of water flow, and mixing from the spillway and powerhouse is complete.

Tailwater in this study is the reach of river downstream of the tailrace to the point where saltwater mixing occurs. Tailwater is synonymous with reservoir or pool when it lies between two dams, but Bonneville Dam is the last dam on the lower Columbia River. The NOAA Fisheries release site was about 2 km downstream of the spillway adjacent to the USACE boat launch and near the upstream boundary of the tailwater.

Passage-route survival is the probability of survival for fish passing through any individual route (e.g., spillway, B2CC, B2 turbines, or B2 JBS) to the boundary between the tailrace and tailwater where reference fish were released. In this study, passage route survival was estimated for fish passing through the B2CC, the JBS, or B2 turbines. The numbers of fish tracked to individual turbine units were too low to warrant the calculation of their survival by individual turbine. Estimates of turbine-specific survival lacked the precision required to detect significant differences in survival among individual turbines.

1.3 Report Contents and Organization

The ensuing sections of this report present the materials and methods used in conducting the acoustic telemetry behavior and survival study at B2 (Section 2.0) and the study results (Section 3.0). Section 4.0 describes the environment and 2008 outmigration conditions and discusses the results of the study, including dead-fish detection, detection performance, egress rates, and the detection and survival of yearling Chinook salmon and steelhead smolts in spring and subyearling Chinook salmon smolts in summer. Recommendations are provided in Section 5.0, followed by a reference list in Section 6.0. Finally, Appendixes A, B, C, D, and E respectively, contain tables of fish-tagging and release data, the tag-life corrections for survival estimates, and detailed survival estimates.

2.0 Study Overview and Background

2.1 Study Overview

This study used acoustic telemetry to evaluate the approach, passage, and survival of juvenile salmon passing B2 in relation to the BGS located in the upstream forebay of B2 (Figure 2.1). Releases of live Juvenile Salmon Acoustic Telemetry System (JSATS) tagged smolts in the Columbia River upstream of B2 totaled 3425 yearling Chinook salmon (YC) and 3427 juvenile steelhead (STH) in spring. In summer, 5909 subyearling Chinook salmon (SYC) were released. Releases were spread over 28 consecutive days (April 29 through May 27) during spring and over 29 consecutive days (June 15 through July 13) during summer. Fish were collected at the John Day Dam (JDA) Smolt Monitoring Facility (SMF) and held overnight before surgery so that they were not overly stressed. Smolts longer than 95 mm were surgically implanted with Juvenile Salmon Acoustic Telemetry System (JSATS) and passive integrated transponder (PIT) tags and held another night to allow time for fish to recover from surgery. Fish tagged the previous day were released by a PNNL team three times per day (morning, midday, and night) at two sites in spring and at three sites in summer. All times in this report are in Pacific Standard Time (PST). For a John Day Dam survival study, fish were released at Arlington, Oregon, above the dam and in the tailwater about 2.5 km downstream of the dam during each season. The same PNNL team released subyearling Chinook salmon smolts three times per day adjacent to the marina 3 km downstream of The Dalles Dam (TDA) in summer specifically to increase the number that might pass through B2. All fish released above B2 were potentially available for detection and were therefore regrouped into virtual releases as treatment fish for B2 routes. Detections of PIT tags in the B2 Juvenile Bypass System (JBS) and B2 Corner Collector (B2CC) and of acoustic detections on hydrophones in a B2 JSATS array were used to assign routes of passage. Fish entering the B2 forebay were detected on a forebay and dam-face array consisting of 44 hydrophones mounted throughout the forebay, and along the dam face. Fish detected on the powerhouse hydrophones were assigned a route of passage relative to the BGS location, as well as assigned bay of passage based upon three-dimensional (3D) tracking and the location of the last of at least four detections of implanted acoustic tags. Detected treatment fish were regrouped as a virtual release group designated as passing the turbines, JBS, or B2CC.

A National Oceanic and Atmospheric Administration (NOAA) Fisheries team released yearling Chinook salmon smolts in spring and subyearling Chinook salmon smolts in summer into the upstream end of the Bonneville Dam (BON) tailwater near the USACE boat launch three times per day (about 0600, 1300, and 2100 hours PST) to serve as reference releases for virtual releases of treatment fish passing B2 daily. Reference releases were made daily from April 30 through June 2 and from June 16 through July 22. The NOAA Fisheries team also released spring and subyearling Chinook salmon smolts directly into the B2CC according to a schedule similar to that described for releases in the tailrace. Pairing the B2CC-specific releases and tailwater releases provided a means of scaling paired release estimates of dam (concrete) survival using a triple-release model.

Single-release survival estimates included losses of fish that occurred as fish travelled from the virtual release point in the spillway forebay down through 34.4 km of tailwater. Reference fish were released 2 km downstream of the spillway near the start of the Bonneville tailwater to create reference-release groups that did not pass through the spillway. Paired-release survival estimates for spillway-passed fish to the tailrace-release site were calculated as the ratio of the survivals of treatment-release groups to the survivals of paired reference-release groups to remove the effects of losses of fish in the common tailwater. Another release of fish into the B2CC for yearling and subyearling Chinook salmon allowed for a triple-release estimate of survival, which can account for the initial post-handling mortality in tailwater reference releases when using those fish with in combination with virtual released fish. The common tailwater for our survival estimates was from the tailrace-release site 2 km downstream of the dam to the first or second of three survival-detection arrays located downstream of the dam. An array is a group of autonomous underwater receivers (nodes) deployed to listen for acoustic tags passing through a cross section of the river. We had three survival arrays located approximately 34.4, 42.4, and 148 km downstream of the dam.

Figure 2.1. The Behavioral Guidance Structure (BGS) with One Section Shown out of the Water (above); and Shown Deployed in the Forebay of the Bonneville Dam Second Powerhouse (B2; below)

2.2 Background

As part of the remand process for the 2004 Biological Opinion on Federal Columbia River Power System (FCRPS) operations, the Action Agencies submitted to the U.S. District Court, District of Oregon a draft Proposed Action dated May 21, 2007. Hydrosystem Strategy 2 of the Proposed Action states, "Modify Columbia and Snake River dams to maximize juvenile and adult fish survival." This strategy includes Action 11, which our proposed study evaluates:

Action 11 – Powerhouse Improvement Actions – "*Providing or enhancing powerhouse surface flow outlets" and "Making improvements to juvenile bypass systems*"

The post-construction evaluations of the new B2CC at B2 in 2004 and 2005 indicated that mean B2CC passage efficiency was significantly higher for steelhead (70%) than it was for yearling Chinook salmon (33%) or for subyearling Chinook salmon (39%) (Evans et al. [2006]; Reagan et al. [2006]; Adams et al. [2006]). Survival studies by Counihan et al. (2006a, b) indicated that the B2CC is a preferred route of passage because survival of juveniles passing through the B2CC was as high as or higher than that of juveniles passing by any other route. In an effort to further improve this efficiency for yearling and subyearling Chinook, the U.S. Army Corps of Engineers installed a shallow-draft, 700-ft-long, 10-ft-deep BGS into the forebay of B2 for the 2008 migration season (Figure 2.1) with the expectation that strategically locating the BGS could significantly increase the efficiency of the B2CC for passing outmigrating smolts and thereby increase the survival through B2 and the Bonneville Dam.

Behavioral guidance structures have been used at several hydropower projects in the Pacific Northwest to divert outmigrating smolts from turbines. In 1998, a large BGS was installed in the forebay of Lower Granite Dam on the Snake River in Washington. This BGS was a steel curtain 330 m long and 17–24 m deep. The purpose of the BGS was to alter the forebay distribution of smolts migrating downstream by guiding them away from turbines on the south side of the dam and toward a surface bypass collector to the north. Using radio telemetry and hydroacoustics, U.S. Geological Survey (USGS) and PNNL studies showed that about 80% of the fish moving toward the south turbines were successfully diverted north (Johnson et al. 2005). Further investigations showed how forebay distribution was affected by the presence of the BGS at Lower Granite. Several acoustic telemetry studies revealed that the deep BGS in addition to a shallow-draft floating log-boom were both successful at diverting fish from the main thalweg to downstream locations better suited to increase survival through the dam (Cash et al. 2002). Hence, the design of the B2 BGS sought to take advantage of the major concepts learned from the deployment at Lower Granite Dam and a shallow draft BGS was installed at B2 to divert outmigrating smolts toward the B2CC.

2.2.1 Site Descriptions

The distance between the uppermost release site at Arlington, Oregon, and the last survival array at Oak Point, Washington, was 304 km. Excluding distances traveled by fish released at sites upstream of Bonneville Dam, the study area covered about 150 km of the lower Columbia River from Bonneville Dam to Oak Point, Washington at river kilometer (rkm) 86 (Figure 2.2). Cabled underwater hydrophones were deployed throughout the B2 forebay and on each of the turbine piers to detect the passage of tagged fish and assign the last detections of tags to the bay where fish passed B2. Two survival arrays of underwater listening devices were deployed at Reed Island and Lady Island to detect passing smolts. These data and detection data from a third array deployed at Oak Point by a post-FCRPS survival study were used to create detection histories and estimate the survival of smolts passing the dam and spillway.

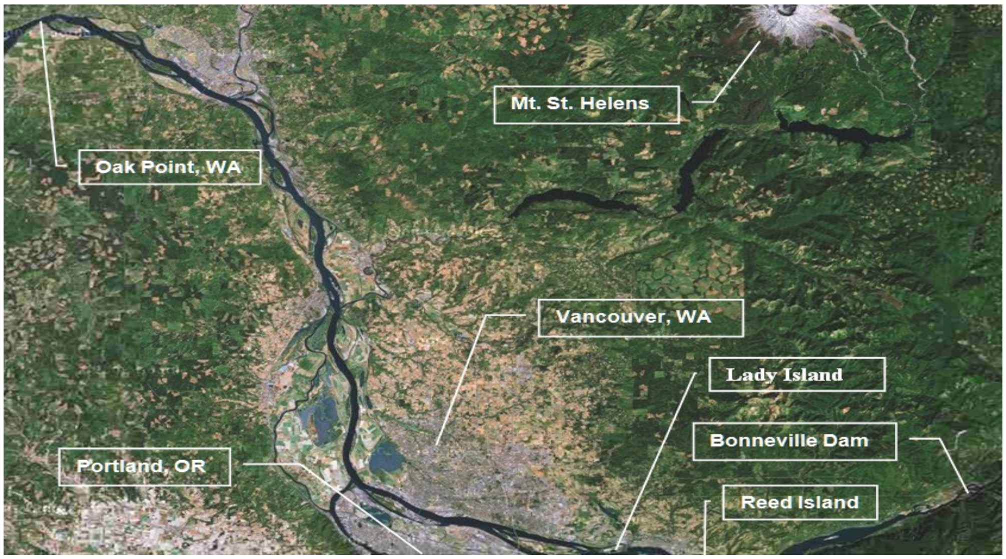


Figure 2.2. Study Area from Bonneville Dam Downstream to Oak Point, Washington. The background image was derived from Google Maps.

Bonneville Lock and Dam consist of several structures that together span the Columbia River between Oregon and Washington near rkm 234.3, about 64 km east of Portland, Oregon (Figure 2.2). From the Oregon shore north toward Washington, Bonneville Dam is composed of a navigation lock, 10-turbine Powerhouse 1 (B1), Bradford Island, an 18-bay spillway, Cascades Island, and 8-turbine B2 (Figure 2.3). The spillway and B1 were constructed between 1933 and 1937 without specific regard for protecting juvenile salmonids migrating downstream. Construction of B2 began in 1974 and was completed in 1982. The CENWP operates Bonneville Dam for hydroelectric power generation for the Bonneville Power Administration (BPA) and the Bonneville Lock for navigation by passing river traffic.

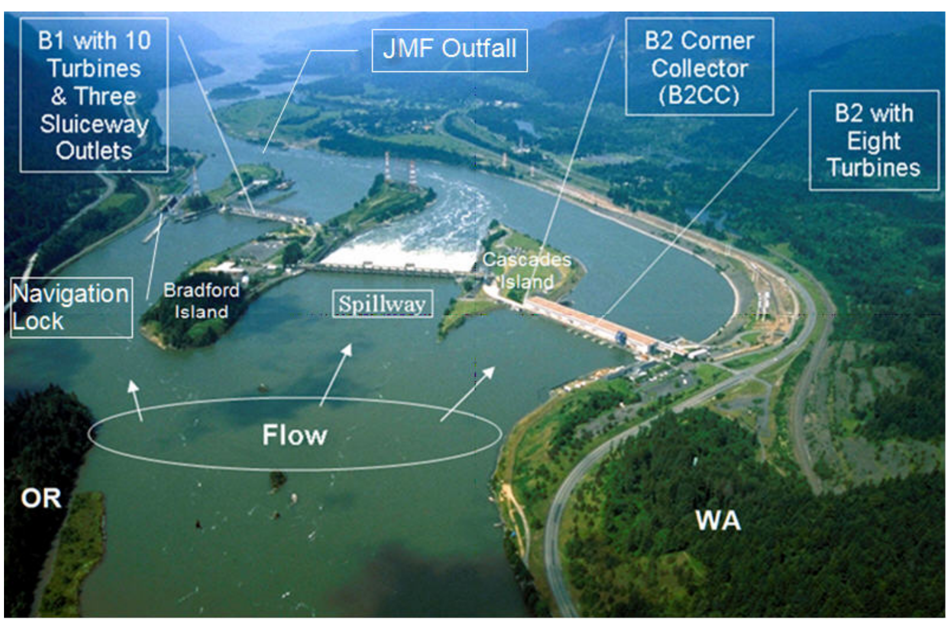


Figure 2.3. Aerial View of Bonneville Dam. JMF = Juvenile Monitoring Facility; B1 = Powerhouse 1; B2 = Powerhouse 2.

3.0 Materials and Methods

This chapter describes materials and methods the 2008 passage and dam survival study at the second powerhouse (B2) at Bonneville Dam. Tasks included fish collection, tagging, release, and detection of tagged migrating fish followed by data processing and analysis. We also describe methods used in a tag-life study that supported all JSATS acoustic tag studies conducted in 2008.

3.1 Fish Collection

The tagging sites, practices related to permitting requirements, and sampling methods for fish collection are briefly described here.

3.1.1 Description of Tagging Sites

Treatment fish were collected and tagged at the JDA SMF for release above Bonneville Dam, and reference fish released into the Bonneville tailrace or B2CC were collected and tagged at the Bonneville JMF. Monitoring facilities at both locations receive fish passing through a JBS. Juvenile salmonids begin moving through each JBS after they are screened from the upper third of 16 turbines at John Day Dam or eight B2 turbines at Bonneville Dam. Most smolts are diverted into gatewell slots located above each turbine intake (three per turbine), and from the gatewell slot, most smolts pass through a 0.305-m-diameter orifice into a collection channel that runs the length of the powerhouse. After considerable dewatering, insulated pipes deliver smolts to monitoring facilities where they may be sampled and examined to evaluate health or condition. Sampled fish typically would be returned to the river in an outfall pipe emptying into fast water in the tailrace. A small percentage of JBS-passed fish at either monitoring site were selected for inclusion in this survival study, and those fish were held two days longer than their counterparts to allow time for surgical implantation of PIT and acoustic tags and the fish to recover prior to their release.

3.1.2 Federal and State Permitting

Records were kept on all smolts handled and collected (both target and non-target species) for permit accounting. Collections were conducted in conjunction with routine sampling at the monitoring facilities to minimize the impacts of handling. Surgical candidates collected from routine target sample sizes were accounted for under permits issued to the monitoring facilities. Additional fish required to meet research needs (beyond typical sampling goals) were accounted for under separate federal and state permits.

All permitting requirements were met by PNNL and NOAA Fisheries teams. A federal scientific permit (SS-08 PNNL-40) issued by the NOAA Fisheries Hydropower Division's FCRPS Branch under the 2004 FCRPS Biological Opinion authorized PNNL researchers to take juvenile salmonids at the John Day Dam SMF. The Oregon Department of Fish and Wildlife also authorized the take of fish for this study under permit number OR2008-4600. The NOAA Fisheries team that tagged juvenile salmonids at the Bonneville JMF also obtained a federal permit (16-08-NWFSC16 from the Hydropower Division, FCRPS Branch), and a state permit (Washington Department of Fish and Wildlife Permit [08-178]).

3.1.3 Sampling Methods

Pacific States Marine Fisheries Commission (PSMFC) staff diverted fish from the JBS at John Day Dam and Bonneville Dam using detailed methods described by Martinson et al. (2006). Several samples of about 250 fish were anesthetized using a tricaine methanesulfonate (MS-222) solution prepared at a concentration of 44 mg/L. Once fish were in the examination trough, MS-222 was added as necessary to maintain induction.

PNNL staff evaluated the candidate fish for inclusion in the survival study using the following specific acceptance and rejection criteria:

- **Accept if the fish**
  - adipose-fin is clipped or unclipped
  - length is >95 mm.
- **Reject if the fish**
  - is a non-target species
  - exhibits descaling greater than 20% on any one side
  - shows signs of prior surgery (for instance: radio tags, sutures, or PIT-tag scars)
  - indicates positive readings when put through a PIT-tag reader
  - has physical injuries, such as to the head (injury on the head or in the eye); operculum damage (torn or folded); popeye; body injury; or fin hemorrhage
  - shows evidence of infections or parasites, such as fungus (infection on the body surface); Bacterial Kidney Disease; Columnaris (yellow rimmed sores, ulcers, or open lesions on the body or fins); or trematodes (subdermal parasites)
  - shows signs of predation, such as bird strikes or injuries inflicted by other fish or mammals that result in punctures or abrasions.

The NOAA Fisheries team tagging at Bonneville Dam used similar acceptance and rejection criteria, but team members only tagged clipped yearling Chinook salmon smolts and tagged no steelhead in 2008.

The percent of smolts rejected for tagging at the John Day Dam SMF was low: 0.8% for yearling Chinook salmon (299 out of 3763), 0.7% for steelhead (361 out of 3815), and 0.7 % for subyearling Chinook salmon (212 out of 6170). Rejection percentages were slightly higher at the Bonneville JMF (3.6% for yearling Chinook salmon and 1.9% for subyearling Chinook salmon). Non-target and rejected fish were released to the river after a 30-minute recovery period. Accepted fish were counted into transfer buckets containing fresh river water, and moved to one of two, 511-L pre-surgical holding tanks. Fish were held in the tanks for 24 hours so that gut contents would be evacuated before surgery.

3.2 Fish Tagging

Acoustic tags were surgically implanted in the fish, which were held for recovery as described here, prior to their being released.

3.2.1 JSATS Acoustic Micro-Transmitter

The JSATS acoustic tags used in this study were manufactured by Advanced Telemetry Systems (ATS), Inc., and each tag weighed about 0.425 g in air and 0.29 g in water. Acoustic tags were 12.04 mm long, 5.27 mm wide, and 3.74 mm thick (Figure 3.1). Fish collected at John Day Dam were implanted with tags that had nominal transmission rates of about 1 pulse every 3 seconds (3-s tags), and fish tagged at Bonneville Dam received tags transmitting once every 5 seconds (5-s tags). Each pulse from a JSATS tag contains a complex phase-encoded signal that uniquely identifies the transmitting tag without varying pulse duration. Within 1 to 5 days of being implanted in fish, each tag was acoustically activated by Cascade Aquatics, Inc., using a Pinger dish designed by ATS to activate or deactivate tags. Nominal tag life was about 30 days for 3-s tags and 45 days for 5-s tags.

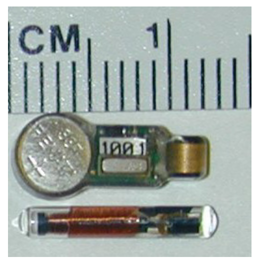


Figure 3.1. The ATS JSATS Acoustic Micro-Transmitter (Top) and a PIT Tag (Bottom)

3.2.2 Fish Collection and Tagging Procedures

Several steps were used in the tagging process to minimize handling impacts. Sterilization of all surgical instruments was a continuous and emphasized protocol. Each surgeon used three to four complete sets of instruments. Once used, the instruments were placed in a 70% ethanol solution for approximately 10 minutes. All instruments were rotated into distilled water for 10 minutes to “wash” off the residual ethanol prior to their use during the next surgery. This procedure reduced the introduction of bacteria and other harmful particulates into the incision and suture site. A synthetic fish slime (Poly-Aqua) was liberally used on the surgical pad to counteract the disruption to mucus membranes during surgical procedures (Table 3.1). Local anesthetic was not used on the incision site because of its characteristic of further disrupting the mucus membrane. The proximity of the incision to the midline was closely monitored to ensure that neither the incision nor the suture went through the midline.

Table 3.1. Dilution of Poly-Aqua Used in Surgical Procedures

Volume (l)	Poly-Aqua
1	0.15
2	0.30
3	0.45
4	0.60
5	0.75
6	0.90
10	1.50
20	3.00
50	7.50

The day before tagging, one person subsampled fish from the routine smolt-monitoring sample. Fish were placed in three 511-L tanks with inflowing and outflowing river water and held overnight to provide time for gut contents to be eliminated. The use of routine smolt-monitoring samples usually provided enough fish to meet our quota each day except occasionally near the beginning or at the end of a migration season when numbers in routine samples may have been low.

A team of eight people participated in the tagging process to reduce handling time from netting to post-surgery recovery. On many days all fish were tagged within a 4- to 5-hour period. The procedure started with one technician netting enough fish (usually five) from 511-L holding tanks to fill one 18.9-L transport bucket. These fish were anesthetized in an 18.9-L "knockdown" bucket with fresh river water and MS-222 at a concentration between 80 and 100 mg/L. After fish lost equilibrium and rolled over, they were monitored closely to assure that breathing, as indicated by gill movements, was continuous and did not weaken before fish were moved into the tagging process. Anesthesia buckets were refreshed regularly to maintain ±2 °C of current river temperatures. Anesthesia solutions were either replaced or cooled with ice when temperatures exceeded protocols. On rare occasions when the surgery routine was delayed, a few fish may have remained in the knockdown bucket minutes longer than usual and exhibited slowed breathing. They were promptly transferred to an adjacent bucket of cool freshwater until their breathing rates returned to normal. Anesthetized fish were transferred one-at-a-time into a 0.25-L plastic container of knockdown solution and handed to a second person who measured (fork length ±1 mm) and weighed (±0.1 g) them. A digitizing board and electronic scale with serial connections to a computer facilitated accurate recording of lengths and weights. The person measuring and weighing fish was stationed at the end of a line of three or four surgeons so that they could see who was available to tag the next fish. The digitizing board had buttons with the names of all surgeons so each fish could be assigned to the next available surgeon with the push of one button. A third individual scanned PIT and acoustic tag codes into the computer, assigned tags to a specific fish, and recorded fish species, run, and adipose fin status (clipped or unclipped). After a fish was weighed and measured, it was placed back into its plastic transfer container along with an assigned PIT tag, activated acoustic tag, and a colored cork matching the color of a piece of foam stationed above the 18.9-L transport bucket receiving fish. The container with fish, tags, and colored cork were then handed to one of three or four surgeons for tag implantation.

During surgery (Figure 3.2), each fish was placed ventral side up and a gravity-fed anesthesia supply line was placed into its mouth. The dilution of this "maintenance" line was 40 mg/L. A 6- to 8-mm incision, using a #10 or #15 stainless-steel surgical blade, was made ventrally, 3 mm from and parallel to the mid-ventral line and equidistant from 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. Two interrupted sutures were made using 5-0 monocryl suture with a RB-1 needle. After closing the incision, the surgeon would check to see whether the colored cork with the fish matched the color of a piece of foam set up near the transport bucket being filled. If the colors were the same, the surgeon placed the tagged fish and colored cork into an opening in the top of a 76-mm-diameter polyvinyl chloride (PVC) pipe that sluiced the tagged fish and cork along the line of surgeon stations (Figure 3.2) down to a dark 18.9-L transport bucket filled with oxygenated river water. If the cork and foam colors were different, the surgeon waited for the transport bucket and colored foam indicator to be switched to the next available bucket and color that matched, or walked the fish down the line to the next bucket to be filled. At the end of the line of surgeons, another technician was responsible for closely observing and counting the number of fish and corks accumulating in the transport bucket, for letting surgeons know what transport bucket was being filled (verbally and by setting out a colored piece of foam, and for switching out transport buckets and colored foam indicators after each bucket was filled to its quota (usually five fish). When fish in transport buckets regained equilibrium, as indicated by vertical posture and active swimming, a lid was added to the bucket, and it was hand carried outside and placed in one of several large holding tanks with flowing river water for 18 to 24 hours.

Figure 3.2. Line of Four Surgery Stations. Each station had an elevated bucket of maintenance anesthetic solution with a plastic line that fed solution to the fish throughout the operation. Tagged fish and colored corks were dropped in one of four openings to a 76-mm-diameter PVC pipe that ran the length of the four stations and were swept river-water-supplied to one end of the pipe to a transport bucket.

3.2.3 Transport and Holding

Each transport buckets had many 3/8-in.-diameter holes drilled through the upper half of its height and around its circumference (Figure 3.3), but while being filled with recently tagged fish, it was nested inside another 18.9-L bucket without holes so that it could be filled to capacity. The location of holes in the upper half of the buckets allowed water to flow through each bucket when submerged in a large post-surgery holding tank that had fresh river water flowing through it (Figure 3.4). The solid bottom half of transport buckets provided a sanctuary that retained about 9 L of water when the bucket was being transported, and this protected fish and reduced weight by half. Most transport buckets were loaded with five fish, although the last bucket for a release site may have had fewer than five or as many as seven if fish were small.

Figure 3.3. Transport Bucket

When fish regained equilibrium after surgery, the 18.9-L buckets were covered with a fitted lid hand carried outside to a larger holding tank with a continuous supply of river water (Figure 3.4). Fish were held for at least 18 hours prior to release in the river. A sensor for monitoring water level, temperature, and dissolved oxygen was installed and set up to automatically telephone staff if water-quality conditions were undesirable for fish. Alert limits were set to a maximum of 21.7°C and a minimum of 7 mg/L of oxygen. The inside of tanks was sectioned off by an aluminum or PVC pipe to keep buckets upright (Figure 3.5).

Figure 3.4. Large Insulated Tanks for Holding Transport Buckets at the Bonneville JMF (top) and John Day Dam SMF (bottom). Holding tanks were plumbed to allow flowing river water to pass through the tanks that held 32 transport buckets, and holes in the upper half of transport buckets allow fresh river water to enter and leave individual buckets.

Figure 3.5. View Inside Large Holding Tanks at Bonneville Dam (left) and John Day Dam (right) Showing Aluminum or PVC Grids for Keeping Transport Buckets Upright

3.3 Transport and Release

To transport fish from the John Day Dam tagging site to release locations, the PNNL team secured 681-L and 265-L Bonar insulated totes in the bed of a pickup truck. The large tote held water and ten 18.9-L transport buckets and the 265-L tote held water and four buckets. Totes had locking lids and extra space to accommodate a wood-frame separator so that ice could be added for cooling on hot days. A network of valves and plastic tubing was attached to oxygen (O_2) tanks for delivering oxygen to the water in each tote from a 2200 psi O_2 tank secured in the truck bed. Fish buckets were removed two at a time from the post-surgery holding tank, and loaded into insulated totes. Dissolved oxygen concentration and temperature in Bonar totes were measured before and after transport with an YSI meter to assure that levels remained satisfactory during transport. Procedures used by the NOAA fisheries team were similar, although the specific vehicle and transport tank were different and the need to measure oxygen concentration and temperature before and after transport was eliminated by the short distances from the Bonneville JMF to the B2CC.

We minimized handling impacts during transport and release in several ways. Dark buckets reduced stress associated with holding fish in confined spaces and transport. During load up from post-surgical holding to transport vehicles, each insulated tank receiving transport buckets was flushed with river water to cool and clean it before it was loaded with fresh river water and fish transport buckets. On boats, transport buckets were shaded to reduce solar heating.

Tagged fish were hauled from tagging sites to release locations (Figure 3.6) three times every day (morning, afternoon, and at night). Fish were released into the B2CC by hose induction system (Figure 3.7). Fish usually were released by boat along a transect line across the river at the Bonneville Dam tailrace (Figure 3.8), upper The Dalles Dam tailwater, upper John Day Dam tailwater, and above John Day Dam at Arlington, Oregon (e.g., Figure 3.9). Buckets were opened to check for dead fish, and all dead fish were scanned with a BioMark portable transceiver PIT-tag scanner so that identities could be established and recorded. Following established protocol, biologists cut through gill arches of all dead fish before releasing them. Boat operators used an onboard global positioning system (GPS) to move the boat to specific latitudes and longitudes and put the motor in neutral while the crew gently poured fish into the river and recorded the location, bucket number, and time of release. Acoustic tags and PIT tags in each bucket were part of the tagging database, so records indicate release time to the nearest minute (PST).

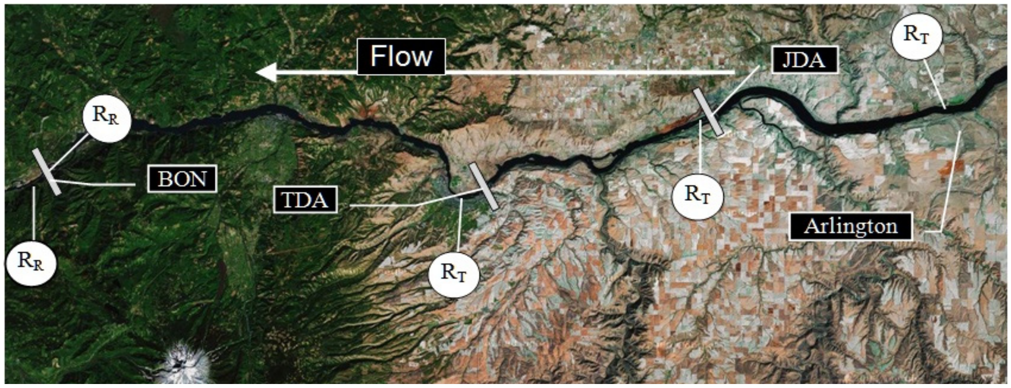


Figure 3.6. Plan View of the Reach of the Columbia River with Fish Release Sites. Approximate locations of dams are indicated by gray rectangles. Reference releases (R_R) were into the B2CC at Bonneville Dam (BON) or in the BON tailwater 2 km downstream of the dam. Treatment releases (R_T) were made 3 km below The Dalles Dam (TDA) in summer only and 2 km below John Day Dam (JDA) and near Arlington, Oregon, above JDA in spring and summer.

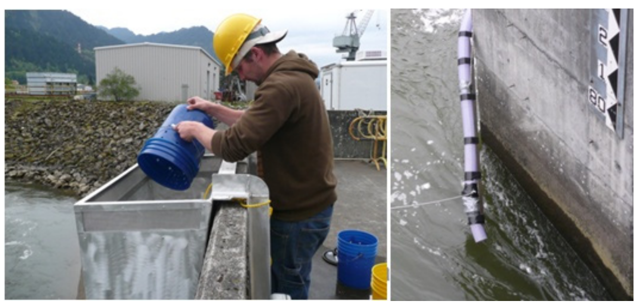


Figure 3.7. Photo of Fish Release Apparatus at the B2CC (courtesy of Jason Everett with the NOAA Fisheries Team). Fish were poured into an induction tank (left) and flushed through a 102-mm-diameter plastic hose into the B2CC entrance.

Figure 3.8. Photo of the Fish Release Barge Maneuvering Along a Line Transect 2 km Downstream of Bonneville Dam. (This photo was provided by Jason Everett with the NOAA Fisheries Team.)

Figure 3.9. Photo of Fish Being Released from a Boat Moving Along a Line Transect Above John Day Dam. Fish were gently poured into the river from each transport bucket.

All survival estimates in this study were based on detections of treatment fish released in the Columbia River at Arlington, Oregon, above John Day Dam, in the uppermost end of the John Day Dam tailwater, and in the uppermost end of the Dalles Dam tailwater and detections of reference fish released in the upper end of the Bonneville Dam tailwater and B2CC. The numbers of treatment fish tagged by this study are listed in Tables 3.2 and 3.3.

Table 3.2. Numbers of Juvenile Salmon Tagged and Released Upstream of Bonneville Dam by Date, Release Location, and Species in Spring. These fish had the opportunity to pass Bonneville Dam. Fish detected by a Bonneville forebay entrance array were regrouped to form daily virtual treatment releases for estimating B2 and route-specific survival.

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Number Dead
4/30/2008	5/1/2008	240	Arlington	Steelhead	120	1
				Yearling Chinook	120	1
5/1/2008	5/2/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/2/2008	5/3/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/3/2007	5/4/2008	246	Arlington	Steelhead	87	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/4/2008	5/5/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	1
				Yearling Chinook	36	1

Table 3.2. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Number Dead
5/5/2008	5/6/2008	123	Arlington	Steelhead	45	0
				Yearling Chinook	48	1
			JDA Tailwaters	Steelhead	15	0
				Yearling Chinook	15	0
5/6/2008	5/7/2008	254	Arlington	Steelhead	90	0
				Yearling Chinook	90	0
			JDA Tailwaters	Steelhead	37	0
				Yearling Chinook	37	0
5/7/2008	5/8/2008	252	Arlington	Steelhead	90	0
				Yearling Chinook	89	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	37	0
5/8/2008	5/9/2008	259	Arlington	Steelhead	89	0
				Yearling Chinook	92	1
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/9/2008	5/10/2008	256	Arlington	Steelhead	88	0
				Yearling Chinook	90	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/10/2008	5/11/2008	265	Arlington	Steelhead	97	0
				Yearling Chinook	90	2
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/11/2008	5/12/2008	264	Arlington	Steelhead	95	0
				Yearling Chinook	91	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/12/2008	5/13/2008	186	Arlington	Steelhead	63	0
				Yearling Chinook	63	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	33	0
5/13/2008	5/14/2008	270	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	1
5/14/2008	5/15/2008	213	Arlington	Steelhead	72	0
				Yearling Chinook	72	0
			JDA Tailwaters	Steelhead	33	0
				Yearling Chinook	36	0

Table 3.2. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Number Dead
5/15/2008	5/16/2008	270	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/16/2008	5/17/2008	226	Arlington	Steelhead	78	0
				Yearling Chinook	78	0
			JDA Tailwaters	Steelhead	35	0
				Yearling Chinook	35	0
5/17/2008	5/18/2008	269	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	38	0
5/18/2008	5/19/2008	276	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	43	1
				Yearling Chinook	41	0
5/19/2008	5/20/2008	191	Arlington	Steelhead	69	0
				Yearling Chinook	66	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	29	0
5/20/2008	5/21/2008	281	Arlington	Steelhead	98	2[a]
				Yearling Chinook	99	0
			JDA Tailwaters	Steelhead	43	0
				Yearling Chinook	41	3[a]
5/21/2008	5/22/2008	223	Arlington	Steelhead	78	0
				Yearling Chinook	74	0
			JDA Tailwaters	Steelhead	37	0
				Yearling Chinook	34	0
5/22/2008	5/23/208	280	Arlington	Steelhead	104	0
				Yearling Chinook	104	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/23/2008	5/24/2008	192	Arlington	Steelhead	68	1
				Yearling Chinook	72	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	25	0
5/24/2008	5/25/2008	292	Arlington	Steelhead	100	0
				Yearling Chinook	106	0
			JDA Tailwaters	Steelhead	44	0
				Yearling Chinook	42	0

Table 3.2. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Number Dead
5/25/2008	5/26/2008	294	Arlington	Steelhead	104	1
				Yearling Chinook	107	0
			JDA Tailwaters	Steelhead	40	0
				Yearling Chinook	43	0
5/26/2008	5/27/2008	295	Arlington	Steelhead	108	0
				Yearling Chinook	108	1
			JDA Tailwaters	Steelhead	37	4[(a)]
				Yearling Chinook	42	4[(a)]
5/27/2008	5/28/2008	194	Arlington	Steelhead	56	0
				Yearling Chinook	60	0
			JDA Tailwaters	Steelhead	42	5[(a)]
				Yearling Chinook	36	3[(a)]
5/28/2008	5/29/2008	44	JDA Tailwaters	Steelhead	22	5[(a)]
				Yearling Chinook	22	2[(a)]
Totals	Totals	6902	Arlington	Steelhead	2453	5[(b)]
				Yearling Chinook	2451	6
			JDA Tailwaters	Steelhead	998	16 [(c)]
				Yearling Chinook	1000	14[(d)]

(a) Sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(b) Two of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(c) Fourteen of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(d) Twelve of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.

Table 3.3. Numbers of Subyearling Chinook Salmon Smolts Tagged and Released Upstream of Bonneville Dam by Date and Release Location in Summer 2008. These fish had the opportunity to pass through Bonneville Dam. Fish detected by a Bonneville forebay entrance array were regrouped to form virtual treatment releases for estimating dam (concrete) survival, and those detected at B2 were assigned to virtual releases at B2 routes.

Tag Date	Release Date	Number Tagged	Release Location	Number Released	Number Dead
6/14/2008	6/15/2008	117	Arlington	81	1
			JDA Tailwater	36	0
6/15/2008	6/16/2008	124	Arlington	87	0
			JDA Tailwater	37	1*
6/16/2008	6/17/2008	122	Arlington	87	1
			JDA Tailwater	35	0
6/17/2008	6/18/2008	123	Arlington	87	0
			JDA Tailwater	36	0

Table 3.3. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Number Released	Number Dead
6/18/2008	6/19/2008	123	Arlington	87	0
			JDA Tailwater	36	0
6/19/2008	6/20/2008	125	Arlington	87	0
			JDA Tailwater	38	2[a]
6/20/2008	6/21/2008	121	Arlington	87	2
			JDA Tailwater	34	0
6/21/2008	6/22/2008	123	Arlington	87	0
			JDA Tailwater	36	0
6/22/2008	6/23/2008	123	Arlington	87	1
			JDA Tailwater	36	0
6/23/2008	6/24/2008	123	Arlington	86	0
			JDA Tailwater	37	1
6/24/2008	6/25/2008	123	Arlington	87	0
			JDA Tailwater	36	0
6/25/2008	6/26/2008	123	Arlington	88	0
			JDA Tailwater	35	0
6/26/2008	6/27/2008	123	Arlington	86	0
			JDA Tailwater	37	1
6/27/2008	6/28/2008	123	Arlington	87	0
			JDA Tailwater	36	0
6/28/2008	6/29/2008	132	Arlington	87	0
			JDA Tailwater	36	0
6/29/2008	6/30/2008	123	Arlington	88	0
			JDA Tailwater	35	0
6/30/2008	7/1/2008	123	Arlington	86	0
			JDA Tailwater	37	1
7/1/2008	7/2/2008	84	Arlington	57	0
			JDA Tailwater	27	0
7/2/2008	7/3/2008	164	Arlington	119	0
			JDA Tailwater	45	1
7/3/2008	7/4/2008	122	Arlington	90	0
			JDA Tailwater	32	0
7/4/2008	7/5/2008	123	Arlington	90	0
			JDA Tailwater	33	0

Table 3.3. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Number Released	Number Dead
7/5/2008	7/6/2008	126	Arlington	92	0
			JDA Tailwater	34	1
7/6/2008	7/7/2008	124	Arlington	88	0
			JDA Tailwater	36	2[(a)]
7/7/2008	7/8/2008	75	Arlington	53	0
			JDA Tailwater	22	0
7/8/2008	7/9/2008	173	Arlington	122	0
			JDA Tailwater	51	2
7/9/2008	7/10/2008	126	Arlington	90	0
			JDA Tailwater	36	0
7/10/2008	7/11/2008	126	Arlington	90	0
			JDA Tailwater	36	0
7/11/2008	7/12/2008	126	Arlington	90	1
			JDA Tailwater	36	1
7/12/2008	7/13/2008	31	JDA Tailwater	31	1[( ]
Totals	Totals	3485	Arlington	2453	6
			JDA Tailwater	1032	14

Table 3.4. Numbers of Smolts Released Alive and Dead by Date, Release Location, and Run at Bonneville Dam by NOAA Fisheries. These reference releases of fish did not have the opportunity to pass B2. Fish released in the upper tailwater 2 km downstream of the dam served as reference releases for pairing with releases of treatment fish listed in Tables 3.2 and 3.3 to calculate paired-release estimates of dam and spillway survival. The ratio of survivals of fish released in the B2CC and tailrace was used to scale a dam (concrete) survival estimate in a triple release model.

Yearling Chinook Salmon in Spring				Subyearling Chinook Salmon in Summer			
	B2CC	Tailrace			B2CC	Tailrace	
Date	Alive	Alive	Dead	Date	Alive	Alive	Dead
				6/15/2008	26	26	
4/30/2008	25	26		6/16/2008	26	26	
5/1/2008	23	22		6/17/2008	30	30	
5/2/2008	23	23		6/18/2008	30	30	
5/3/2008	24	24		6/19/2008	30	30	3
5/4/2008	24	24	3	6/20/2008	30	30	3

Table 3.4. (contd)

Yearling Chinook Salmon in Spring				Subyearling Chinook Salmon in Summer			
	B2CC	Tailrace			B2CC	Tailrace	
Date	Alive	Alive	Dead	Date	Alive	Alive	Dead
5/5/2008	23	24	3	6/21/2008	30	30	3
5/6/2008	24	23	4	6/22/2008	30	30	3
5/7/2008	18	19	3	6/23/2008	30	30	
5/8/2008	30	28		6/24/2008	30	30	
5/9/2008	24	25		6/25/2008	30	29	1
5/10/2008	25	25		6/26/2008	30	30	4
5/11/2008	24	24	2	6/27/2008	30	30	2
5/12/2008	24	24	3	6/28/2008	31	30	3
5/13/2008	23	24	3	6/29/2008	30	30	3
5/14/2008	25	24	3	6/30/2008	30	30	
5/15/2008	24	24		7/1/2008	30	30	
5/16/2008	24	24		7/2/2008	30	30	
5/17/2008	24	24		7/3/2008	30	30	3
5/18/2008	12	4	3	7/4/2008	30	30	3
5/19/2008	24	24		7/5/2008	30	30	3
5/20/2008	26	30	3	7/6/2008	29	30	6
5/21/2008	32	34	4	7/7/2008	30	30	
5/22/2008	32	31	4	7/8/2008	31	30	
5/23/2008	27	30		7/9/2008	30	30	
5/24/2008	27	25		7/10/2008	30	30	
5/25/2008	26	28		7/11/2008	30	30	2
5/26/2008	24	24		7/12/2008	30	30	3
5/27/2008	24	24	3	7/13/2008	30	29	3
5/28/2008	24	24	3	7/14/2008	30	31	3
5/29/2008	24	24	3	7/15/2008	28	29	
5/30/2008	24	24	3	7/16/2008	25	25	
5/31/2008	24	24		7/17/2008	25	25	
6/1/2008	23	23		7/18/2008	25	25	
6/2/2008	22	22		7/19/2008	24	25	1
Spring Total	826	826	50	Summer Total	1020	1020	52

3.4 Detection of Tagged Fish

Underwater listening devices (called nodes) were deployed in groups called arrays to detect tagged fish moving downstream from release locations. The following sections describe nodes, arrays, array locations, and node deployment, retrieval, servicing, and redeployment practices.

3.4.1 Nodes and Arrays

The Sonic Concepts autonomous acoustic telemetry receiver (node) used in this study consisted of two coupled parts. The top was made from Schedule 40 10.16-cm-diameter PVC pipe that was capped at the top and had a fitting with male threading at the bottom (Figure 3.10). The cap was modified for watertight seating of a hydrophone, and the body below the cap housed the analog and digital boards for processing detected tag signals. A lubricated 10.16-cm-diameter rubber O-ring was fitted over the lower threaded end so that it would form a watertight seal when the node top was screwed together with the bottom. The node bottom was made from approximately 1 m of 10.16-cm-diameter PVC pipe and the upper end had a fitting with female threads for coupling it to the node top. The lower end of the node bottom was capped and a stainless-steel harness was located just below the upper fitting so the node could be attached to an anchor system, which is described later. An acoustic beacon that transmitted a signal four times louder than acoustic tags once every 15 seconds was attached to the outside of the battery housing just below the threaded end of the housing. This beacon was used to determine the location of a node if it didn't surface after it was acoustically released from an anchor. Beacons also could be used to determine when an adjacent node disappeared. All autonomous nodes were received with version 2006 software and were thoroughly tested by Precision Acoustic Systems (PAS) to ensure that nodes met acceptance-testing criteria. Functionality also was verified just before each deployment in the river.

Figure 3.10. Side (left) and Bottom (right) View of a Node Top

Before deployment, two 30-day lithium-ion batteries were gently lowered into the node bottom and secured in place with a battery-retention device. Wires from the batteries were attached to connectors from the analog board in the node top. One end of a serial cable was connected to a plug from the board set in the node top and the other end was plugged into a laptop computer so that staff could communicate with the node, set its date and time, and verify detection of a beacon tag. Next, a 1-GB SanDisk Extreme III CompactFlash (CF) card was mounted in a slot on the board set, and the node top and bottom were screwed together until beveled edges of each piece compressed the O-ring to form a watertight seal. Just before putting the node into the water, we verified that a light-emitting diode (LED) on the node top housing was flashing, which indicated that the node was functioning properly and data would be written to the CF card. In the water, air space within the sealed node provided positive buoyancy, while the batteries in the node bottom provided ballast to help keep the node upright.

An array is defined as a group of nodes deployed within 1 km of a specific river cross section to detect passing acoustically tagged fish. Nodes in line transects were deployed at distances ≤150 m from each other and ≤90 m from the shore. However, additional nodes sometimes had to be deployed in entrances to or exits from side channels formed by islands downstream of Bonneville Dam.

3.4.2 Array Locations

Figure 3.11 shows the location of all arrays deployed to detect fish and estimate survival under this study. The B2 array was composed of 11 receiver systems; 5of the 11 systems monitored passage routes and 6 systems monitored behavior relative to the BGS. Each system was cabled to four hydrophones and running on 110-volt alternating current. All other arrays located away from the dam were composed of autonomous nodes running on two lithium battery packs. Internal clocks in autonomous nodes were set based upon GPS time each week that they were serviced but time could drift several minutes per week so those nodes were only used to detect fish and not to track them.

3.4.2.1 Bonneville Forebay Array

The cabled hydrophone system that was deployed in the B2 forebay was designed to detect passage location at B2 and track movement of tagged smolts relative to the BGS deployment (Figure 3.12 and 3.13). The 19 dam-mounted hydrophones were used to detect tagged juvenile salmonids from about 50 m upstream of B2 and their passage into the turbine or corner collector. The hydrophones monitoring the BGS were used to track fish about 50 m upstream and adjacent to the BGS, including monitoring the fish passing through the north and south gaps. Tracking successive positions of tagged fish required us to synchronize digital signal processing (DSP) cards to within 0.4 µs using five GPSs and Meinberg GPS time cards. Individual hydrophones on B2 piers were baffled by plastic cones lined with an anechoic material throughout sampling in 2008 to exclude loud noises emanating from turbines or corner collector downstream of hydrophones. The pier-mounted hydrophones were angled toward specific units to determine the route of passage based on the last detection of the tag. Baffling these hydrophones greatly increased the ratio of tag signals relative to background noise levels, and significantly increased the percentage of successful tag decodes. Table 3.5 provides GPS coordinates and depths of cabled hydrophones deployed in the B2 forebay that were used to accomplish these tasks.

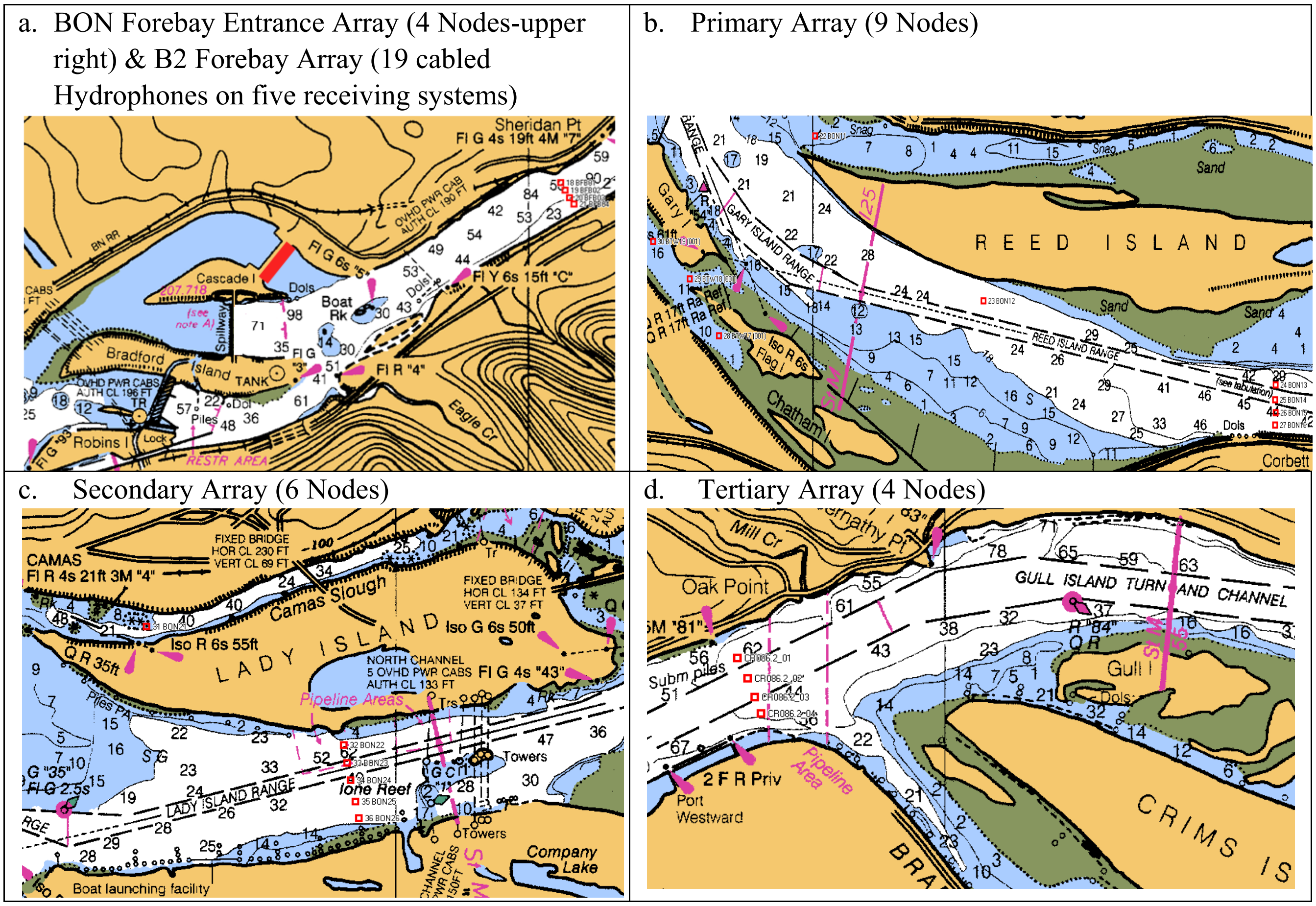


Figure 3.11. Maps Showing Approximate Locations of Underwater Listening Devices in Deployed Arrays for this Study. Twenty three autonomous node locations are marked with red squares, and the 19 cabled hydrophones deployed on B2 turbine piers appear as a thick red line on the forebay side of B2. Flow is from right to left in all panels.

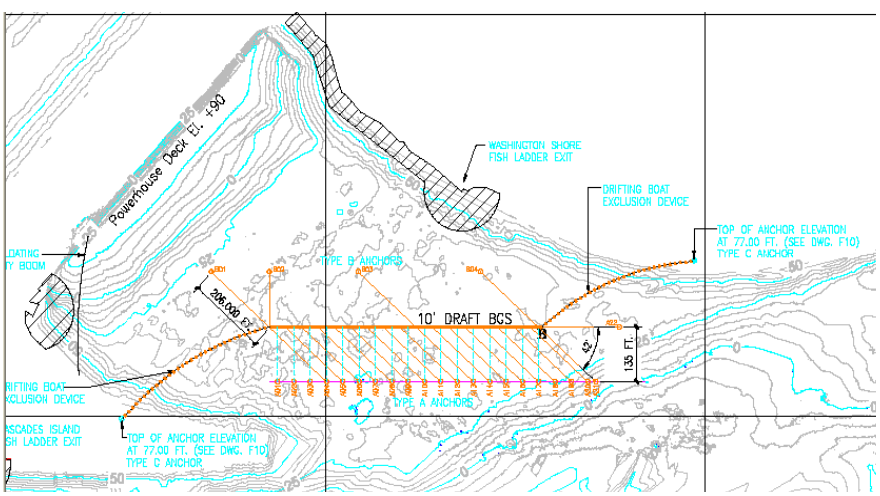
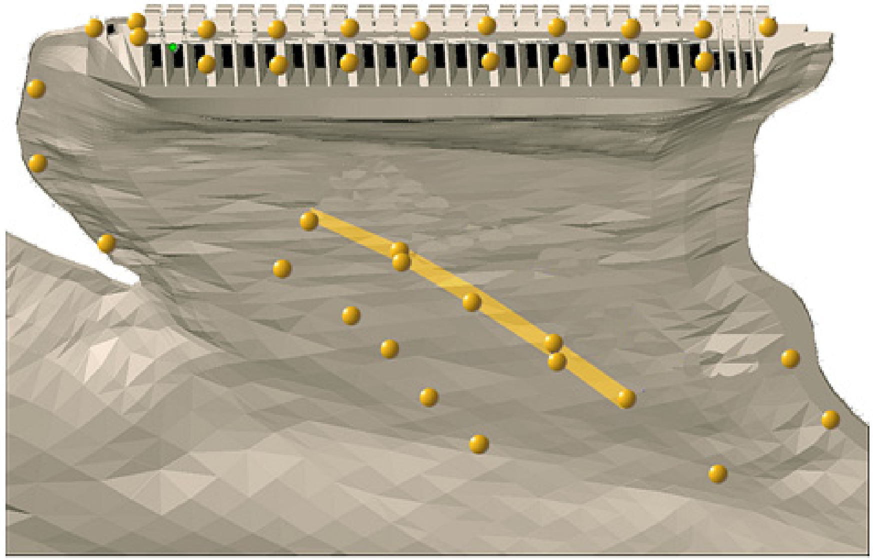


Figure 3.12. BGS Deployment in the B2 Forebay. The diagram shows the overhead view of the BGS and locations of anchor lines that tether the BGS to the river bed and to the shoreline. (The schematic was created by the BGS contractor Tuffboom.)



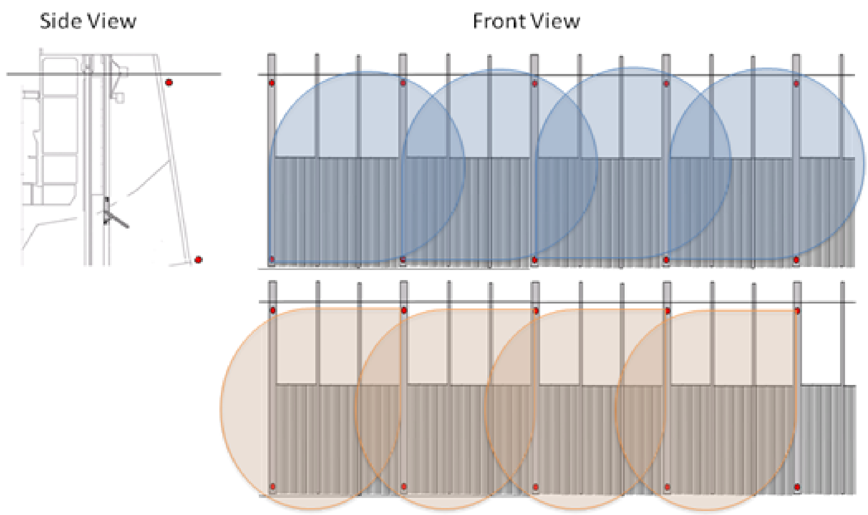


Figure 3.13. Three-Dimensional Depiction of the B2 Forebay Showing the Hydrophone Locations (yellow spheres) in Relation to the BGS Deployment (yellow polygon). The hydrophones deployed along the BGS were in two or three hydrophone clusters that monitored both the front and back of the BGS from the same location. The bottom view depicts the overlapping coverage of a "double array" for hydrophones deployed on the main turbine piers. Each hydrophone on the piers was angled so that its reception area was turbine unit specific, which allowed for assignment of passage route that did not require the 3D positioning of the fish.

Table 3.5. Global Positioning System Coordinates (WGS84 Datum; latitude and longitude) of Cabled Hydrophones Deployed in the Forebay of the Bonneville Dam Second Powerhouse in 2008

Location Name	Fixed or Moving	Latitude (Deg)	Longitude (Deg)	Elevation (MSL, m)
B1	Moving	45.6465251	-121.9353974	21.59
B2	Moving	45.6464727	-121.9347081	21.59
B3	Moving	45.6464407	-121.9340951	21.59
B4	Moving	45.6464727	-121.9334671	21.59
B5	Moving	45.6464687	-121.9326961	21.49
B6	Moving	45.6469687	-121.9320011	21.59
B7	Moving	45.6472146	-121.9379931	21.59
D1	Fixed	45.6472265	-121.9383678	20.27
D10	Fixed	45.6479839	-121.9373574	4.08
D11	Fixed	45.6481862	-121.9371397	19.14
D12	Fixed	45.6481707	-121.9371191	4.26
D13	Fixed	45.648378	-121.9368937	19.05
D14	Fixed	45.6483625	-121.9368731	4.18
D15	Fixed	45.6485707	-121.9366504	18.83
D16	Fixed	45.6485552	-121.9366298	3.96
D17	Fixed	45.6487627	-121.9364047	18.82
D18	Fixed	45.6487472	-121.9363841	3.94
D19	Fixed	45.6489532	-121.93616	20.27
D2	Fixed	45.6472226	-121.9383626	16.51
D3	Fixed	45.6474181	-121.938119	19.09
D4	Fixed	45.6474026	-121.9380984	4.22
D5	Fixed	45.6476113	-121.9378749	18.68
D6	Fixed	45.6475958	-121.9378543	3.80
D7	Fixed	45.6478072	-121.9376222	19.22
D8	Fixed	45.6477917	-121.9376015	4.34
D9	Fixed	45.6479994	-121.9373781	18.96
F1	Fixed	45.6470992	-121.9384766	21.17
G1	Moving	45.6468737	-121.9360011	21.07
G10	Moving	45.6469403	-121.9332961	21.13
G11	Moving	45.6469403	-121.9332961	21.13
G12	Moving	45.6469403	-121.9332961	21.13
G2	Moving	45.6468737	-121.9360011	21.07
G3	Moving	45.6468737	-121.9360011	21.07

Table 3.5. (contd)

Location Name	Fixed or Moving	Latitude (Deg)	Longitude (Deg)	Elevation (MSL, m)
G4	Moving	45.6469579	-121.9353778	18.80
G5	Moving	45.6469579	-121.9353778	21.59
G6	Moving	45.6469622	-121.9347155	21.39
G7	Moving	45.6469622	-121.9347155	21.39
G8	Moving	45.6469571	-121.9339678	18.80
G9	Moving	45.6469571	-121.9339678	21.59
Y1	Moving	45.6475441	-121.9330945	22.10
Y2	Moving	45.6473799	-121.9324031	22.10
Y3	Moving	45.646171	-121.9365121	22.10
Y4	Moving	45.6466471	-121.9380992	22.10

3.4.2.2 Survival Arrays

The primary survival array with nine autonomous nodes was centered on rkm 202.7 near Reed Island. The secondary array with six autonomous nodes was centered on rkm 192 near Lady Island and Camas, Washington (Figure 3.11c). The tertiary array located at rkm 86.2 had four autonomous nodes and was deployed by the post-FCRPS (estuary) survival study. Table 3.6 lists GPS coordinates and approximate depths of each autonomous node deployed in arrays above and below BON.

3.4.3 Autonomous Node Rigging

The length of autonomous node rigging varied with water depth at deployment sites. As shown in Figure 3.14, a 1.5-m section of line with three 2.72-kg buoyancy floats was attached to a strap half way between the node tip and node bottom. An InterOcean Systems Model 11 acoustic release was attached to the other end of the 1.5-m line. The length of the 0.48-cm-diameter wire rope anchor line deployed varied with water depth, from 0.3 to 2 m long. One end of the anchor line was swagged to a 76.2-mm ring that fit into the mechanical latch end of the acoustic release and the other end was shackled to a 34-kg anchor. In water <5.5 m deep, we bound the node, float line, and acoustic release together with 1-m-long zip-ties and used a short (0.3-m) anchor line to keep the entire package under 1.5 m long.

Table 3.6. Approximate GPS Coordinates of Autonomous Nodes Deployed in 2008 by Array. The universal transverse mercator (UTM) zone was 10t. Primary, secondary, and tertiary arrays were used to estimate survival.

Array Name	Array Function	Latitude (Deg)	Longitude (Deg)	Approximate Depth (m)
BFB01	Forebay Entrance	45.6526278	-121.9140195	19.8
BFB02	Forebay Entrance	45.6521960	-121.9136593	28.2
BFB03	Forebay Entrance	45.6517643	-121.9132991	22.9
BFB04	Forebay Entrance	45.6514046	-121.9129389	16.4
BTW11	Primary	45.5589048	-122.3330537	6.0
BTW12	Primary	45.5496636	-122.3167645	12.8
BTW13	Primary	45.5449652	-122.2884518	15.9
BTW14	Primary	45.5441388	-122.2885033	18.1
BTW15	Primary	45.5434062	-122.2884599	19.4
BTW16	Primary	45.5427175	-122.2885132	20.8
BTW17	Primary	45.5476987	-122.3423970	9.8
BTW18	Primary	45.5508925	-122.3452551	10.0
BTW19	Primary	45.5530010	-122.3488051	8.3
BTW21	Secondary	45.5750091	-122.4352865	11.1
BTW22	Secondary	45.5687937	-122.4205678	21.9
BTW23	Secondary	45.5678520	-122.4203114	19.8
BTW24	Secondary	45.5669466	-122.4200549	17.2
BTW25	Secondary	45.5658238	-122.4196958	10.4
BTW26	Secondary	45.5649545	-122.4194395	11.5
BTW31	Tertiary	46.1859280	-123.1802780	21.3
BTW32	Tertiary	46.1849910	-123.1796010	20.8
BTW33	Tertiary	46.1841270	-123.1791320	15.8
BTW34	Tertiary	46.1833700	-123.1787150	20.6

3.4.4 Node Retrieval, Servicing, and Redeployment

Autonomous nodes were deployed between April 4 and May 1, 2008, retrieved weekly to download data, and redeployed until about July 25, 2008. The post-FCRPS study deployed the Oak Point array, which we used as a tertiary survival array, on April 14, 2008 and removed it on September 3, 2008. The first step in servicing a node was to trigger its acoustic release by entering a release-specific code into a transceiver to transmit an acoustic signal to the release mechanism to free the acoustic release and node from the anchor. After the node, floats, and acoustic release surfaced, they were retrieved by boat

(Figure 3.15). The next step was to dry the node with a towel, open it, eject the CF card, and download data from the card to a laptop computer. We checked the data file to verify that the node collected data throughout its deployment, records were continuous, and records included time stamps and tag detections. We replaced the CF card every time nodes were retrieved and replaced batteries at about 28-day intervals. When data were corrupt, the node top was replaced with a new one and the faulty top was sent to Sonic Concepts in Seattle for repair. The most common problem was damage to the hydrophone tip.

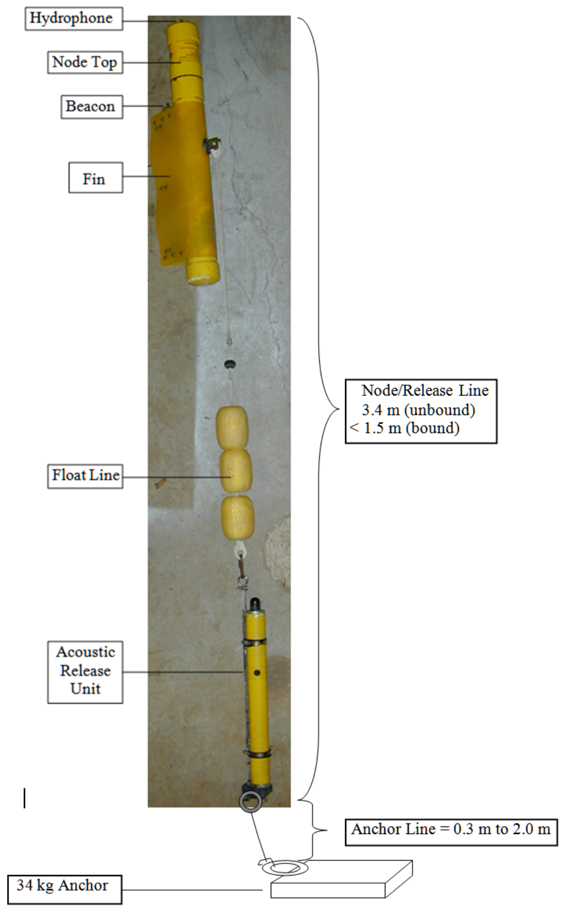


Figure 3.14. Autonomous Node Rigging

Figure 3.15. Autonomous Node Retrieval

3.5 Project Discharge and Water Temperature

Project discharge data by spill bay and turbine unit and forebay and tailwater elevations were acquired in 5-minute increments by the automated data-acquisition systems at Bonneville Dam and provided to us by the Portland District. Average discharge and forebay water temperature data from 1999 through 2008 were downloaded from the DART (Data Access in Real Time) website (http://www.cbr.washington.edu/dart) and plotted. Five-minute discharges for the entire project and spillway were averaged by day and plotted along with 10-year averages.

3.6 Data Processing and Validation

As in previous studies (Ploskey et al. 2007b; Ploskey et al. 2009, tag-detection data from JSATS autonomous nodes were processed in two ways as a quality-control measure, and we found no significant difference in detection and survival estimates based upon detection histories. One method involved using TagViz software, and the other involved processing data with programs written in the Statistical Analysis System (SAS) code.

Tag, release, and detection data were merged together into separate datasets for autonomous and cabled systems, and system-specific filtering rules were applied to decoded data to identify detections and generate detection histories for every tag. To filter out false positive detections, which are detections of otherwise valid tag codes, we ran post-processing programs according to the filtering rules for autonomous and cabled systems.

The rules for autonomous nodes were as follows:

1. Tag codes were among those assigned to tags that were implanted in released fish.
2. Tag codes were detected after the release date and time.
3. Decodes of the same tag within 0.156 second of the previous decode were deleted (multipath filter).
4. A detection event was initiated when the time interval between any four identical decodes was ≤47.8 seconds (3-s tags) or 79 seconds (5-s tags). Once started, the event continued until the time lapse between any two successive decodes exceeded the same respective time intervals.

5. The time spacing between these detections had to match the ping rate interval (PRI) of the tag, or be a multiple of the PRI for the detections to be kept in the valid detection file.

The data collected by the JSATS cabled hydrophones were binary time-domain waveform files that had a high probability of containing Binary Phase Shift Keying (BPSK) to representing tag codes. The BPSK is a digital modulation technique that transmits messages by altering the phase of the carrier wave. Waveform data were post-processed with software to produce comma-separated variable (CSV) files with decodes and time of arrival data. Several filtering algorithms were then applied to the raw results from the decoding utilities to exclude spurious data and false positives.

The rules for cabled hydrophones at B2 were as follows:

1. Tag codes were among those assigned to tags that were implanted in released fish.
2. Tag codes detected were downstream of the release site.
3. Tag codes were detected after the release date and time.
4. The signal-to-noise ratio of decoded signals was at least 3:1.
5. The time gap between two consecutive decodes by one hydrophone had to be longer than 0.5 seconds or the second decode of a pair was eliminated as multipath.
6. A minimum of four decodes in 36 seconds for 3-s tags and in 60 seconds for 5-s tags.

Tracking of fish movements in the forebay was based upon differences in time of arrival data for each tag from four hydrophones, as required to solve 3D source location (Watkins and Schevill 1972; Foy 1976; Spiesberger and Fristrup 1990; Wahlberg et al. 2001). If more than four hydrophones detected the same tag signal, the four with the best geometric configuration for 3D tracking were then selected (Wahlberg et al 2001; Ehgrenberg and Steig 2002).

3.7 Tag-Life Study

As part of the 2008 Tag Effects Study, Dr. Richard Brown and colleagues implanted tags sub-sampled from all tags used in this study into juvenile Chinook salmon from Priest Rapids Hatchery and monitored transmissions from those tags until every tag quit transmitting (reports in process). When a tagged fish died, the tag was re-implanted in another fish until the tag died. A JSATS mobile node was used to listen for tags daily and tag-life history data were compiled to produce tag-life curves, which indicate the percent of each tag type transmitting as a function of days since activation. There were 44 ATS 3-s tags, 40 ATS 5-s tags, and 27 ten-second tags. There also were 94 five-second tags recovered when fish were removed from the river at smolt monitoring facilities using a sort-by-code diversion. The results from this study were used to model tag life with respect to downstream detections of tags for use in survival estimates. The model allowed for a “tag-life correction” of survival estimates, based on the expected life of tags relative to the time it took tagged smolts to navigate through survival arrays (Townsend et al. 2006). The final survival estimates included a tag-life correction.

3.8 Statistical Methods

Using upstream releases of acoustic-tagged yearling and subyearling Chinook salmon and steelhead smolts in conjunction with onsite smolt releases, we examined passage dynamics and survival through B2. Specific statistical objectives include the following:

1. Estimate dam passage survival of yearling and subyearling Chinook salmon smolts using a triple release-recapture model based on fish arriving at the forebay paired with direct B2CC and tailrace releases at Bonneville Dam.
2. Estimate dam passage survival of yearling and subyearling Chinook salmon smolts using a paired release-recapture model based on fish arriving at the forebay paired with a tailrace release at Bonneville Dam.
3. Estimate dam passage survival of yearling and subyearling Chinook salmon smolts using a single release-recapture model based on fish arriving at the forebay of Bonneville Dam.
4. Estimate relative route-specific survival and passage proportions through the B2, JBS, and B2CC for yearling and subyearling Chinook salmon smolts.
5. Estimate dam passage survival for steelhead using a single release-recapture model based on fish arriving at the forebay of Bonneville Dam.
6. Estimate passage distribution of outmigrating smolts relative to approach distribution of smolts relative to the deployment of the BGS.

Analyses for yearling and subyearling Chinook salmon smolts (Objectives 1–4) were similar for both fish stocks. Steelhead survival was limited to single-release estimates because there was no tailrace release of steelheads in 2008.

3.8.1 Release-Recapture Designs and Analyses

All release recapture analyses described below are based upon estimating the survival of virtual releases of fish relative to the survival of reference releases or other virtual releases. Tagged fish were detected on upstream arrays and passed through the B2CC, turbines or JBS, whereas reference fish were released in the tailrace or the B2CC and did not pass through the turbines or JBS. Detections on the forebay entrance array were grouped by species and run in blocks of two or more days to form virtual releases of fish for estimating dam (concrete) survival. Virtual releases also were formed by species/run and blocks of two or more days. The number of days pooled to form virtual releases depended on the rate of fish passage and the number of fish required for a reasonably precise estimate of survival. We tried to pool the same number of days (most virtual releases pooled over 2 days, except for JBS and turbine routes when there were insufficient numbers of fish) to make reasonably precise estimates of survival.

In the next section, we use dam passage survival to describe most of the details, including a description of model assumptions and tag-life corrections. We also describe the distribution of fish in relation to the BGS deployment and their subsequent passage at B2 routes. .

We conducted a chi-square goodness of fit test to indicate if detection probabilities on three survival arrays were homogeneous over time (χ^2 not significant); however, all of these tests were significant so we didn't report pooled survival estimates for the season. Instead, the capture histories were not homogeneous (significant χ^2), so we therefore reported sample-weighted averages of the trial-specific relative survival estimates:

$$\hat{\hat{S}}_i = \frac{\sum_{j=1}^{n} w_j \hat{S}_{ij}}{\sum_{j=1}^{n} w_j} \tag{3.1}$$

The first choice for calculating weights was

$$w_j = \frac{1}{\left[\frac{\text{Var}\left(\hat{S}_{ij}\right)}{\left(\hat{S}_{ij}\right)^2}\right]} = \frac{1}{\text{CV}\left(\hat{S}_{ij}\right)^2} \tag{3.2}$$

Using the weights based on the inverse of the coefficient of variation squared (CV^2) eliminates the correlation between the estimates of relative survival (RS) and their variance estimates. The variance of the weighted average was calculated as follows:

$$\text{Var}\left(\hat{\hat{S}}_i\right) = \frac{\sum_{j=1}^{n} w_j \left(S_{ij} - \hat{\hat{S}}_i\right)^2}{\sum_{j=1}^{n} w_j (n-1)} \tag{3.3}$$

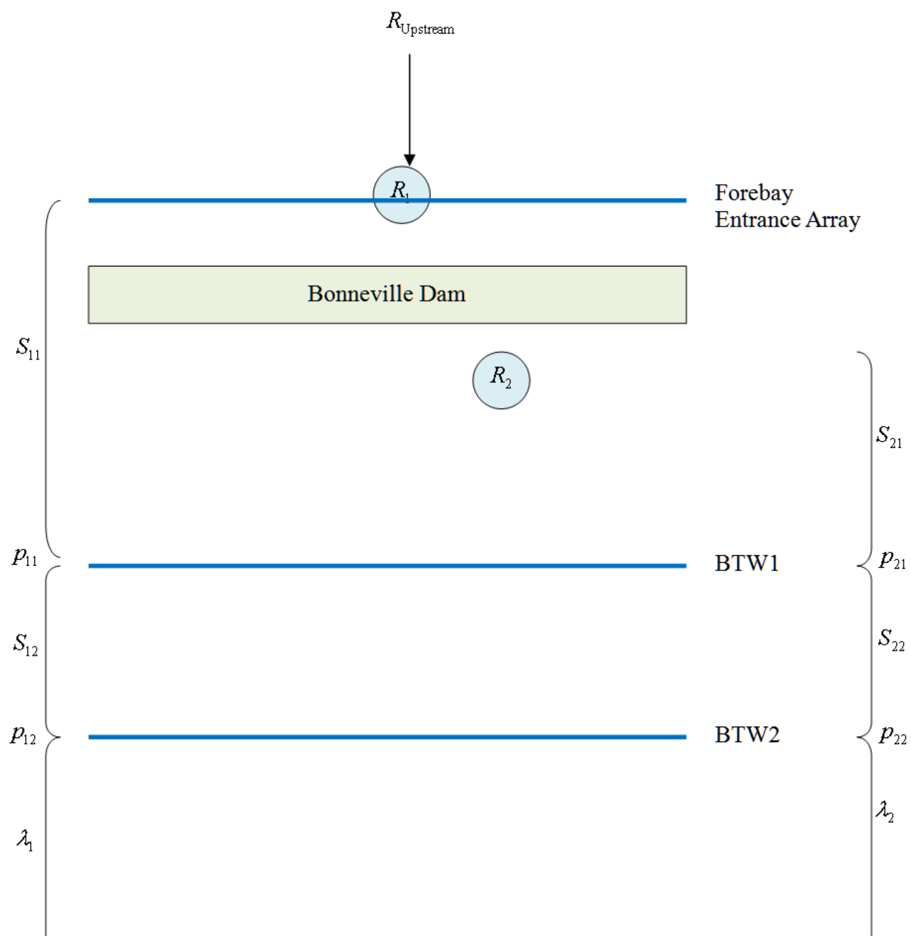
On rare occasions, the model would return a survival estimate of 1.000 (SE = 0.000) for one or more trials, and this overly weighted those trials in the seasonal estimate. In those cases, we weighted by the sample size of each release or virtual release of fish in Equations (3.1) and (3.2).

3.8.1.1 Dam Passage Survival

Dam passage survival is described by species below.

3.8.1.2 Dam Passage Survival of Yearling Chinook and Subyearling Chinook Salmon

A paired release-recapture design was used to estimate dam passage survival at Bonneville Dam. Using the forebay entrance array, fish known to have arrived at Bonneville Dam from upstream releases were regrouped to form virtual releases (R_1) and were paired with tailrace releases (R_2; Figure 3.16). Capture data also were pooled or averaged over the course of the season. Downstream detections at three survival arrays below Bonneville Dam were used to estimate single- and paired-release survivals (Figure 3.16). The three downstream arrays will produce $2^3 = 8$ possible capture histories.



Dam passage survival $\hat{S}_{\text{Dam}} = \dfrac{\hat{S}_{11}}{\hat{S}_{21}}$

Figure 3.16. Schematic of the Release-Recapture Design Used to Estimate Dam Passage Survival at B2 in 2008. The forebay entrance array was located about 2 km upstream of B2, and the downstream arrays of autonomous nodes were located 33, 42, and 149 km downstream of the dam. (BTW = Bonneville tailwater.)

The joint likelihood for the model is as follows:

$$
\begin{aligned}
L = & \binom{R_1}{\underset{\sim}{n}} \left(S_{11} p_{11} S_{12} p_{12}\right)^{n_{111}} \left(S_{11}\left(1-p_{11}\right) S_{12} p_{12} \lambda_1\right)^{n_{011}} \\
& \cdot\left(S_{11} p_{11} S_{12}\left(1-p_{12}\right) \lambda_1\right)^{n_{101}} \left(S_{11}\left(1-p_{11}\right) S_{12}\left(1-p_{12}\right) \lambda_1\right)^{n_{011}} \\
& \cdot\left(S_{11} p_{11} S_{12} p_{12}\left(1-\lambda_1\right)\right)^{n_{110}} \left(S_{11}\left(1-p_{11}\right) S_{12} p_{12}\left(1-\lambda_1\right)\right)^{n_{010}} \\
& \cdot\left(S_{11} p_{11}\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{100}} \\
& \cdot\left(\left(1-S_{11}\right)+S_{11}\left(1-p_{11}\right)\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{000}} \\
& \cdot\binom{R_2}{\underset{\sim}{m}} \left(S_{21} p_{21} S_{22} p_{22} \lambda_2\right)^{m_{111}} \left(S_{21}\left(1-p_{21}\right) S_{22} p_{22} \lambda_2\right)^{m_{011}} \\
& \cdot\left(S_{21} p_{21} S_{22}\left(1-p_{22}\right) \lambda_2\right)^{m_{101}} \left(S_{21}\left(1-p_{21}\right) S_{22}\left(1-p_{22}\right) \lambda_2\right)^{m_{011}} \\
& \cdot\left(S_{21} p_{21} S_{22} p_{22}\left(1-\lambda_2\right)\right)^{m_{110}} \left(S_{21}\left(1-p_{21}\right) S_{22} p_{22}\left(1-\lambda_2\right)\right)^{m_{010}} \\
& \cdot\left(S_{21} p_{21}\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{100}} \\
& \cdot\left(\left(1-S_{21}\right)+S_{21}\left(1-p_{21}\right)\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{000}},
\end{aligned}
\tag{3.4}
$$

where $\underset{\sim}{n}$ and $\underset{\sim}{m}$ are the vector of counts associated with the downstream capture histories of releases R_1 and R_2, respectively. For example, n_{101} is the number of R_1 fish detected at Bonneville tailwater primary survival array (BTW1), not detected at Bonneville tailwater secondary survival array (BTW2), and subsequently detected at Bonneville tailwater tertiary survival array (BTW3) (Figure 3.16).

Similarly, a triple-release survival model was used to compensate for post-handling mortality of control fish (Figure 3.17). This model used an additional release of yearling and subyearling Chinook salmon into the B2CC to parameterize post-handling mortality of tailwater releases, and adjust for this potential bias with this model. The following equations show how spillway and B2 paired-release survival estimates would be calculated based on this additional (third) release.

$$
S_{\text{Dam\& Tailrace}} = S_{B2CC} \bullet P_{B2CC} + S_{B2CC} \bullet R_{\frac{Spill}{B2CC}} \bullet P_{Spill} + S_{B2CC} \bullet R_{\frac{Turbines}{B2CC}} \bullet P_{Turbines} + S_{B2CC} \bullet R_{\frac{JBS}{B2CC}} \bullet P_{JBS}
$$

where: $P_{JBS} + P_{Spill} + P_{Turbines} + P_{B2CC} = 1$

$$
R_{\frac{Spill}{B2CC}} = \frac{S_{Spill}}{S_{B2CC}}
$$

$$
R_{\frac{Turbines}{B2CC}} = \frac{S_{Turbines}}{S_{B2CC}}
$$

$$R_{\frac{JBS}{B2CC}} = \frac{S_{JBS}}{S_{B2CC}}$$

Figure 3.17. Schematic of the Triple Release-Recapture Design Used to Estimate Dam Passage Survival at B2 in 2008. The forebay entrance array was located about 2 km upstream of B2, and the downstream arrays of autonomous nodes were located 33, 42, and 149 km downstream of the dam. VR1 is the virtual release of tagged outmigrating smolt at the spillway and B2 routes, R2 is the tailwater release, and R3 is the release of fish directly into the B2CC.

Model selection procedures were used to find the most parsimonious model to describe the paired release-recapture data (Equation [3.1]). Forward-sequential test procedures were used in model selection based on likelihood ratio tests (LRTs) of nested models. The first test in the sequence evaluated whether $p_{11} = p_{21} = p_1$, assuming that all other parameters of the paired releases were unique (Figure 3.14). When the LRT indicated that $p_{11} \neq p_{21}$, the next test in the sequence evaluated whether $S_{12} = S_{22} = S_2$ (Figure 3.14). If the LRT indicates $S_{12} \neq S_{22}$, the next test in the sequence will evaluate whether $p_{12} = p_{22} = p_2$, etc. At any stage in the testing, if the null hypothesis of homogeneity is not rejected, a reduced model will be assumed. All parameters will be assumed to be homogeneous at and below the location of nonsignificance. This reduced model will then be compared to the fully parameterized Cormack-Jolly-Seber (CJS) model to assess whether any unexplained heterogeneity between releases exists.

The most efficient estimates of reach survival were based on the statistical model for the paired releases that properly share all common parameters. The best model for characterizing the paired releases was found using the Survival Under Proportional Hazards (SURPH) Program Version 2.2 (http://www.cbr.washington.edu/paramest/surph/).

It needs to be noted that the fish known to have arrived at Bonneville Dam were paired with a fresh release of fish in the tailrace. If the downstream controls experience post-release handling mortality, they would have positively biased the estimates of dam passage survival. This was the reason for conducting a triple release model, which took advantage of an additional release into the B2CC to remove the bias associated with post-handling mortality.

Model of Assumptions

Each release group (i.e., R_1 and R_2) provides the data to estimate reach survival based on the single release-recapture model (Skalski et al. 1998). The assumptions of the single release-recapture model include the following:

1. Individuals marked for the study are a representative sample from the population of interest.
2. Survival and capture probabilities are not affected by tagging or sampling. That is, tagged animals have the same probabilities as untagged animals.
3. All sampling events are "instantaneous." That is, sampling occurs over a negligible distance relative to the length of the intervals between sampling events.
4. The fate of each tagged individual is independent of the fate of all others.
5. All tagged individuals alive at a sampling location have the same probability of surviving until the end of that event.
6. All tagged individuals alive at a sampling location have the same probability of being detected at that event.
7. All tags are correctly identified and the status of the smolt (i.e., alive or dead), is correctly assessed.

The first assumption concerns making inferences from the sample to the target population. For example, if inferences are sought to Chinook salmon smolts, then the sample of tagged fish should be drawn from that class of fish. Otherwise, nonstatistical inferences are necessary to justify the similarity between the target population and the representation of acoustic-tagged fish. These assumptions could also be violated if smolts selected for acoustic tagging are, on the average, larger than the population of smolts in general.

Assumption (2) again relates to making inferences about the population of interest (i.e., untagged fish). If tagging has a detrimental effect on survival, then survival estimates from the single release-recapture design will tend to be negatively biased (i.e., underestimated). This is compensated for with the selection of the triple-release model for the ultimate survival estimate.

The third assumption specifies that mortality is negligible immediately in the vicinity of the sampling stations, so that the estimated mortality is related to the river reaches in question and not the sampling event. In the case of outmigrating smolts, the time they spend in the vicinity of a hydrophone array is brief and small, relative to the size of the river reaches in question. This assumption is for sake of mathematical convenience and should be fulfilled by the nature of the outmigration dynamics and deployment of the hydrophone array.

The assumption of independence (4) implies that the survival or death of one smolt has no effect on the fates of others. In the larger river system with tens of thousands of smolts, this is likely true. Furthermore, this assumption is common to all tag analyses with little or no evidence collected to suggest it is not generally true. Nevertheless, violations of assumption (4) have little effect on the point estimate but might bias the variance estimate with precision being less than calculated.

Assumption (5) specifies that a smolt's prior detection history has no effect on subsequent survival. This could be violated if some smolts were self-trained to repeatedly go through turbine or spill routes or, alternatively, avoid routes because of prior experience. This occurrence is unlikely and can be assessed from the detection histories of the individual smolts. The lack of handling following initial release of acoustic-tagged smolts further minimizes the risk that subsequent detections influence survival. Similarly, assumption (6) could be violated if downstream detections are influenced by the upstream passage routes taken by the smolts. Violation of this assumption is minimized by placing hydrophone arrays across the breadth of the river or below the mixing zones for smolts following different passages at the dam.

Assumption (7) implies that the smolts do not lose their tags and are not subsequently misidentified as dead or not captured, nor are dead fish falsely recorded as alive at detection locations. The use of surgically implanted tags should minimize the chance of tag loss. Tag loss and tag failure would tend to result in a negative bias (i.e., underestimation) of smolt survival rates. The possibility of tag failure will depend on travel time relative to battery life. Dead fish drifting downstream could also result in a false-positive detections and upwardly bias survival estimates.

To estimate survival components from the paired releases and triple releases, two additional assumptions for valid survival estimates are necessary. These assumptions are as follows:

8. Survival in the lower river segment of the first reach is conditionally independent of survival in the upper river segment.
9. Releases R_1 and R_2 experience the same survival probabilities in the lower river segment of the first reach they share in common.

Assumption (8) implies that there is no synergistic relationship between survival processes in the two river segments within the first reach. In other words, smolts that survive the first river segment are no more or less susceptible to mortality in the second river segment than smolts released in the second river segment. Assumption (9) is satisfied by the in-river mixing of the release groups but can also be satisfied if the survival processes are stable over the course of smolt passage by the releases. A stable survival process might well be expected for one to a few days under similar flow and spill conditions. Furthermore, unlike the paired-release methods of the earlier Mid-Columbia survival studies, the assumption of equal capture probabilities is unnecessary for estimation.

Tests of Assumptions Within a Release

For the single release-recapture model to be valid, certain data patterns should be evident from the capture histories. Both releases R_1 and R_2 permit tests of goodness-of-fit to the release-recapture model. A series of tests of assumptions was performed to determine the validity of the model (i.e., goodness-of-fit). The data from release R_1 can be summarized by an m-array matrix of the form shown below.

Release Site	Recovery Site		
	BTW1(2)	BTW2 (3)	BTW3 (4)
Forebay (1)	m_{12}	m_{13}	m_{14}
BTW1 (2)		m_{23}	m_{24}
BTW2 (3)			m_{34}

The value of m_{ij} are the number of smolts detected at site i that are next detected at site j.

Burnham et al. (1987:65[71-74]) present a series of tests of assumptions called Test 2 that examine whether upstream detections affect downstream survival and/or detection. For release R_1, a contingency table test was performed, as follows:

Test 2.2

m_{13}	m_{14}
m_{23}	m_{24}

χ_1^2 (3.2)

Burnham et al. (1987:65 [71-74]) also present a series of tests of assumptions called Test 3 that examine whether upstream capture histories affect downstream survival and/or capture.

For release R_1, a contingency table of the following form can be constructed:

		Capture History to BTW2	
		101	111
Capture History at BTW3	1		
	0		

χ_1^2 (3.3)

This contingency table tested whether detection at BTW1 has a subsequent effect on the capture history at BTW3.

Tests of Mixing

For the estimates of project survival to be valid, the detection data need to conform to the assumptions of the statistical model. One assumption is the downstream mixing of release groups. Chi-squared R × C contingency tables are used to test the assumption of homogeneous arrival distributions for releases R_1 and R_2 at the primary survival array (BTW1), secondary survival array (BTW2), and tertiary survival array (BTW3). The chi-squared contingency table tests of homogeneity are of the following form:

		Release	
		R_1	R_2
	1		
Arrival Date	2		
	⋮	⋮	⋮
	D		

(3.4)

Under the evaluation reported here, the chi-square test of homogeneous arrival timing was calculated for the paired releases (e.g., R_1 and R_2) at each detection location. Each test was performed at $\alpha = 0.10$. Because of multiple tests across release pairs, Type I error rates were adjusted for an overall experimental-wide error rate of 0.10.

Tag-Life Correction

Acoustic tags were used to characterize tag life from systematically sampling tags used in the survival studies. The tags were initiated and continually monitored in ambient river water until they failed. The failure times or tag lives were recorded for tags with 3-s and 5-s ping rates. The failure-time data were fit to a Gompertz distribution (Elandt-Johnson and Johnson 1980) of the form

$$f(x) = \beta e^{\frac{\beta}{\alpha}\left(1-e^{\alpha x}\right)+\alpha x} \tag{3.5}$$

Weibull distribution of the form

$$f(x) = e^{-\left(\frac{x-\gamma}{\eta}\right)^{\beta}} \left(\frac{\beta}{\eta^{\beta}}\right)(x-\gamma)^{\beta-1} \tag{3.6}$$

and logistic distribution of the form

$$f(x) = \beta e^{\alpha-\beta x}\left[1+e^{\alpha-\beta x}\right]^{-2} \tag{3.7}$$

Based on the results of the tag-life study, the need for a tag-life correction to the survival estimates was determined by evaluating the cumulative percent of fish exiting the study (i.e., detected on BTW3). If 100 percent exited prior to the time of the first tag failure, no tag-life correction would be required.

In the case of potential tag failure, additional parameters need to be added to the above model (3.5) based on methods of Townsend et al. (2006). Table 3.7 presents the expected probabilities of occurrence for each of the possible capture histories under tag failure

where: L_{11} = probability a tag from release R_1 survives the first reach

L_{12} = probability a tag from release R_1 survives both reach 1 and reach 2

L_{13} = probability a tag from release R_1 survives reaches 1 through 3

L_{21} = probability a tag from release R_2 survives the first reach

L_{22} = probability a tag from release R_2 survives both reach 1 and reach 2

L_{23} = probability a tag from release R_1 survives reaches 1 through 3.

The joint likelihood can be expressed as

$$L = L\left(S_{11}, p_{11}, S_{12}, p_{12}, \lambda_1 \middle| R_1, \underset{\sim}{n}, \underset{\sim}{L}_1\right) \cdot L\left(S_{21}, p_{21}, S_{22}, p_{22}, \lambda_2 \middle| R_2, \underset{\sim}{m}, \underset{\sim}{L}_2\right) \tag{3.8}$$

The estimates of survival from likelihood model (Equation 3.8) should be more reliable because the model takes into account possible tag failure and tag-life probabilities less than one.

Table 3.7. Detection Histories and Expected Probabilities of Occurrences for Releases and in the Presence of Tag Failure

Release	Detection History	Expected Probabilities
R_1	111	$S_{11}p_{11}S_{12}p_{12}\lambda_1 L_{13}$
	011	$S_{11}\left(1-p_{11}\right)S_{12}p_{12}\lambda_1 L_{13}$
	101	$S_{11}p_{11}S_{12}\left(1-p_{12}\right)\lambda_1 L_{13}$
	001	$S_{11}\left(1-p_{11}\right)S_{12}\left(1-p_{12}\right)\lambda_1 L_{13}$
	110	$S_{11}p_{11}S_{12}p_{12}\left(L_{12}-L_{13}\lambda_1\right)$
	010	$S_{11}\left(1-p_{11}\right)S_{12}p_{12}\left(L_{12}-L_{13}\lambda_1\right)$
	100	$S_{11}p_{11}\left[\left(L_{11}-L_{12}S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(L_{12}-L_{13}\lambda_1\right)\right]$
	000	$\left(1-L_{11}S_{11}\right)+S_{11}\left(1-p_{11}\right)\left\lfloor\left(L_{11}-L_{12}S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(L_{12}-L_{13}\lambda_1\right)\right\rfloor$
R_2	111	$S_{21}p_{21}S_{22}p_{22}\lambda_2 L_{23}$
	011	$S_{21}\left(1-p_{21}\right)S_{22}p_{22}\lambda_2 L_{23}$
	101	$S_{21}p_{21}S_{22}\left(1-p_{22}\right)\lambda_2 L_{23}$
	001	$S_{21}\left(1-p_{21}\right)S_{22}\left(1-p_{22}\right)\lambda_2 L_{23}$
	110	$S_{21}p_{21}S_{22}p_{22}\left(L_{22}-L_{23}\lambda_2\right)$
	010	$S_{21}\left(1-p_{21}\right)S_{22}p_{22}\left(L_{22}-L_{23}\lambda_2\right)$
	100	$S_{21}p_{21}\left[\left(L_{21}-L_{22}S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(L_{22}-L_{23}\lambda_2\right)\right]$
	000	$\left(1-L_{21}S_{21}\right)+S_{21}\left(1-p_{21}\right)\left\lfloor\left(L_{21}-L_{22}S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(L_{22}-L_{23}\lambda_2\right)\right\rfloor$

The estimates of the survival and capture parameters in the likelihood model (Equation [3.8]) are calculated, treating the estimates of tag life (i.e., $\hat{L}_{11}$, $\hat{L}_{12}$, $\hat{L}_{21}$, and $\hat{L}_{22}$) as known constants. However, to calculate a realistic variance estimator for the survival parameters, the error in the estimation of the tag-life probabilities must be incorporated into an overall variance calculation. The variance of the survival estimates is calculated using the total variance formula

$$\operatorname{Var}\left(\hat{S}_{PR}\right)=\operatorname{Var}_{\underset{\sim}{\hat{L}}}\left[E\left(\hat{S}_{PR}\middle|\underset{\sim}{\hat{L}}\right)\right]+E_{\underset{\sim}{\hat{L}}}\left[\operatorname{Var}\left(\hat{S}_{PR}\middle|\underset{\sim}{\hat{L}}\right)\right] \tag{3.9}$$

The above variance can therefore be estimated in stages using the expression

$$\operatorname{Var}\left(\hat{S}_{PR}\right) = s^2_{\hat{S}_{PR}|\hat{\underset{\sim}{L}}} + \operatorname{Var}\left(\hat{S}_{PR}\middle|\hat{\underset{\sim}{L}}\right) \tag{3.10}$$

The second term in Equation (3.10) is derived from the maximum likelihood model (3.8) that utilizes the tag-life probabilities (i.e., $\hat{\underset{\sim}{L}}$). The first variance component in Equation (3.10) is calculated using bootstrap resampling techniques (Efron and Tibshirani 1993). Alternative estimates of $\hat{\underset{\sim}{L}}$ are computed by bootstrapping both the observed tag-life data and travel-time data. For each estimated vector of tag-life parameters, survival is estimated using likelihood model (3.8). One thousand bootstrap estimates of the tag-life parameters are calculated along with the corresponding conditional maximum likelihood estimates of survival.

The first variance component in Equation (3.10) is then estimated by the quantity

$$s^2_{\hat{S}_{PR}|\hat{\underset{\sim}{L}}} = \frac{\sum_{b=1}^{1000}\left(\hat{S}_b - \hat{\bar{S}}\right)^2}{(1000-1)}$$

where $\hat{S}_b$ = the bth bootstrap estimate of survival $(b = 1,\ldots,1000)$,

$$\hat{\bar{S}} = \frac{\sum_{b=1}^{1000}\hat{S}_b}{1000}.$$

Use of Equations (3.9) and (3.10) also permits the examination of the contribution of the sampling error in the tag-life parameters to the overall variance in survival estimates.

Dam Passage Survival of Steelhead

No tailrace release of steelhead was performed in 2008. Dam passage survival from the forebay array to the first downstream detection site at BTW1 was estimated using the single release-recapture model. The three downstream detection sites will produce $2^3 = 8$ capture histories were analyzed using the following likelihood model:

$$\begin{aligned}
&\binom{R_1}{\underset{\sim}{n}}\left(S_{11}p_{11}S_{12}p_{12}\lambda_1\right)^{n_{111}}\left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\lambda_1\right)^{n_{011}}\\
&\cdot\left(S_{11}p_{11}S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{101}}\left(S_{11}\left(1-p_{11}\right)S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{001}}\\
&\cdot\left(S_{11}p_{11}S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{110}}\left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{010}}\\
&\cdot\left(S_{11}p_{11}\left[\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right]\right)^{n_{100}}\\
&\cdot\left(\left(1-S_{11}\right)+S_{11}\left(1-p_{11}\right)\left[\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\lambda_1\right]\right)^{n_{000}},
\end{aligned} \tag{3.11}$$

where n_{ijk} is the number of smolts with capture history ijk (0 = not detected, 1 = detected). This estimation procedure was used to analyze yearling and subyearling Chinook salmon data for comparison with steelhead results.

3.8.1.3 Estimating Absolute Passage Survival for B2 routes

The tailrace releases below Bonneville Dam were used in conjunction with virtual releases formed from detections by the B2 array to estimate absolute passage survival by route (Figure 3.16). The ratio of reach survivals for known B2-passed fish to tailrace-released fish were used to estimate survival through the JBS, B2CC, and turbines. This is essentially the same paired release-recapture model described previously. Estimates were made on a per-trial basis and a weighted average (Equation 3.12) was calculated across trials with an associated variance estimator (Equation 3.14). The three downstream arrays produced eight (2^3) possible capture histories. The joint likelihood for the model was formulated as follows:

$$
\begin{aligned}
L = & \binom{R_1}{\underset{\sim}{n}} \left(S_{11}p_{11}S_{12}p_{12}\right)^{n_{111}} \left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\lambda_1\right)^{n_{011}} \\
& \cdot\left(S_{11}p_{11}S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{101}} \left(S_{11}\left(1-p_{11}\right)S_{12}\left(1-p_{12}\right)\lambda_1\right)^{n_{011}} \\
& \cdot\left(S_{11}p_{11}S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{110}} \left(S_{11}\left(1-p_{11}\right)S_{12}p_{12}\left(1-\lambda_1\right)\right)^{n_{010}} \\
& \cdot\left(S_{11}p_{11}\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{100}} \\
& \cdot\left(\left(1-S_{11}\right)+S_{11}\left(1-p_{11}\right)\left(\left(1-S_{12}\right)+S_{12}\left(1-p_{12}\right)\left(1-\lambda_1\right)\right)\right)^{n_{000}} \\
& \cdot\binom{R_2}{\underset{\sim}{m}} \left(S_{21}p_{21}S_{22}p_{22}\lambda_2\right)^{m_{111}} \left(S_{21}\left(1-p_{21}\right)S_{22}p_{22}\lambda_2\right)^{m_{011}} \\
& \cdot\left(S_{21}p_{21}S_{22}\left(1-p_{22}\right)\lambda_2\right)^{m_{101}} \left(S_{21}\left(1-p_{21}\right)S_{22}\left(1-p_{22}\right)\lambda_2\right)^{m_{011}} \\
& \cdot\left(S_{21}p_{21}S_{22}p_{22}\left(1-\lambda_2\right)\right)^{m_{110}} \left(S_{21}\left(1-p_{21}\right)S_{22}p_{22}\left(1-\lambda_2\right)\right)^{m_{010}} \\
& \cdot\left(S_{21}p_{21}\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{100}} \\
& \cdot\left(\left(1-S_{21}\right)+S_{21}\left(1-p_{21}\right)\left(\left(1-S_{22}\right)+S_{22}\left(1-p_{22}\right)\left(1-\lambda_2\right)\right)\right)^{m_{000}},
\end{aligned}
\tag{3.12}
$$

where $\underset{\sim}{n}$ and $\underset{\sim}{m}$ are the vectors of counts associated with the downstream capture histories of releases R_1 and R_2, respectively. For example, n_{101} would be the number of R_1 fish detected at BTW1, not detected at BTW2, and subsequently detected at BTW3.

B2 route-specific survival was estimated as the ratio

$$
\hat{S}_{B2} = \frac{\hat{S}_{11}}{\hat{S}_{21}}
\tag{3.13}
$$

with associated variance estimator

$$\mathrm{Var}\left(\hat{S}_{\mathrm{B2}}\right)=\hat{S}_{\mathrm{B2}}^{2}\left[\frac{\mathrm{Var}\left(\hat{S}_{11}\right)}{\hat{S}_{11}^{2}}+\frac{\mathrm{Var}\left(\hat{S}_{21}\right)}{\hat{S}_{21}^{2}}\right] \qquad (3.14)$$

3.8.1.4 Model Fitting

Unless otherwise noted, straight lines and curves on graphs are linear and quadratic fits using ordinary least-squares regression. We only considered the use of higher-order polynomials when r^2 increased by ≥ 0.05. Notable exceptions included the distributions used to fit tag-life curves (Equations [3.5] and [3.6]).

3.8.1.5 Positioning of Tagged Fish

Tracking tagged fish using three or more hydrophones is a common technique that uses time-of-arrival differences (TOADs) at each hydrophone to calculate the position of a tagged fish. Usually, the technique requires a 3-hydrophone array for two-dimensional (2D) tracking and 4-hydrophone array for 3D tracking. For this study, only 2D tracking was performed.

Positioning a tagged fish followed the following procedure: consider a transmitting source (tag) in a 4-hydrophone array. The boldface letters indicate matrices or vectors. The source (**S**) and receiver (**r**) position vectors are defined as follows:

$$\mathbf{S}=(s_x, s_y, s_z)^{\mathrm{T}}$$
$$\mathbf{r}_i=(x_i, y_i, z_i)^{\mathrm{T}} \qquad i=0,1,2,3 \qquad (3.15)$$

The distance between transmitting source and receivers gives

$$(s_x-x_i)^2+(s_y-y_i)^2+(s_z-z_i)^2=c^2(t_i+T_0)^2, \qquad i=0,1,2,3 \qquad (3.16)$$

where c is the speed of sound, T_0 is the time of travel from the source to the reference receiver (receiver 0), and t_i is the TOAD between receiver *i* and the reference receiver. With t_i measured by the common clock, the source position vector and T_0 are the four unknowns to be solved by the four distance equations.

There are several mathematical ways to obtain the exact solutions to the equations above (Watkins and Schevill 1972; Fang 1990; Spiesberger and Fristrup 1990; Juell and Westerberg 1993; Wahlberg et al. 2001). Wahlberg et al. (2001) applied a synthesis of the methods used by Watkins and Schevill (1971) and Spiesberger and Fristrup (1990). It has the advantage of giving the same mathematical form for 2D and 3D array systems, and for both minimum number of receivers arrays and over-determined arrays.

The detailed steps for 2D tracking are as follows:

- Pool together all detections of the same signal from different hydrophones. If more than four hydrophones detect the same tag signal, select the four with the best geometry configuration for 2D tracking (Wahlberg et al 2001; Ehgrenberg and Steig 2002). Compute TOADs directly from detection time because all hydrophones are synchronized to a universal global positioning system (GPS) clock with accuracy within 0.4 μs.

- Apply tracking solvers to estimate 3D locations and output solutions that are physical and within the pre-specified ΔT (10 μs for B2 dam in the current study).
- Apply order 3 median filtering (Lim 1990) for removing spurious locations and smoothing fish tracks.
- Assign tagged fish to the nearest 10-m grid vertex within the tracking volume covered by the hydrophones monitoring the upstream side BGS.
- Base the route-of-passage assignment relative to the BGS and to dam routes solely on the last detection of the nearest hydrophone monitoring the passage route, and not on the 2D positioning of the fish. Use 2D tracks only to map the distribution of tagged fish relative to the BGS.

Due to restricted access for maintenance of hydrophones, intermittent outages occurred for hydrophones deployed on and near the BGS. Therefore, tagged fish were only tracked during days of continuous monitoring where the array was fully functional. These dates included May 2 to May 8 for spring, and June 25 to July 17 for summer.

4.0 Results

Evaluation results described in the following sections begin with a description of environmental conditions present during the study, followed by tests of survival model assumptions and detection and survivals of the three targeted species through all B2 routes. Then the LGR releases of yearling Chinook Salmon and Lower Columbia River releases of spring steelhead and summer subyearling Chinook salmon, as well as the effects of dam operations on survival over time, and travel times and rates are described. Species distributions related to diel, B2 passage, forebay and passage relative to BGS deployment, and forebay outmigrating smolts follows. The continuity of data, historic survival and passage data, and B2CC PIT detector performance are described in the final sections.

4.1 Environmental Conditions

The description of environmental conditions during the 2008 study provided here includes seasonal changes in river and spill discharge, water temperature, and tailrace elevation. Seasonal trends in discharge and temperature were plotted alongside averages for the previous 10 years. We also looked at the species composition of all juvenile salmonids in B2 JMF samples, and plotted length frequencies of tagged and un-tagged juvenile Chinook salmon.

4.1.1 Project Discharge and Temperature

Daily discharge and forebay water temperatures for Bonneville Dam were plotted against 10-year average discharge and forebay water temperatures (1998 to 2008). During spring, tagged fish were released when most of the discharge was higher than that of the 10-year average, but for summer releases, the 2008 discharge was higher than the 10-year (Figure 4.1). Forebay water temperatures were lower than the 10-year average in both spring and summer (Figure 4.2).

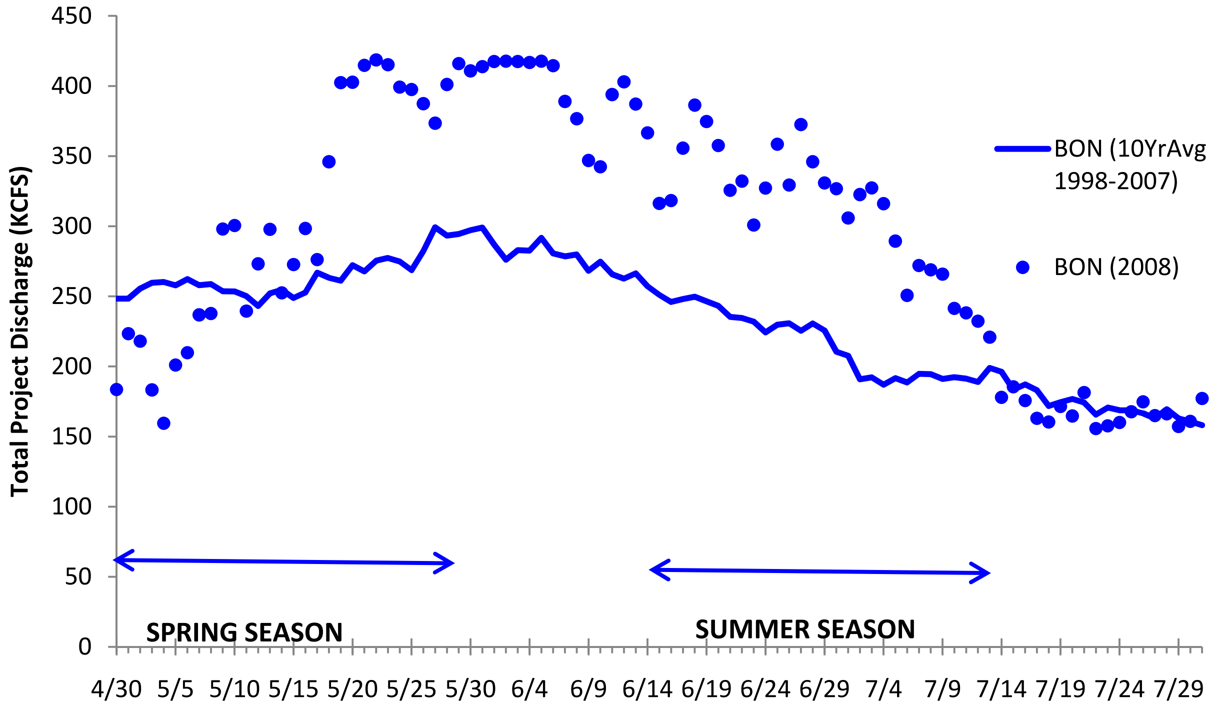


Figure 4.1. Ten-Year Average Daily Project Discharge (kcfs) Versus 2008 Daily Project Discharge for Bonneville Dam

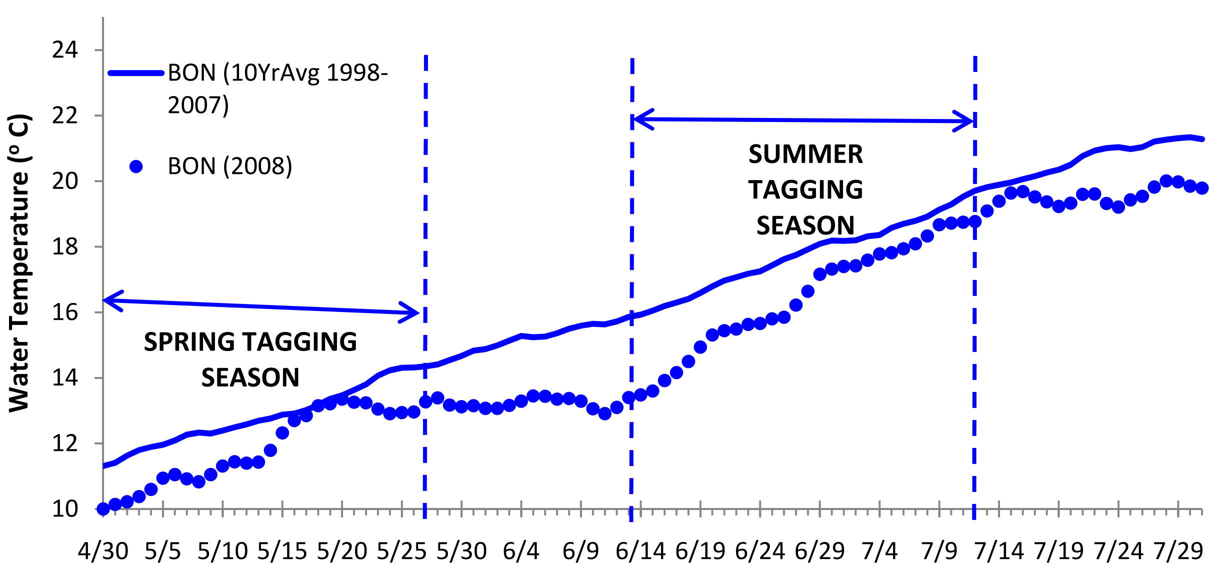


Figure 4.2. Ten-Year Average Forebay Water Temperature (°C) Versus 2008 by Day (April 30 Through July 29) at Bonneville Dam

4.1.2 Run Timing of Juvenile Salmonids

Smolt indexes, based on data provided by DART (Columbia River Data Access in Real Time; www.cbr.washington/dart/dart.html), were used to create figures comparing the number of fish tagged by day to the smolt index by day (Figures 4.3 through 4.5). This was done for steelhead and both yearling and subyearling Chinook. Fish collection at the John Day Dam SMF and the tagging period for the spring was from April 30 to May 28, 2008. Fish collection during the summer period was from June 14 to July 12, 2008.

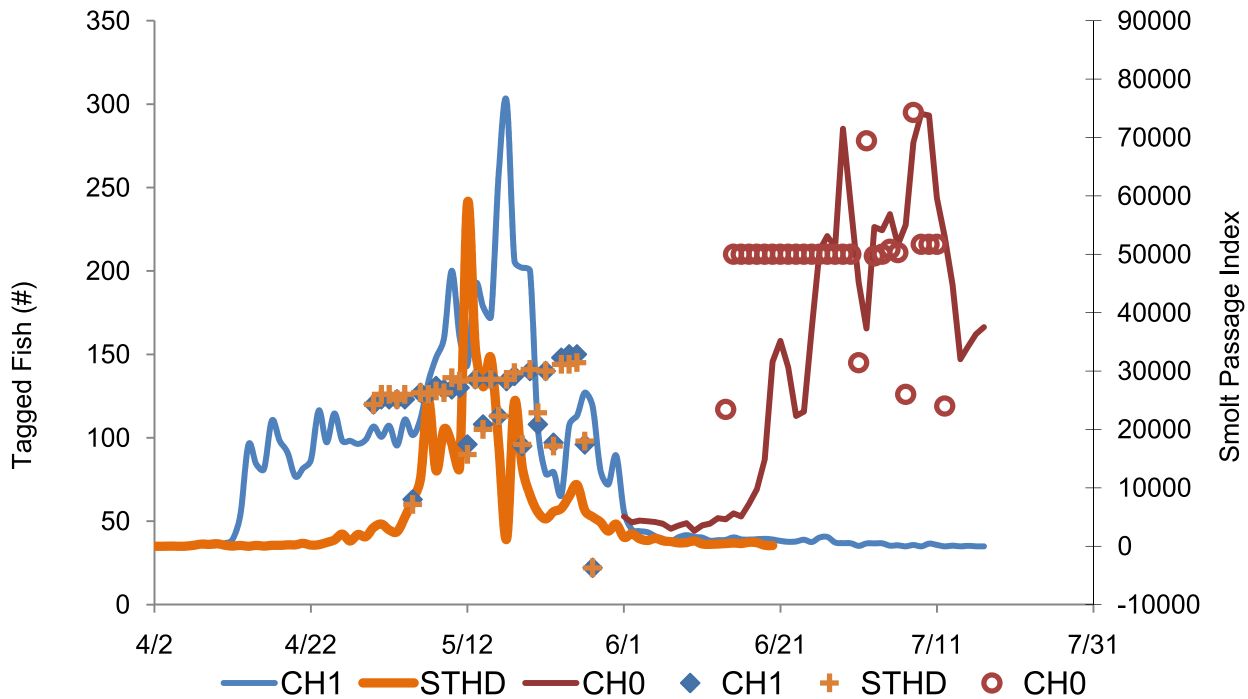


Figure 4.3. Smolt Monitoring Program (SMP) Passage Index (lines) for March 2 – July 21, 2008, and Fish Tagged per Day (symbols) for Yearling Chinook (CH1), Steelhead (STHD), and Subyearling Chinook (CH0) based upon data from the Bonneville Dam Smolt Monitoring Facility

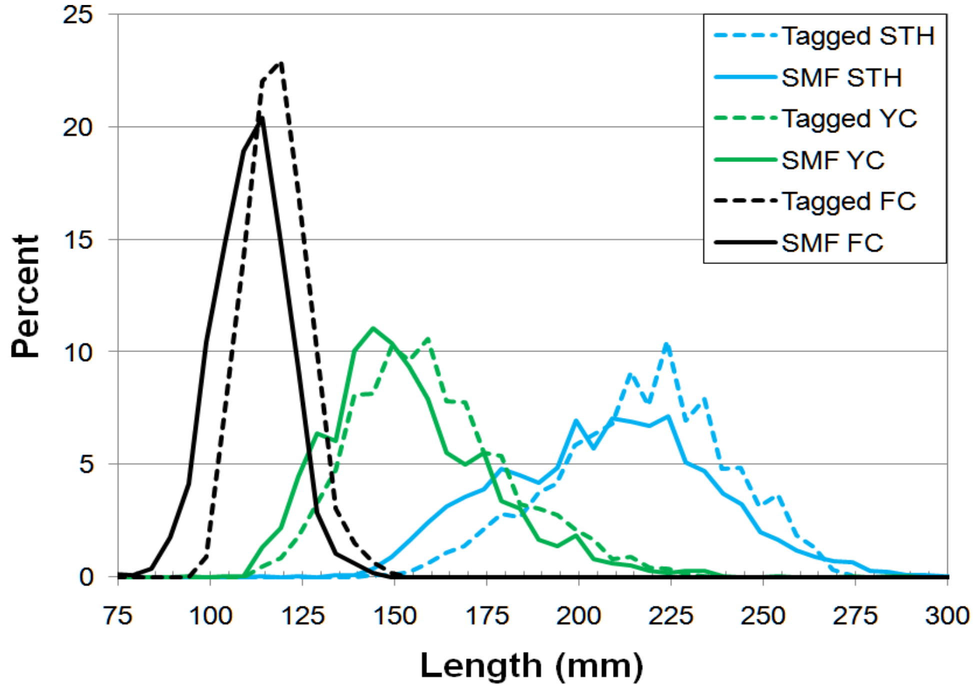


Figure 4.4. Length Frequencies of Tagged and Untagged Steelhead, Yearling Chinook Salmon, and Subyearling Chinook Salmon at the John Day Smolt Monitoring Facility

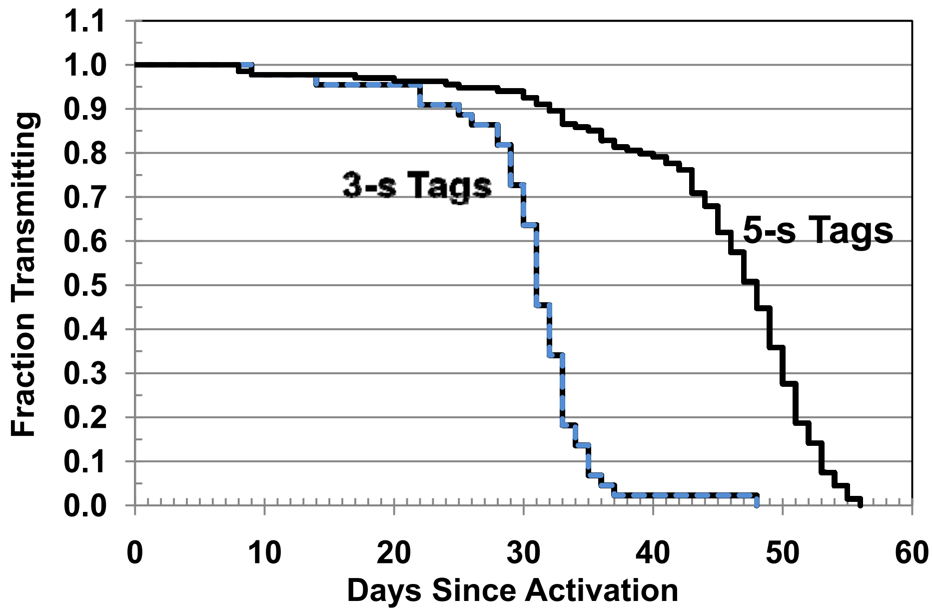


Figure 4.5. A Graph of Tag-Life Survival was Constructed for Both 5-s Tags and 3-s Tags. The relationships were developed based on the results of the tag-life study.

4.2 Tests of Assumptions

In this section the testable assumptions for the survival model are addressed. In particular, these are assumptions that the tagged sample is representative of the population of interest, all tags identify samples correctly as alive or dead, all fish releases experience the same survival probabilities in the upper reaches as in the lower reaches, and survival and capture probabilities are not affected by tagging (addressed by the triple-release model).

4.2.1 Fish Rejection Rates and Length Frequencies During Tagging

The percent of smolts rejected for tagging at John Day Dam SMF was low: 0.8% for yearling Chinook salmon (299 out of 3763), 0.7% for steelhead (361 out of 3815), and 0.7 % for subyearling Chinook salmon (212 out of 6170). Rejection percentages were slightly higher at the Bonneville JMF (3.6% for yearling Chinook and 1.9% for subyearling Chinook salmon).

Length frequency distributions of tagged fish were slightly skewed (5–10 mm) toward longer fish than were the respective distributions of untagged fish passing through the John Day Dam SMF (Figure 4.6). The median length of tagged yearling Chinook salmon (156 mm) was 9 mm longer than that of untagged yearling Chinook salmon (147 mm), and the difference in medians was much greater for unclipped fish (21 mm) than it was for clipped fish (7 mm). The median length of tagged steelhead (217 mm) was 6 mm longer than that of untagged steelhead (211 mm). The median length of tagged subyearling Chinook salmon (115 mm) also was 6 mm longer than that of untagged subyearling Chinook salmon (109 mm).

Additional information about fish in virtual releases at the forebay entrance array at the BGS and B2 arrays and reference releases in the tailrace are presented in Appendix A. Tables A.1 and A.2 describe the CSV files for spring and summer that are on a CD that accompanies printed version of this report. The CSV files contain detailed data associated with every fish that was regrouped to form virtual releases at the Bonneville forebay entrance array and spillway or that was released in the Bonneville tailrace, including season, release date, release time, PIT-tag code, acoustic-tag code, acoustic-tag activation date, fork length, weight, mortality status, and release location, as well as Bonneville Dam operations at the time of each virtual release.

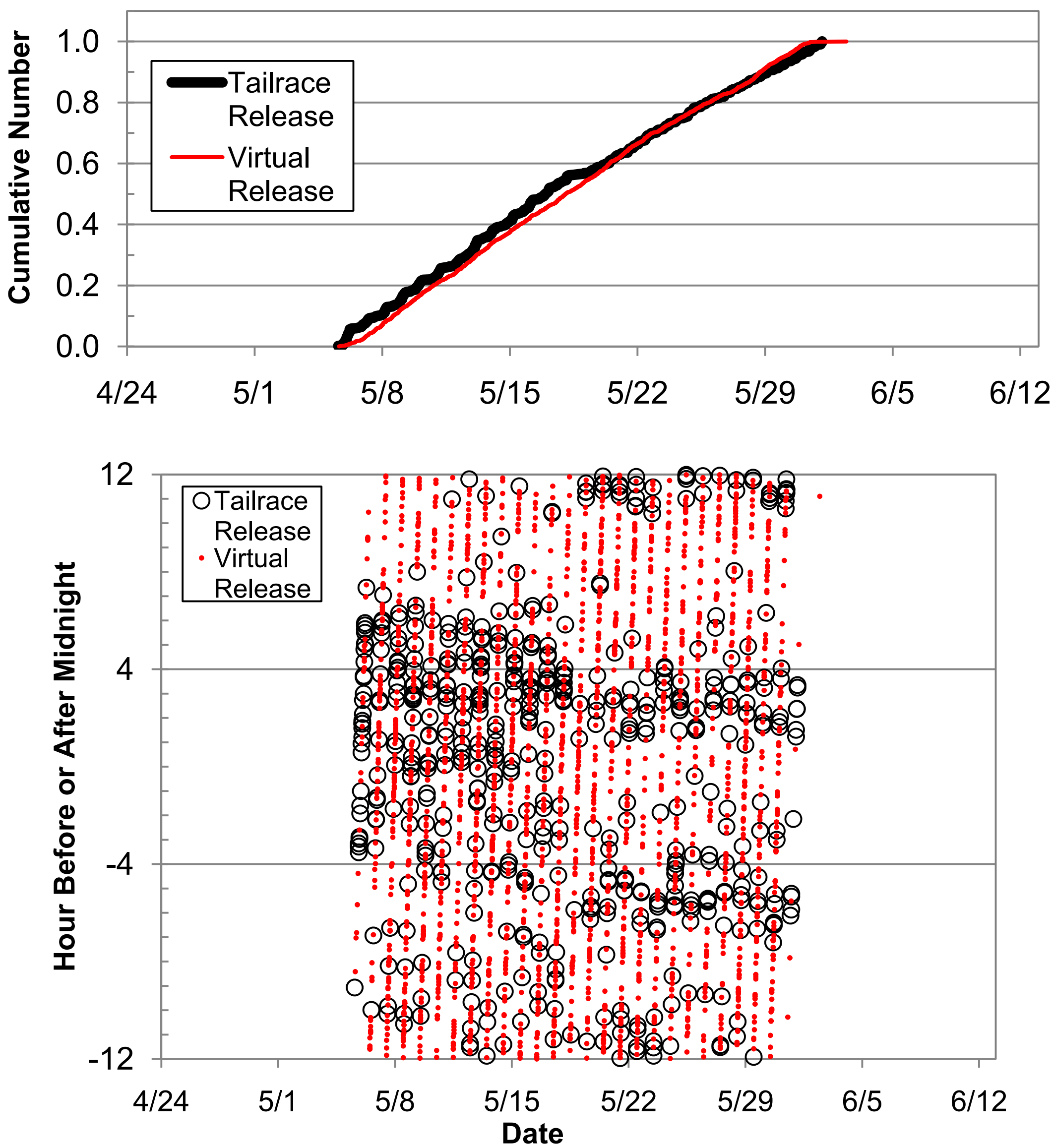


Figure 4.6. Graphs of Mixing of Yearling Chinook Used in Paired-Release Estimates of Survival by Date (top) and by Time of Day (bottom). Virtual releases of individual fish are represented by the red dots, and paired tailrace releases of fish are represented by the black circles.

4.2.2 Detection of Dead Fish by Survival Arrays

We detected one dead tagged yearling Chinook salmon smolt released in the BON tailrace on the primary and secondary survival arrays and on a Kalama array located 113 km downstream of the dam. This fish was not detected on the tertiary array (BTW3) located at Oak Point 148 km downstream of Bonneville Dam. The travel rate of this dead fish to the primary array was 26.4 hours compared to a rate of 26.6 hours for tagged fish released live at the same time into the Bonneville tailrace. Its travel rate to the secondary array (BTW2; 30.90 hours) also was very similar to that of live fish released at the same time (30.94 hours). The single dead fish detection represented brought the cumulative dead-fish detection probability (D) to 0.0126, which is 2 dead fish detections out of 159 dead fish released over 3years of acoustic telemetry study.

4.2.3 Tag-Life Study

A total of 134 thirty-day tags sampled from tag lots used for yearling Chinook salmon were continuously monitored until their failure to develop a tag-life curve. The failure time data were fit to a logistic curve with the following parameterization:

$$S(t) = \left(1 + e^{\frac{t-52.71695}{9.636928}}\right)^{-1} \tag{4.1}$$

The raw-data (non-parameterized, Figure 4.5) tag-life curve that follows this model was used to account for tag loss when calculating the survival for the yearling Chinook salmon releases from the Lower Granite Dam tailrace.

For all yearling Chinook, subyearling Chinook salmon, and juvenile steelhead released from the Lower Columbia River dams, including John Day Dam, Bonneville Dam, and below, 23-day tags were used. A separate tag-life curve was estimated from 44 twenty-three-day tags monitored until their failure. Their failure times were fit to a logistic curve with the following parameterization (Figure 3.5):

$$S(t) = \left(1 + e^{\frac{t-31.17829}{1.80689}}\right)^{-1} \tag{4.2}$$

Again, the raw-data (non-parameterized) tag-life curve that follows this model was used to account for tag loss when calculating the survival for the yearling Chinook salmon releases from Lower Columbia River dams.

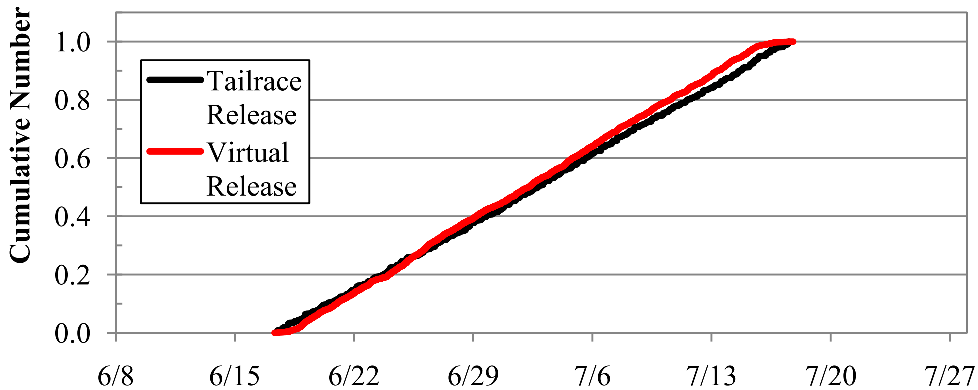
The probabilities associated with the findings of this tag-life study were used to calculate the survival estimates in a procedure described under methods. The new tag-life corrected survival estimates were used to approximate the actual survival rates of fish passing B2 routes.

4.2.3.1 Assessment of Mixing for Single-Release Survival Estimates

When performing the single release-recapture analysis, the effect of mixing at detection sites was addressed to verify that survival was independent from upstream and downstream detections and independent of capture history. In this case, two Burnham tests were performed to address mixing. Burnham Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Virtual release groups of fish passing through B2 were compared to downstream detection at survival arrays during both the spring and summer. The results of the single-release Burnham tests for mixing of Lower Columbia river released yearling Chinook salmon, juvenile steelhead, and subyearling Chinook are summarized in Appendix D.

4.2.3.2 Assessment of Mixing for Paired-Release Survival Estimates

When evaluating the paired release-recapture analysis, mixing of upstream and downstream release groups is a good indicator of whether the paired releases shared similar downstream conditions. In this case, virtual release groups of fish passing through B2 were compared to tailrace release groups over time of day and season of release (spring or summer). Burnham tests were used to evaluate these relationships.



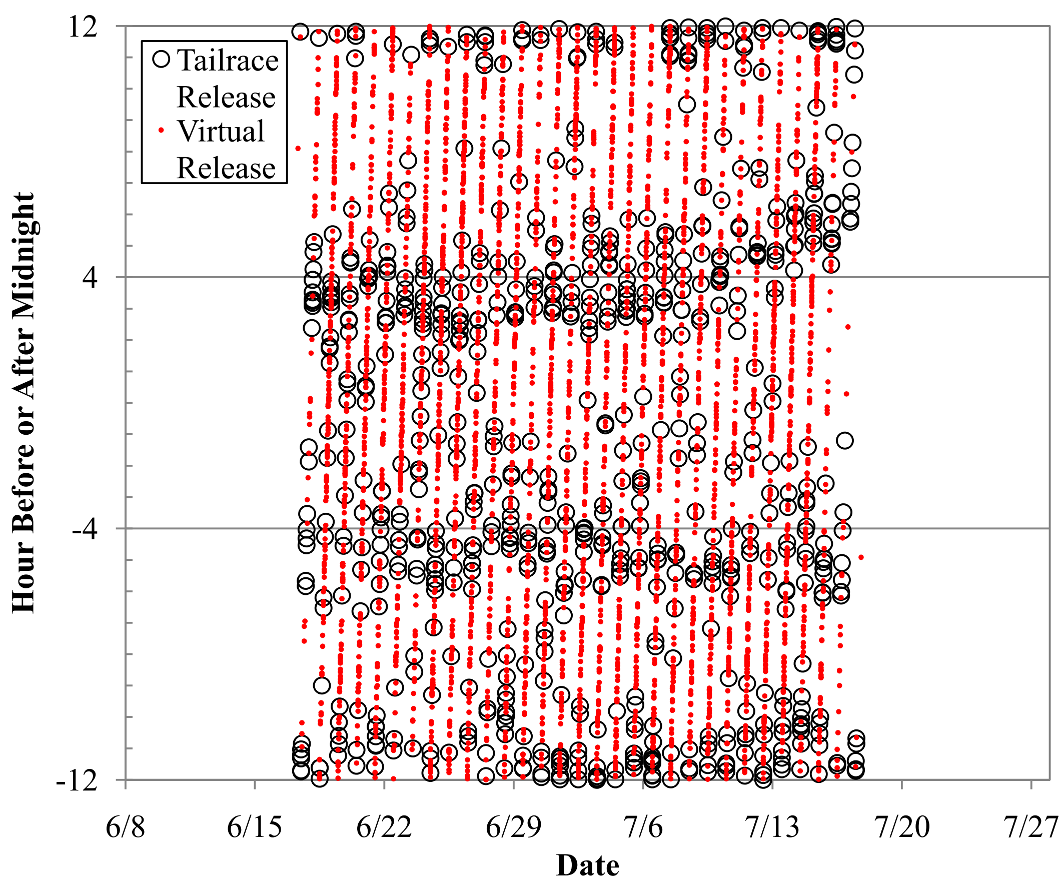


Figure 4.7. Graphs of Mixing of Subyearling Chinook Used in Paired-Release Estimates of Survival by Date (top) and by Time of Day (bottom). Virtual releases of individual fish are represented by red dots, and paired tailrace releases of fish are represented by black circles.

Table 4.1. Burnham Tests for Goodness of Fit of the Model to the Data (Test 2) and Tests for Parameters that Are Specific to Individual Capture Histories (Test 3)(a)

B2 BGS		*p*-values: Treatment Test 2	Treatment Test 3	Tailrace Reference Test 2	Tailrace Reference Test 3
Juvenile Steelhead	at B2	0.683	0.684	NA	NA
	at B2 Turbines	0.297	0.945		
	at B2CC	0.846	0.660		
	at JBS	0.623	0.923		
Yearling Chinook	into B2CC	0.001	0.833	< 0.001	0.864
	at B2	< 0.001	0.998	0.001	0.856
	at B2 Turbines	0.001	0.824		
	at B2CC	0.107	0.682		
	at JBS	0.108	0.845		
Subyearling Chinook	into B2CC	0.155	0.238	0.274	0.868
	at B2	0.163	0.466	0.387	0.914
	at B2 Turbines	0.025	0.666		
	at B2CC	0.700	0.767		
	at JBS	0.443	0.363		

(a) Test 2 explores the survival and detection parameters that are specific to sampling occasions within each group (Ho), and Test 3 explores whether the survival and detection parameters do not depend on the capture histories of fish released on any release occasion (Ho). Instances when these tests were violated to the $p < 0.05$ are highlighted in gray.

4.3 Detection and Survival of Yearling Chinook, Juvenile Steelhead and Subyearling Chinook Salmon in B2 Routes

Three different models were used to extract survival information from the outmigrating smolts implanted with acoustic-tags. Single-release, paired–release, and triple-release CJS models were used for this analysis (Cormack 1964; Skalski 1998; Townsend 2006). After presentation of tag-life study results and arrival times, we present detection and survival results for each of these models using tag-life corrections. Survival estimates were generated by route of passage through B2 (including turbines, JBS, and B2CC), and B2 as a whole for each group of smolts. Groups of smolts included yearling Chinook, steelhead, and subyearling Chinook. Yearling Chinook smolts were divided into groups that included smolts released at Lower Granite Dam and those released in the Lower Columbia River. Tagged fish that were released at Lower Granite Dam were a part of the Tag Effects project, and were released at one location in the tailrace of Lower Granite Dam on the Snake River. Tagged yearling Chinook that were released as a part of the current study (Lower Columbia Released), included fish released at Arlington, the tailrace of John Day and The Dalles dams, as well as fish released into the B2CC and the Bonneville tailrace. Steelhead smolts and subyearling Chinook were also evaluated as separate release groups for this analysis, all of which were released in the Lower Columbia River. Detailed detection histories and survival estimates for each route are included in Appendix C.

4.3.1 Tag-Life Study Correction

Examination of the tag-life curve and arrival distributions of fish to downstream detection arrays indicated that the vast majority of fish arrived before the time of first tag failure. In these cases, no tag-life correction was necessary (Appendix B); however fish from the Bonneville tailrace, the virtual release above Bonneville Dam, and The Dalles tailrace release showed the potential need for tag-life correction. In all three cases, the need for such correction was only for the last detection array and the expected probability of tag life ≥ 0.999. Despite the small probability of tag failure, the survival estimates were adjusted using the tag-life correction methods highlighted in this report, and described by Townsend et al. (2006) to reflect the possibility of tag failure.

4.4 Lower Granite Dam Releases

Releases of yearling Chinook from the tailrace of Lower Granite Dam were analyzed with single-release and paired release-recapture models by using detection arrays from the Bonneville Dam primary, secondary, and tertiary arrays. Capture data were generated from these arrays to estimate reach survival. Only the full dam (concrete) survival rate is reported (Table 4.18) because survival biases were induced for route-specific survivals. Bias inducement was required because fish were removed at the JBS as a part of a separate study. That study used sort-by-PIT-code at the juvenile bypass facility at Bonneville Dam to remove JSATS tagged fish migrating from Lower Granite releases.

Table 4.2. Tag-Life Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Lower Granite Released Yearling Chinook Salmon in Reference Releases for all Bonneville Survival(a)

Paired Release	S to Tailrace	1/2 95% CI
5/07-5/14	0.937	0.067
5/15-5/16	0.911	0.059
5/17-5/18	0.95	0.063
5/19-5/20	0.972	0.104
5/21-5/22	1.084	0.171
5/23-5/24	1.075	0.156
5/25-5/26	0.961	0.044
5/27-5/28	1.000	0.055
5/29-5/30	1.103	0.212
5/31-6/04	1.000	0.131
N-Wt Mean	0.998	0.037

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

4.5 Detection and Survival of Lower Columbia Released Yearling Chinook Salmon in Spring

Releases of yearling Chinook in the Lower Columbia River were analyzed using single release, paired release, and triple release-recapture models by using detection arrays from the Bonneville Dam primary, secondary, and tertiary arrays. Capture data were generated from these arrays to estimate reach survival. Paired-release estimates used a separate tailwater release of yearling Chinook into the Bonneville Tailwater conducted by NOAA Fisheries, and the capture data for those fish were derived from the same downstream arrays used by the single-release model. These data are shown in Table 4.3. The triple-release model also used the tailwater releases in combination with a direct release into the B2CC. All routes of passage through B2 are reported (B2CC, JBS, and turbines), in addition to B2 as a whole.

Table 4.3. Tag-Life-Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Lower Columbia Released Yearling Chinook Salmon in Reference Releases for all Bonneville Survival(a)

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/06	0.974	0.057
5/07-5/08	1.019	0.069
5/09-5/10	0.964	0.057
5/11-5/12	0.981	0.021
5/13-5/14	1.001	0.046
5/15-5/16	0.964	0.030
5/17-5/18	0.977	0.033
5/19-5/20	0.941	0.095
5/21-5/22	1.072	0.166
5/23-5/24	1.098	0.150
5/25-5/26	0.973	0.045
5/27-5/28	0.944	0.065
5/29-6/04	1.058	0.104
N-Wt Mean	1.001	0.025

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

Table 4.4. Summary of Survival Estimates for Yearling Chinook Salmon Released into the Lower Columbia River and Regrouped Passing Routes at Bonneville Dam(a)

	Bonneville Corner Collector	Juvenile Bypass System	B2 Turbines	Bonneville 2nd Powerhouse	B2CC Direct Release
Single Release Survival	0.987 (0.012)	0.983 (0.022)	0.946 (0.030)	0.970 (0.017)	0.976 (0.014)
Paired Release Survival	1.021 (0.034)	1.017 (0.045)	0.979 (0.037)	1.005 (0.030)	1.011 (0.027)
Triple Release Survival		1.007 (0.037)	0.969 (0.042)	0.994 (0.034)	

(a) Cormack-Jolly-Seber single-release, paired-release and triple-release survival estimates are shown. Survival estimates were variance or sample-weighted (N-weighted) as appropriate based on chi-square results and sample size. One-half 95% confidence intervals are reported in parentheses.

4.6 Detection and Survival of Juvenile Steelhead in Spring

Releases of juvenile steelhead released in the Lower Columbia River were analyzed using a single release model as there were no steelhead reference releases below Bonneville. The single release model used detection arrays from the Bonneville Dam primary, secondary, and tertiary arrays. Capture data were generated from these arrays to estimate reach survival, as shown in Tables 4.21 and 4.22. All routes of passage through B2 are reported (B2CC, JBS and Turbines), in addition to B2 as a whole.

Table 4.5. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) survival (S) and Detection Probabilities for Juvenile Steelhead in Virtual Releases at the Bonneville Forebay Array Based on Three Downstream Arrays(a)

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	0.996	0.030	0.999	0.020	0.949	0.030	0.988	0.020	0.687	0.060
5/07-5/08	0.977	0.031	1.000	0.017	0.916	0.031	0.911	0.017	0.723	0.064
5/09-5/10	0.978	0.028	1.000	0.000	0.907	0.028	0.735	0.000	0.722	0.053
5/11-5/12	0.953	0.027	1.000	0.000	0.959	0.027	0.845	0.000	0.697	0.057
5/13-5/14	0.968	0.025	1.000	0.014	0.936	0.025	0.885	0.014	0.623	0.065
5/15-5/16	0.951	0.033	1.000	0.000	0.962	0.033	0.767	0.000	0.544	0.074
5/17-5/18	0.972	0.033	0.905	0.101	0.901	0.033	0.566	0.101	0.586	0.089
5/19-5/20	0.946	0.052	0.851	0.152	0.838	0.052	0.438	0.152	0.477	0.104
5/21-5/22	1.000	0.000	1.000	0.000	0.780	0.000	0.441	0.000	0.314	0.061
5/23-5/24	0.972	0.061	0.957	0.216	0.778	0.061	0.455	0.216	0.334	0.098
5/25-5/26	0.948	0.044	1.000	0.097	0.874	0.044	0.465	0.097	0.372	0.068
5/27-5/28	0.985	0.049	0.902	0.181	0.835	0.049	0.416	0.181	0.398	0.100
5/29-6/04	0.985	0.071	0.855	0.229	0.783	0.071	0.375	0.229	0.364	0.116
N-Wt Mean	0.972	0.010	0.959	0.032						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table 4.6. Summary of Survival Estimates for Juvenile Steelhead Released into the Lower Columbia River and Regrouped Passing Routes at Bonneville Dam(a)

	Bonneville Corner Collector	Juvenile Bypass System	B2 Turbines	Bonneville 2nd Powerhouse
Single Release Survival	0.984 (0.027)	0.984 (0.039)	0.982 (0.024)	0.982 (0.019)

(a) Cormack-Jolly-Seber single-release estimates are shown. Survival estimates were sample-weighted (N-weighted) as appropriate based on chi-square results and sample size. One-half 95% confidence intervals are reported in parentheses.

4.7 Detection and Survival of Subyearling Chinook Salmon in Summer

Releases of subyearling Chinook in the Lower Columbia River were analyzed using single release, paired release, and triple release-recapture models by detecting tagged fish on the Bonneville Dam primary, secondary, and tertiary arrays. Capture data were generated from these arrays to estimate reach survival rate. Paired-release estimates used a separate tailwater release of subyearling Chinook into the tailwater conducted by NOAA Fisheries, and the capture data for those fish were derived from the same downstream arrays used by the single-release model. The triple-release model also used the tailwater releases in combination with direct release into the B2CC. All routes of passage through B2 are reported (B2CC, JBS, and turbines), in addition to B2 as a whole.

Table 4.7. Tag-Life-Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Lower Columbia Released Subyearling Chinook Salmon in Reference Releases for all Bonneville Dam Survival(a)

Paired Release	S to Tailrace	1/2 95% CI
6/17-6/18	0.973	0.060
6/19-6/20	0.989	0.067
6/21-6/22	0.953	0.026
6/23-6/24	1.035	0.075
6/25-6/26	1.006	0.096
6/27-6/28	0.979	0.058
6/29-6/30	0.945	0.036
7/01-7/02	0.986	0.054
7/03-7/04	0.965	0.039
7/05-7/06	0.954	0.024
7/07-7/08	0.958	0.040
7/09-7/10	0.930	0.043
7/11-7/12	0.945	0.053
7/13-7/14	0.951	0.041
7/15-7/17	0.930	0.070
N-Wt Mean	0.970	0.014

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

Table 4.8. Summary of Survival Estimates for Subyearling Chinook Salmon Released into the Lower Columbia River and Regrouped Passing Routes at Bonneville Dam(a)

	Bonneville Corner Collector	Juvenile Bypass System	B2 Turbines	Bonneville 2nd Powerhouse	B2CC Direct Release
Single Release Survival	0.978 (0.014)	0.975 (0.021)	0.937 (0.018)	0.964 (0.014)	0.991 (0.010)
Paired Release Survival	0.996 (0.016)	0.991 (0.024)	0.954(0.020)	0.981 (0.016)	1.009 (0.01)
Triple Release Survival		1.006 (0.028)	0.967 (0.025)	0.990 (0.022)	

(a) Cormack-Jolly-Seber single-release, paired–release, and triple-release survival estimates are shown. Survival estimates were sample-weighted (N-weighted) as appropriate based on chi-square results and sample size. One-half 95% confidence intervals are reported in parentheses.

4.8 Dam Operations Effects on Survival Over Time

We calculated and examined correlations of survival probabilities with total B2 project discharge, B2CC discharge, and discharge over time for each group of smolts passing through B2 routes in spring and summer; relevant data are shown in Figures 4.8 – 4.10. Here we present the significant correlations ($\alpha = 0.05$) that were found between single-release survival of smolts and total B2 discharge and B2CC discharge. In spring, survival probabilities for yearling Chinook released in the Lower Columbia River passing through B2 turbines were positively correlated with B2CC discharge (r^2=0.54), whereas yearling Chinook survival for tagged fish passing through B2 and the B2CC were negatively correlated with total B2 discharge (r^2 =0.15, r^2=0.25 respectively). Survival of steelhead smolts showed no correlation with discharge at B2, the discharge through the B2CC, or over time. However, survival of subyearling Chinook passing through B2 routes in the summer showed strong positive correlations between B2 discharge and total B2 survival (r^2 = 0.64), as well as B2 turbine survival (r^2=0.48). Survival at B2 for subyearling Chinook was significant (p [0.05]) but weaker when compared to B2CC discharge (r^2=0.20). Over time, survival of subyearling Chinook was significantly and inversely correlated for all routes (r^2=0.63, Figure 4.1). Total discharge for B2 was strongly and negatively correlated with time during the spring and summer outmigration (r^2=0.72, r^2=0.64, respectively). B2CC discharge was negatively correlated with total B2 discharge in the spring (r^2=0.60), but not during the summer. No other significant correlations were found.

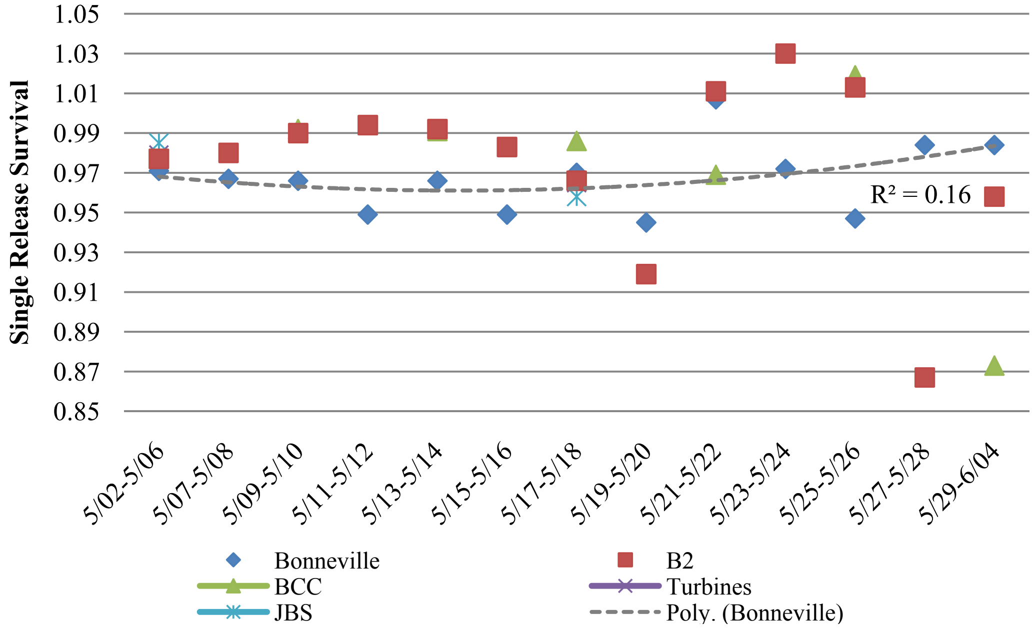


Figure 4.8. Cormack-Jolly-Seber Single-Release Survival Estimates for Juvenile Steelhead Passing Through Bonneville Dam Displayed by Virtual Release Group and Route of Passage. The trend line shown is a third-order polynomial regressed with the single-release survival estimate for all fish passing through Bonneville Dam. The associated r2 value is displayed next to the trend line.

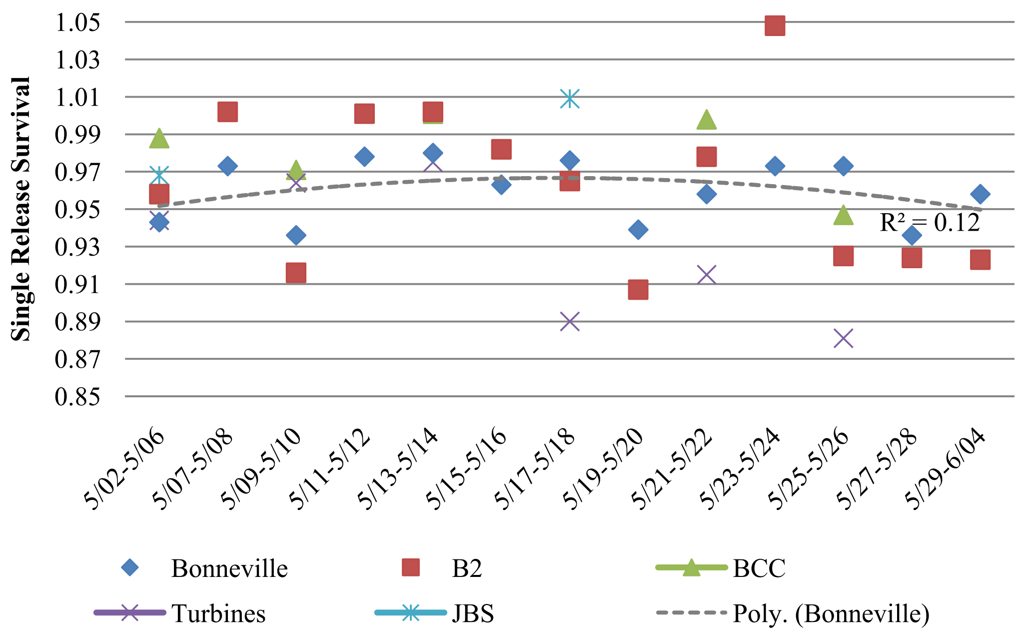


Figure 4.9. Cormack-Jolly-Seber Single-Release Survival Estimates for Yearling Chinook Passing Through Bonneville Dam Displayed by Virtual Release Group and Route of Passage. The trend line shown is a third-order polynomial regressed with the single-release survival estimate for all fish passing through Bonneville Dam. The associated r^2 value is displayed next to the trend line.

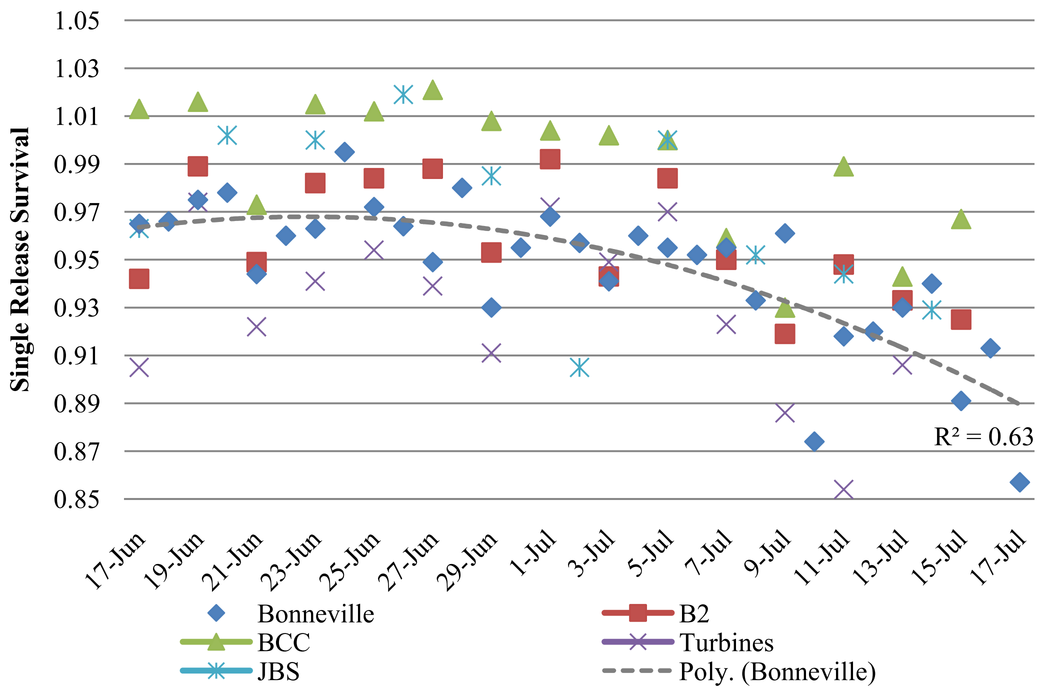


Figure 4.10. Cormack-Jolly-Seber Single-Release Survival Estimates for Subyearling Chinook Passing Through Bonneville Dam Displayed by Virtual Release Group and Route of Passage. The trend line shown is a third-order polynomial regressed with the single-release survival estimate for all fish passing through Bonneville Dam. The associated r^2 value is displayed next to the trend line.

4.9 Travel Time and Rate

Travel times and rates were calculated for all fish released from the Lower Granite Dam, John Day forebay, and the John Day, The Dalles, and Bonneville tailraces. Travel times and rates were also calculated for virtual releases at Bonneville and The Dalles dams, and are published in a separate report by Ploskey et al. (2009).

4.10 Diel Distribution

Fish arrived at Bonneville Dam during all hours of the day as was evident from the daily time of arrival distribution at the Bonneville forebay array (rkm 236). This distribution did not correspond to the diel passage distribution at B2, which showed opposing and strong diel components for corner collector and turbine passage (see Figures 4.11, 4.12, and 4.13).

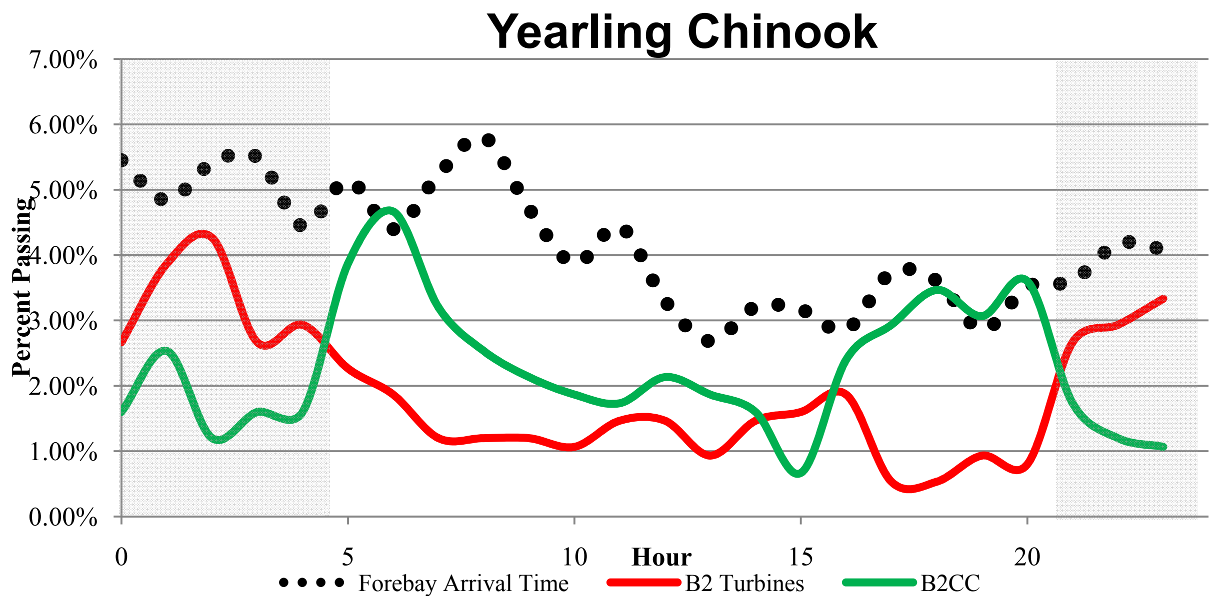


Figure 4.11. Diel Passage Distribution of Tagged Yearling Chinook Salmon Detected Arriving and Passing Through Bonneville Dam. The "percent passing" is the percent of the number of fish passing through either the B2 turbines or the B2CC for the entire spring study period by hour of the day and route of passage. Shaded regions are approximate nighttime hours and un-shaded areas are daytime hours.

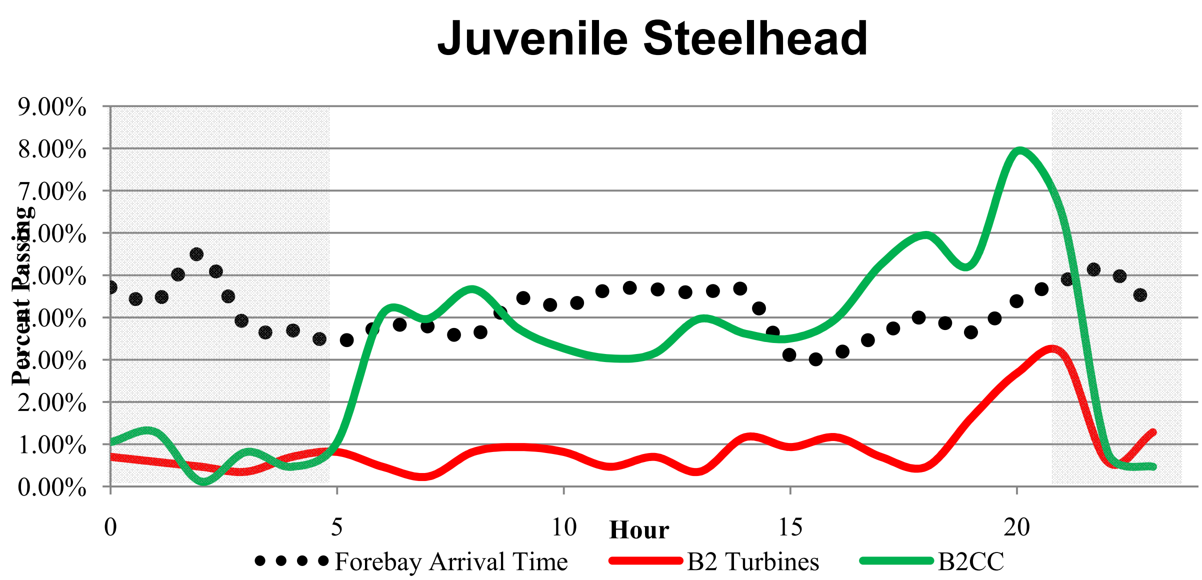


Figure 4.12. Diel Passage Distribution of Tagged Juvenile Steelhead Detected Arriving at and Passing Through Bonneville Dam. The "percent passing" is the percent of the number of fish passing through either the B2 turbines or the B2CC for the entire spring study period by hour of the day and route of passage. Shaded regions are approximate nighttime hours and un-shaded areas are daytime hours.

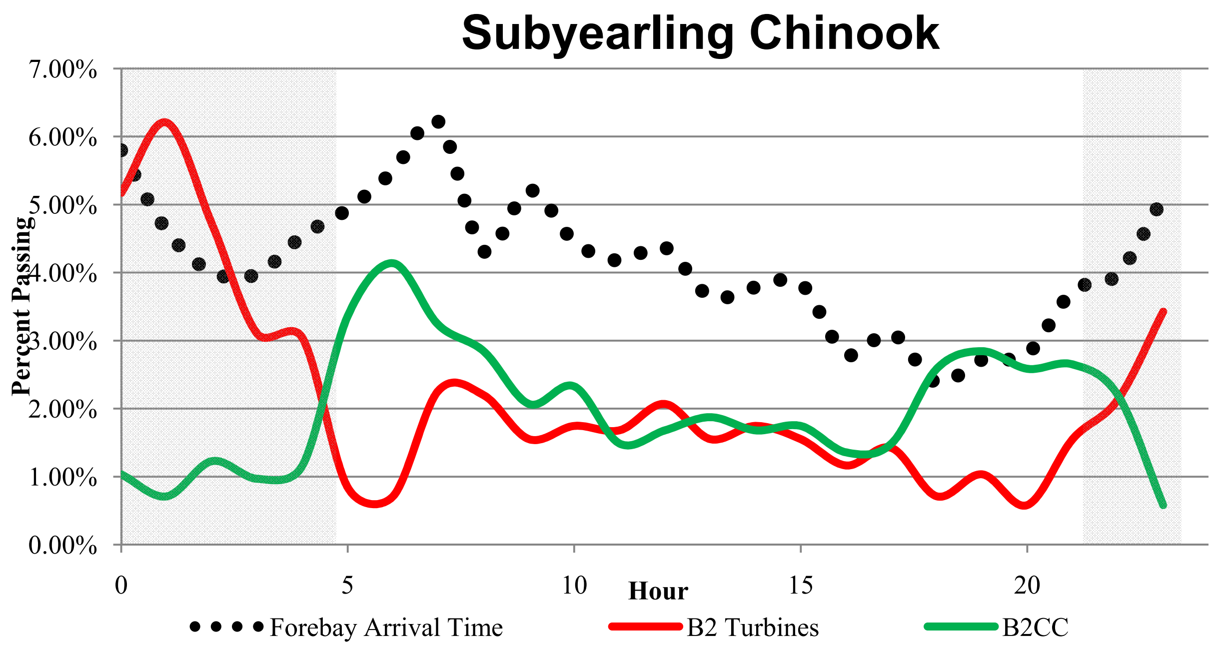


Figure 4.13. Diel Passage Distribution of Tagged Subyearling Chinook Salmon Detected Arriving at and Passing Through Bonneville Dam. The "percent passing" is the percent of the number of fish passing either the B2 turbines or the B2CC for the entire spring study period by hour of the day and route of passage. Shaded regions are approximate nighttime hours and un-shaded areas are daytime hours.

4.11 Passage Distribution at Bonneville Powerhouse 2

Tables 4.9–4.15 and Figures 4.14–4.26 show the passage distribution of JSATS-tagged fish as they approached and passed through B2. Included in the tables are metrics associated with passage numbers. These metrics include fish guidance efficiency (FGE), which is the total number of fish passing into the JBS versus those passing either through turbines or the JBS; and fish passage efficiency (FPE), which is the number of fish passing through the JBS or the B2CC versus those passing through all of B2. The data are separated by species, route of passage, day or night (passage time between sunrise and sunset for day, and sunset and sunrise for night), as well as crepuscular period (defined as the time one hour prior to and after sunrise or sunset).

Table 4.9. Passage Numbers and Associated FGE for Tagged Juvenile Salmon and Steelhead Migrating Downstream Through B2 Routes

Species	Unit	Guided	UnGuided	FGE
Yearling Chinook Lower Granite Released	TU11	11	12	48%
	TU12	11	35	24%
	TU13	0	3	0%
	TU14	15	92	14%
	TU15	0	2	0%
	TU16	13	59	18%
	TU17	8	40	17%
	TU18	2	12	14%
	FU2	2	13	13%
	Unknown	1		
Yearling Chinook Lower Columbia Released	TU11	2	6	25%
	TU12	13	27	33%
	TU13	6	12	33%
	TU14	31	82	27%
	TU15	6	25	19%
	TU16	28	63	31%
	TU17	22	52	30%
	TU18	9	25	26%
	FU2	2	7	22%
	Unknown	41		
Juvenile Steelhead	TU11	0	2	0%
	TU12	8	18	31%
	TU13	9	9	50%
	TU14	15	64	19%
	TU15	2	11	15%
	TU16	7	17	29%
	TU17	5	15	25%
	TU18	3	9	25%
	FU2	0	1	0%
	Unknown	38		
Subyearling Chinook	TU11	0	5	0%
	TU12	49	87	36%
	TU13	38	81	32%
	TU14	48	89	35%
	TU15	56	145	28%
	TU16	66	167	28%
	TU17	19	101	16%
	TU18	23	85	21%
	FU2	5	34	13%
	Unknown	24		

Table 4.10. Passage Numbers and Associated Percentage for Tagged Juvenile Salmon and Steelhead Migrating Downstream Through B2 Routes

Species	Unit	N	Passage (%)
Yearling Chinook Lower Granite Released	B2CC	291	47%
	TU11	23	4%
	TU12	46	7%
	TU13	3	0%
	TU14	107	17%
	TU15	2	0%
	TU16	72	12%
	TU17	48	8%
	TU18	14	2%
	FU2	15	2%
	Unknown	1	0%
	Total	**622**	
Yearling Chinook Lower Columbia Released	B2CC	442	49%
	TU11	8	1%
	TU12	40	4%
	TU13	18	2%
	TU14	113	13%
	TU15	31	3%
	TU16	91	10%
	TU17	74	8%
	TU18	34	4%
	FU2	9	1%
	Unknown	41	5%
	Total	**901**	
Juvenile Steelhead	B2CC	693	75%
	TU11	2	0%
	TU12	26	3%
	TU13	18	2%
	TU14	79	9%
	TU15	13	1%
	TU16	24	3%
	TU17	20	2%
	TU18	12	1%
	FU2	1	0%
	Unknown	38	4%
	Total	**926**	
Subyearling Chinook	B2CC	741	40%
	TU11	5	0%
	TU12	136	7%
	TU13	119	6%
	TU14	137	7%
	TU15	201	11%
	TU16	233	13%
	TU17	120	6%
	TU18	108	6%
	FU2	39	2%
	Unknown	24	1%
	Total	**1863**	

Table 4.11. Diel Total and Percent Passage by Unit for Tagged Yearling Chinook, Juvenile Steelhead, and Subyearling Chinook Passing Through B2 Routes

Species	Unit	Day (N)	Passage (%)	Night (N)	Passage (%)
Yearling Chinook Lower Granite Released	B2CC	200	63%	91	30%
	TU11	7	2%	16	5%
	TU12	16	5%	30	10%
	TU13	0	0%	3	1%
	TU14	43	14%	64	21%
	TU15	1	0%	1	0%
	TU16	30	9%	42	14%
	TU17	14	4%	34	11%
	TU18	2	1%	12	4%
	FU2	4	1%	11	4%
	Unknown	0	0%	1	0%
	Total	**317**		**305**	
Yearling Chinook Lower Columbia Released	B2CC	290	55%	152	41%
	TU11	3	1%	5	1%
	TU12	18	3%	22	6%
	TU13	9	2%	9	2%
	TU14	60	11%	53	14%
	TU15	16	3%	15	4%
	TU16	54	10%	37	10%
	TU17	40	8%	34	9%
	TU18	9	2%	25	7%
	FU2	1	0%	8	2%
	Unknown	26	5%	15	4%
	Total	**526**		**375**	
Juvenile Steelhead	B2CC	541	81%	152	59%
	TU11	0	0%	2	1%
	TU12	22	3%	4	2%
	TU13	12	2%	6	2%
	TU14	51	8%	28	11%
	TU15	8	1%	5	2%
	TU16	7	1%	17	7%
	TU17	8	1%	12	5%
	TU18	1	0%	11	4%
	FU2	0	0%	1	0%
	Unknown	18	3%	20	8%
	Total	**668**		**258**	
Subyearling Chinook	B2CC	548	49%	193	26%
	TU11	0	0%	5	1%
	TU12	64	6%	72	10%
	TU13	52	5%	67	9%
	TU14	78	7%	59	8%
	TU15	125	11%	76	10%
	TU16	145	13%	88	12%
	TU17	37	3%	83	11%
	TU18	34	3%	74	10%
	FU2	18	2%	21	3%
	Unknown	17	2%	7	1%
	Total	**1118**		**745**	

Table 4.12. Route-Specific Total and Associated Percent Passage Through B2 by Route for Yearling Chinook, Juvenile Steelhead, and Subyearling Chinook

Species	Route	Number	Passage (%)
Yearling Chinook Lower Granite Released	B2CC	291	47%
	JBS	63	10%
	Turbine	268	43%
	Total	**622**	
Yearling Chinook Lower Columbia Released	B2CC	442	49%
	JBS	160	18%
	Turbine	299	33%
	Total	**901**	
Juvenile Steelhead	B2CC	693	75%
	JBS	87	9%
	Turbine	146	16%
	Total	**926**	
Subyearling Chinook	B2CC	741	40%
	JBS	328	18%
	Turbine	794	43%
	Total	**1863**	

Table 4.13. Tagged Yearling Chinook, Juvenile Steelhead, and Subyearling Chinook that Passed Through B2 Routes During Crepuscular and Non-Crepuscular Periods. The crepuscular period was defined as one hour prior to and after sunrise or sunset.

Species	Route	Crepuscular (N)	Crepuscular (%)	Non- Crepuscular (N)	Non- Crepuscular (%)
Yearling Chinook Lower Granite Released	B2CC	70	59%	221	44%
	JBS	7	6%	56	11%
	Turbine	42	35%	226	45%
	Total	**119**		**503**	
Yearling Chinook Lower Columbia Released	B2CC	117	64%	325	45%
	JBS	21	12%	139	19%
	Turbine	44	24%	255	35%
	Total	**182**		**719**	
Juvenile Steelhead	B2CC	177	68%	516	77%
	JBS	33	13%	54	8%
	Turbine	50	19%	96	14%
	Total	**260**		**666**	
Subyearling Chinook	B2CC	165	58%	576	36%
	JBS	43	15%	285	18%
	Turbine	75	27%	719	46%
	Total	**283**		**1580**	

N = Number

Table 4.14. Tagged Yearling Chinook, Juvenile Steelhead, and Subyearling Chinook that Passed Through B2 Routes During Daytime and Nighttime Periods. Daytime and nighttime fish were separated at time of passage before sunrise or sunset.

Species	Route	Day (N)	Day (%)	Night (N)	Night (%)
Yearling Chinook Lower Granite Released	B2CC	200	63%	91	30%
	JBS	46	15%	17	6%
	Turbine	71	22%	197	65%
	Total	**317**		**305**	
Yearling Chinook Lower Columbia Released	B2CC	290	55%	152	41%
	JBS	120	23%	40	11%
	Turbine	116	22%	183	49%
	Total	**526**		**375**	
Juvenile Steelhead	B2CC	541	81%	152	59%
	JBS	49	7%	38	15%
	Turbine	78	12%	68	26%
	Total	**668**		**258**	
Subyearling Chinook	B2CC	548	49%	193	26%
	JBS	222	20%	106	14%
	Turbine	348	31%	446	60%
	Total	**1118**		**745**	

Table 4.15. Total Tagged Yearling Chinook, Juvenile Steelhead, and Subyearling Chinook that Passed Through B2 Routes, and Their Associated FPE and FGE Values

Species	B2CC	JBS	Turbine	Guided (B2CC or Screens)	Unguided (Screens)	Total	FPE	FGE
Yearling Chinook Lower Granite Released	291	63	268	354	268	622	57%	19%
Yearling Chinook Lower Columbia Released	442	160	299	602	299	901	67%	35%
Juvenile Steelhead	693	87	146	780	146	926	84%	37%
Subyearling Chinook	741	328	794	1069	794	1863	57%	29%

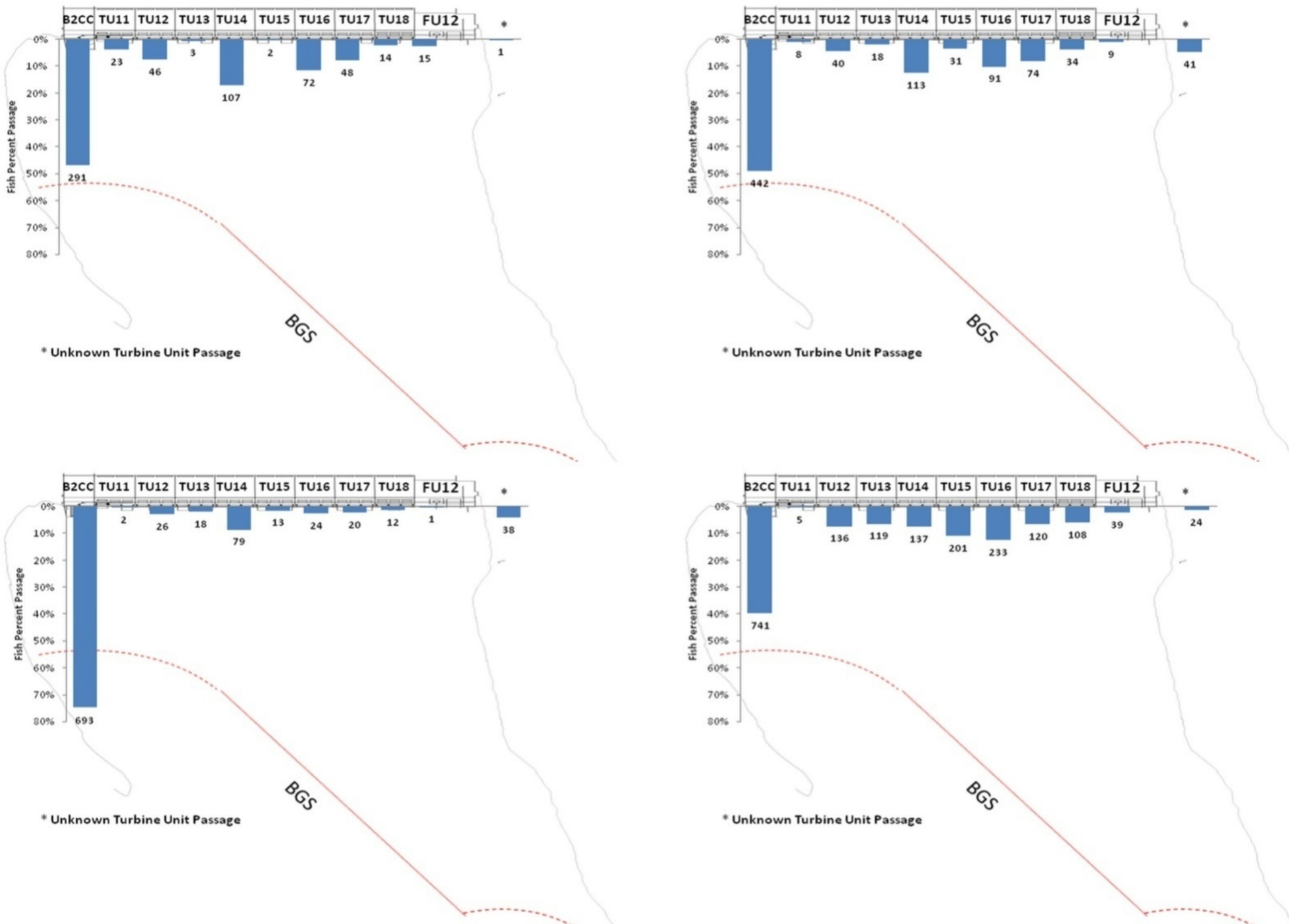


Figure 4.14. Percent Passage Distribution for Juvenile Salmon and Steelhead Migrating Through B2 Routes. Figure displays tagged yearling Chinook released above Lower Granite Dam (top left), yearling Chinook released in the Lower Columbia River (top right), steelhead (bottom left), and subyearling Chinook (bottom right). The distribution of fish that passed into turbines but the turbine unit was unknown are shown to the right of the figure.

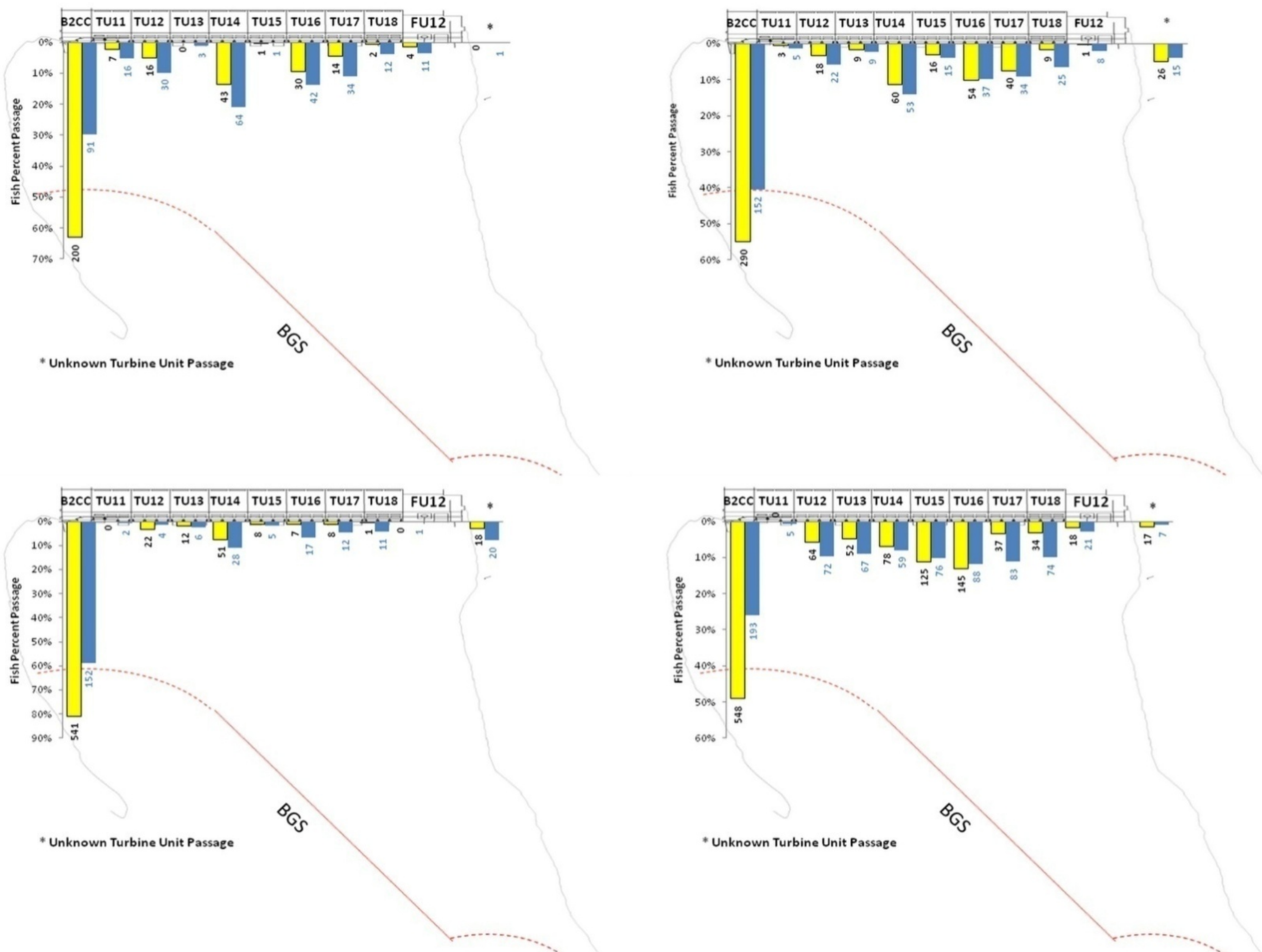


Figure 4.15. Percent Distribution of Day (yellow) and Night (blue) Passage of Juvenile Salmon and Steelhead Migrating Through B2 routes. Figure displays tagged yearling Chinook released above Lower Granite Dam (top left), yearling Chinook released in the Lower Columbia River (top right), steelhead (bottom left), and subyearling Chinook (bottom right). Distribution of fish that passed into turbines but the turbine unit was unknown are shown to the right of the figure.

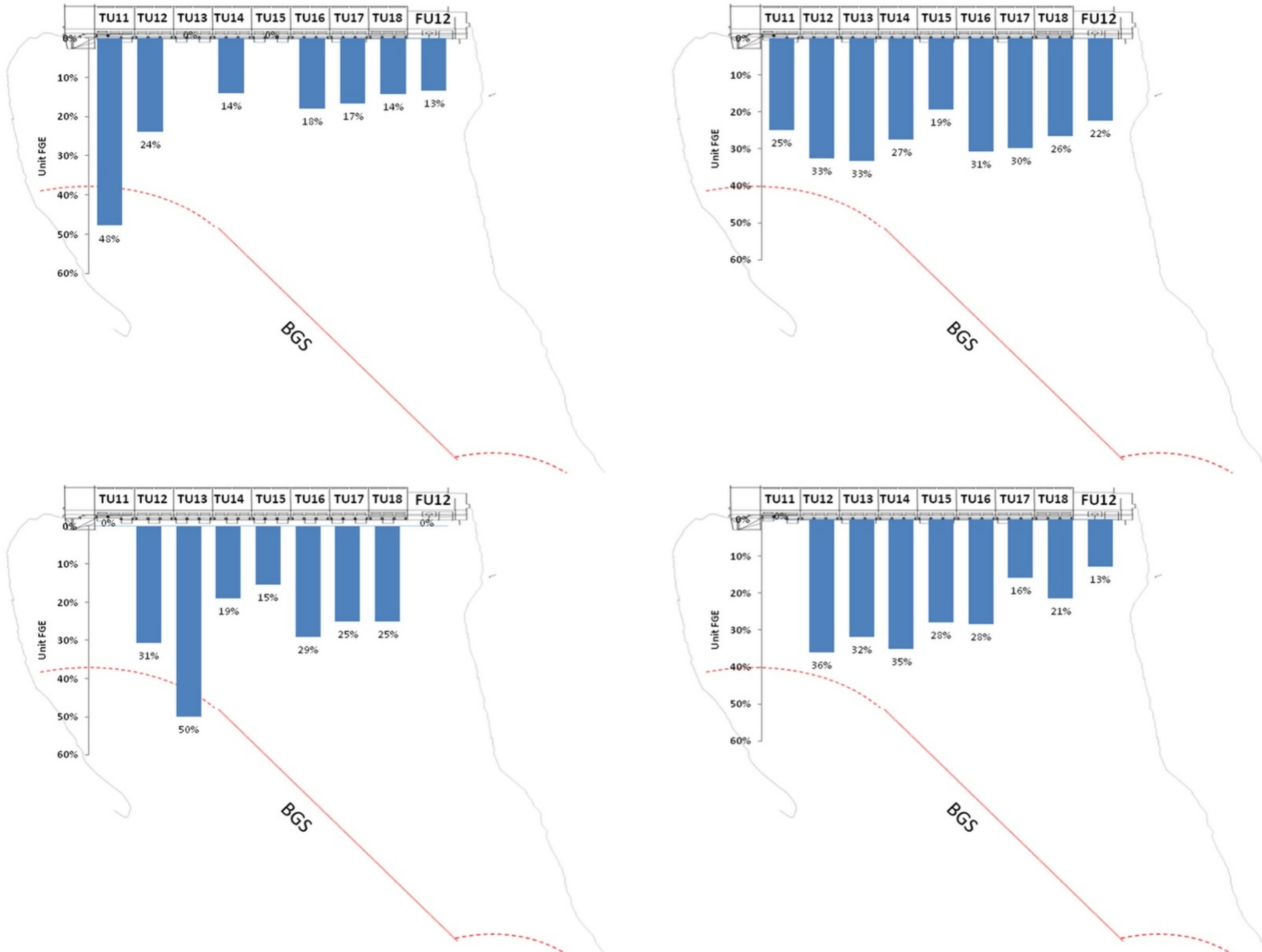


Figure 4.16. Fish Guidance Efficiency (FGE) for Juvenile Salmon and Steelhead Migrating Through B2 turbines. Figure displays FGE for tagged yearling Chinook released above Lower Granite Dam (top left), yearling Chinook released in the Lower Columbia River (top right), steelhead (bottom left), and subyearling Chinook (bottom right). FGE is defined as the number of fish guided by screens into the juvenile bypass facility compared to the total number passing into the turbine that are guided or unguided.

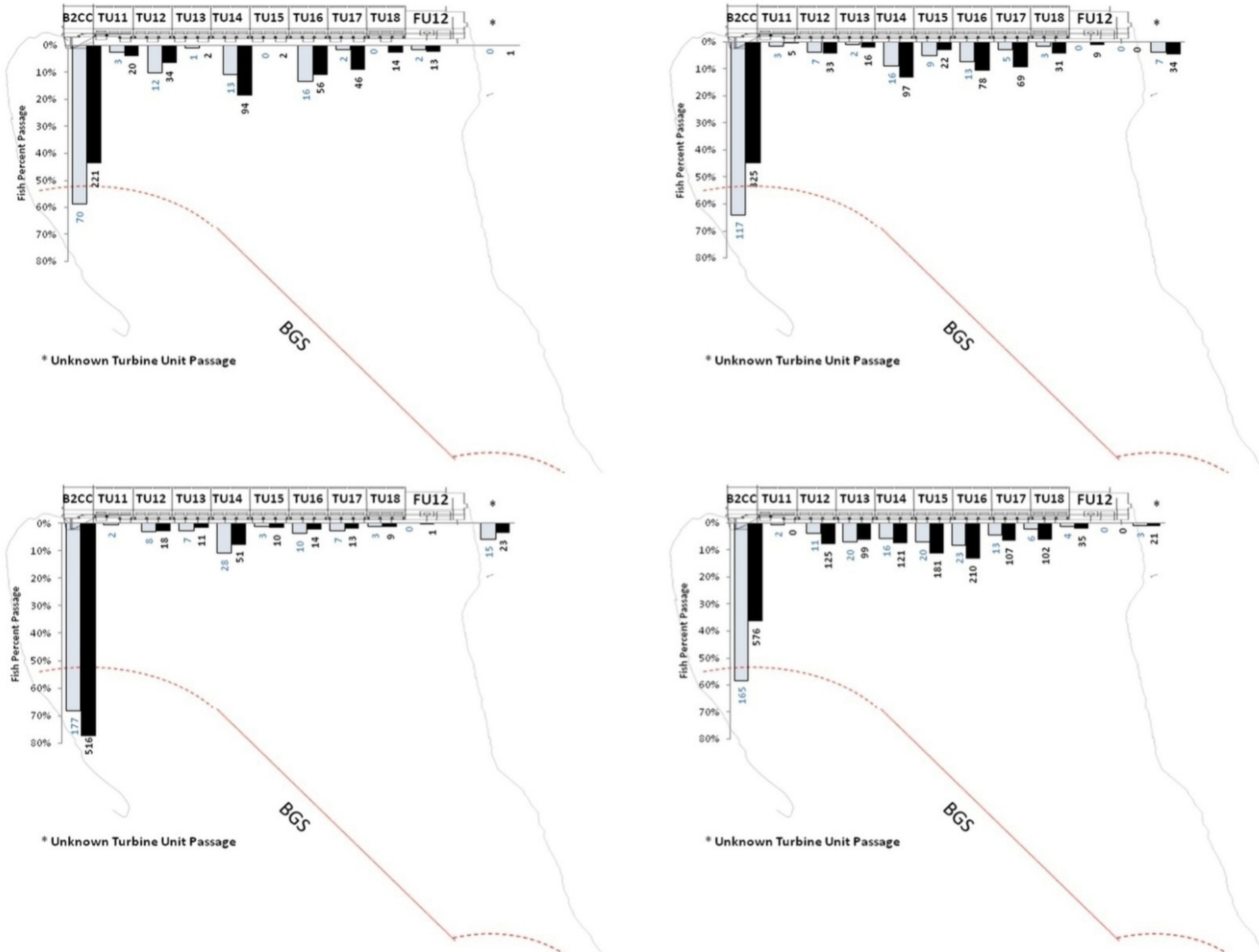


Figure 4.17. Percent Distribution During Crepuscular (grey) and Non-Crepuscular (black) Periods for Juvenile Salmon and Steelhead Migrating Through B2 Routes. Figure displays tagged yearling Chinook released above Lower Granite Dam (top left), yearling Chinook released in the Lower Columbia River (top right), steelhead (bottom left), and subyearling Chinook (bottom right). Crepuscular periods were defined for this purpose as one hour before and after sunrise or sunset. All other hours were defined as non-crepuscular periods.

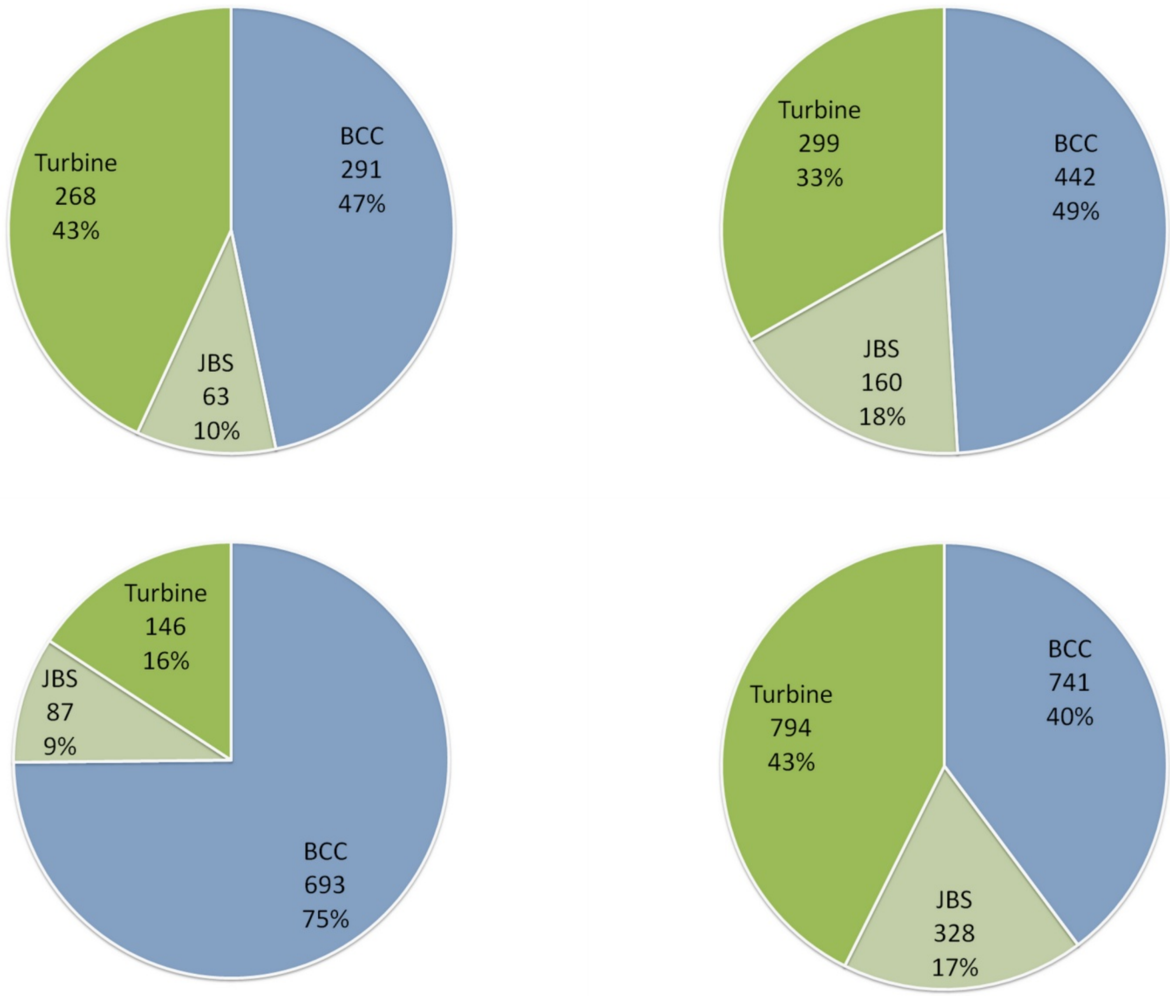


Figure 4.18. Percent Passage Distribution for Juvenile Salmon and Steelhead Migrating Through B2 Routes. Figure displays tagged yearling Chinook released above Lower Granite Dam (top left), yearling Chinook released in the Lower Columbia River (top right), steelhead (bottom left), and subyearling Chinook (bottom right).

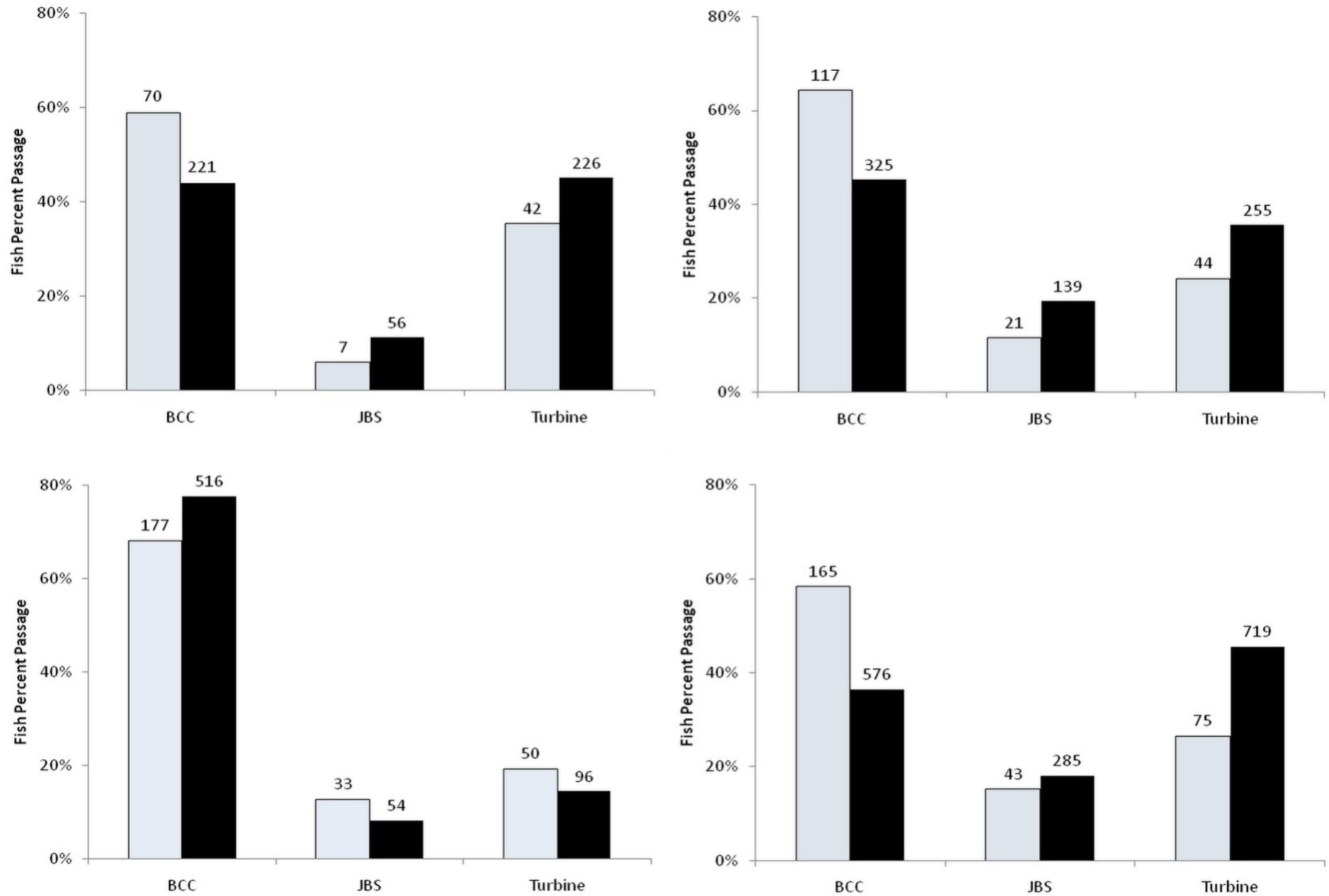


Figure 4.19. Percent Distribution During Crepuscular (grey) and Non-Crepuscular (black) Periods for Juvenile Salmon and Steelhead Migrating Through B2 Routes. Figure displays tagged yearling Chinook released above Lower Granite Dam (top left), yearling Chinook released in the Lower Columbia River (top right), steelhead (bottom left), and subyearling Chinook (bottom right). Crepuscular periods were defined for this purpose as one hour before and after sunrise or sunset. All other hours were defined as non-crepuscular periods.

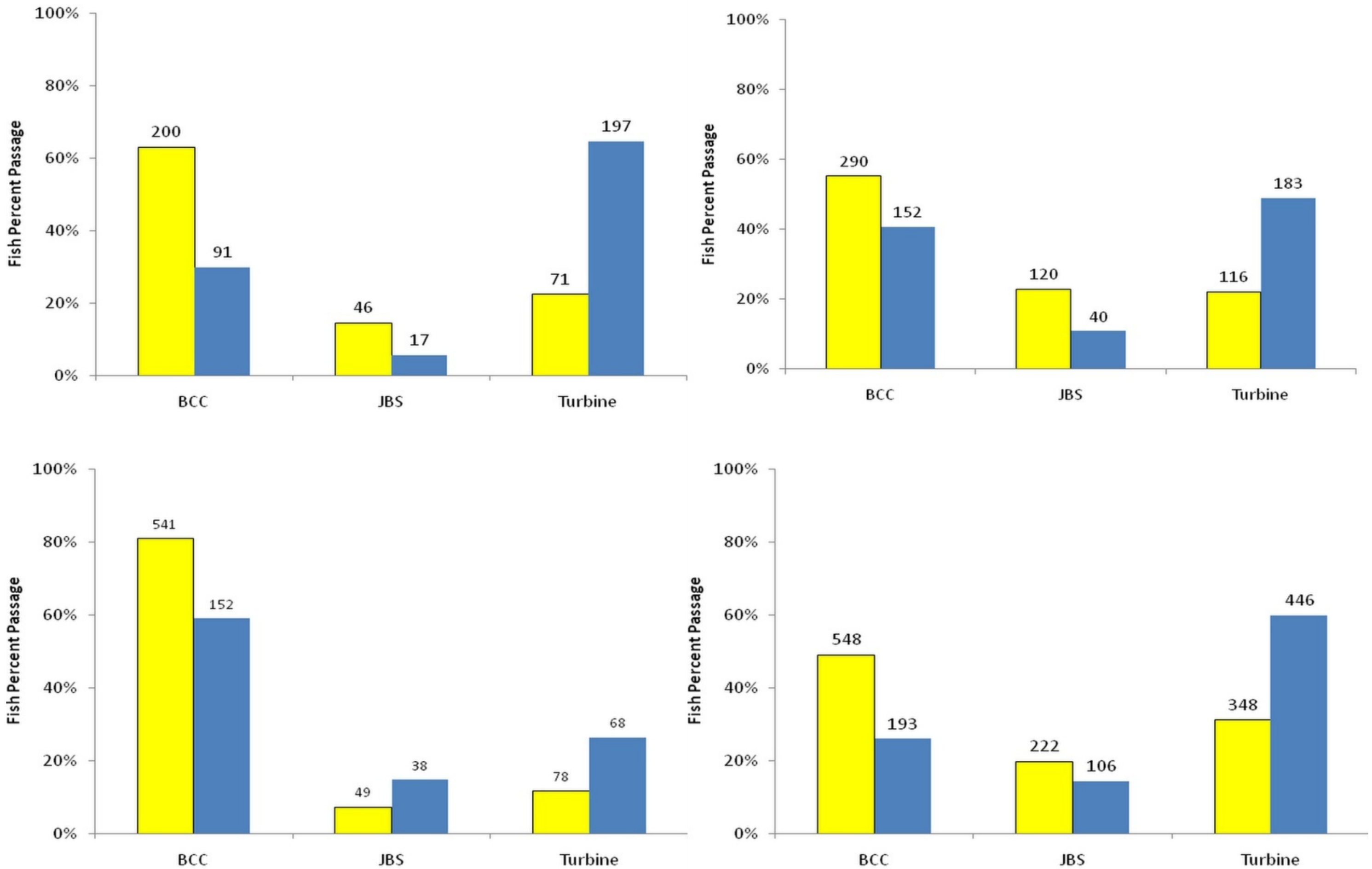


Figure 4.20. Percent Distribution of Day (yellow) and Night (blue) Passage of Juvenile Salmon and Steelhead Migrating Through B2 Routes. Figure displays tagged yearling Chinook released above Lower Granite Dam (top left), yearling Chinook released in the Lower Columbia River (top right), steelhead (bottom left), and subyearling Chinook (bottom right). Distribution of fish that passed into turbines but the turbine unit was unknown are shown to the right of the figure.

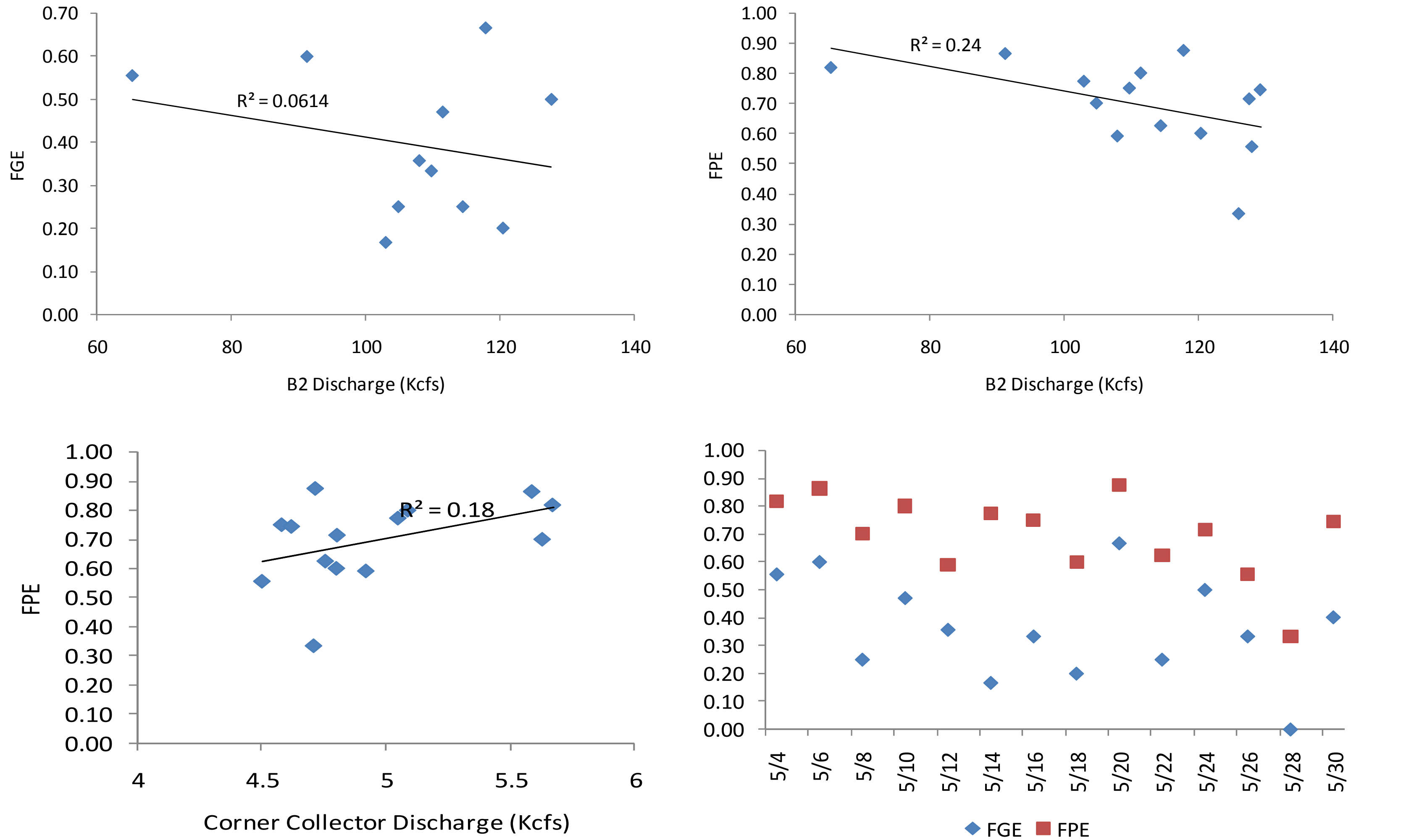


Figure 4.21. Scatter Plots of Daytime FGE and FPE Estimates Compared to Average Daily Discharge for Yearling Chinook Salmon Released in the Lower Columbia River. Daytime FGE and FPE were plotted in relation to total B2 discharge (upper left and upper right respectively). Daytime FPE was plotted against the average daily corner collector discharge (lower left). Daytime estimates of FGE and FPE were also plotted over time (lower right). The displayed R-squared values were calculated using linear regression of passage metrics compared to average discharge.

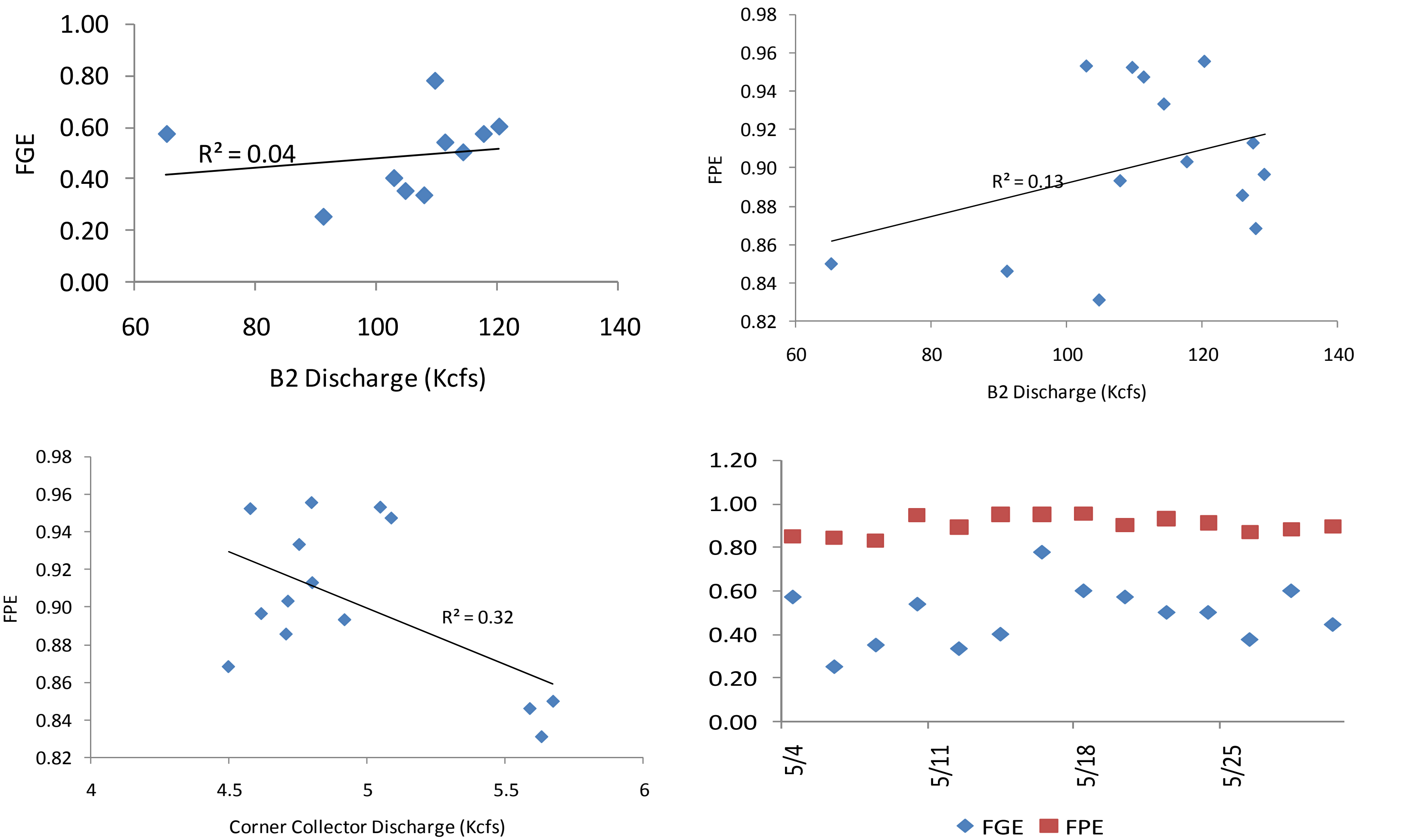


Figure 4.22. Scatter Plots of Nighttime FGE and FPE Estimates Compared to Average Discharge for Yearling Chinook Salmon Released in the Lower Columbia River. Nighttime FGE and FPE were plotted in relation to total B2 discharge (upper left and upper right respectively). Nighttime FPE was plotted against the average daily corner collector discharge (lower left). Nighttime estimates of FGE and FPE were also plotted over time (lower right). The displayed R-squared values were calculated using linear regression of passage metrics compared to average discharge. Dates associated with nighttime values are the beginning date for a continual night.

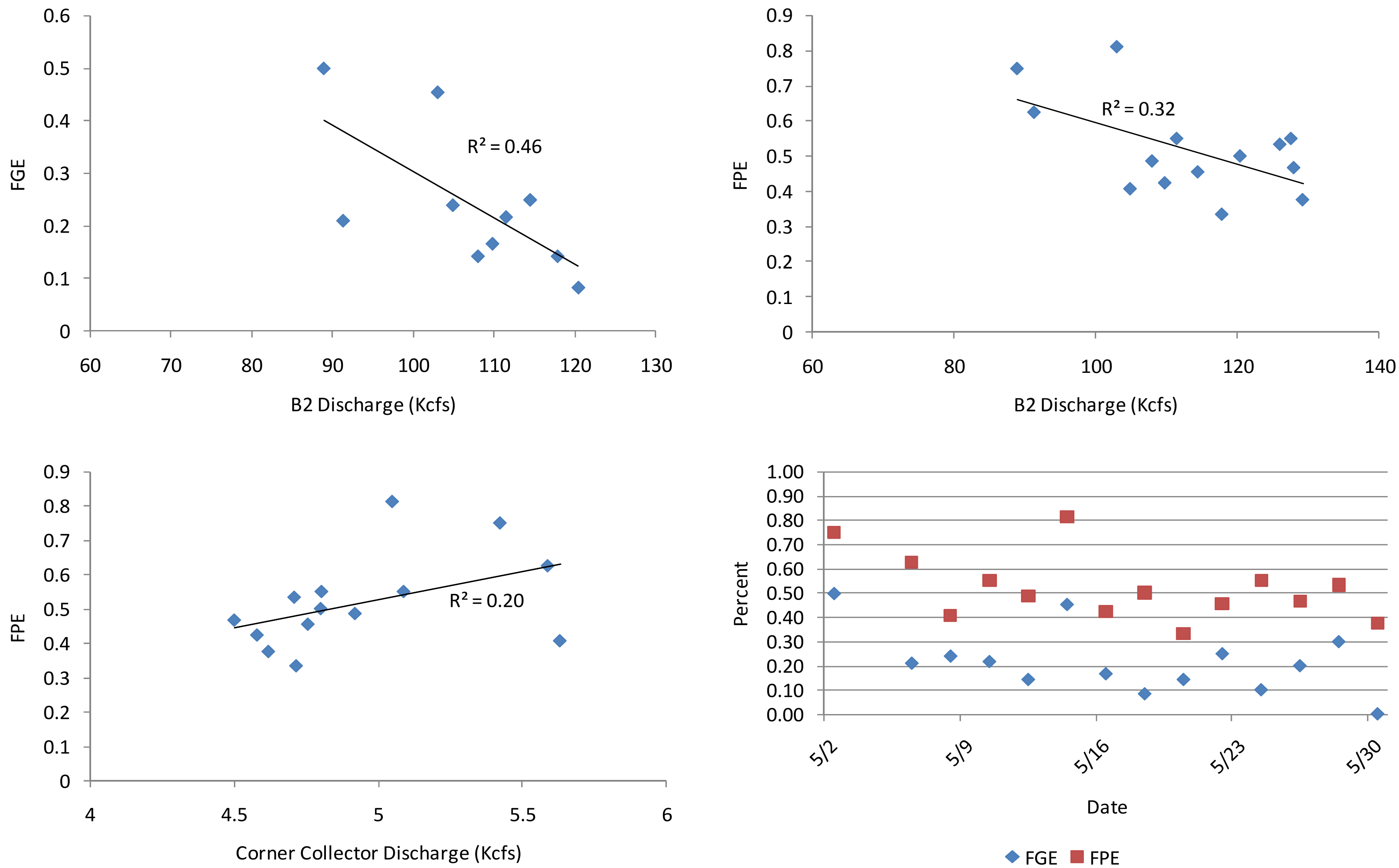


Figure 4.23. Scatter Plots of Daytime FGE and FPE Estimates Compared to Average Daily Discharge for Juvenile Steelhead. Daytime FGE and FPE were plotted in relation to total B2 discharge (upper left and upper right respectively). Daytime FPE was plotted against the average daily corner collector discharge (lower left). Daytime estimates of FGE and FPE were also plotted over time (lower right). The displayed R-squared values were calculated using linear regression of passage metrics compared to average discharge.

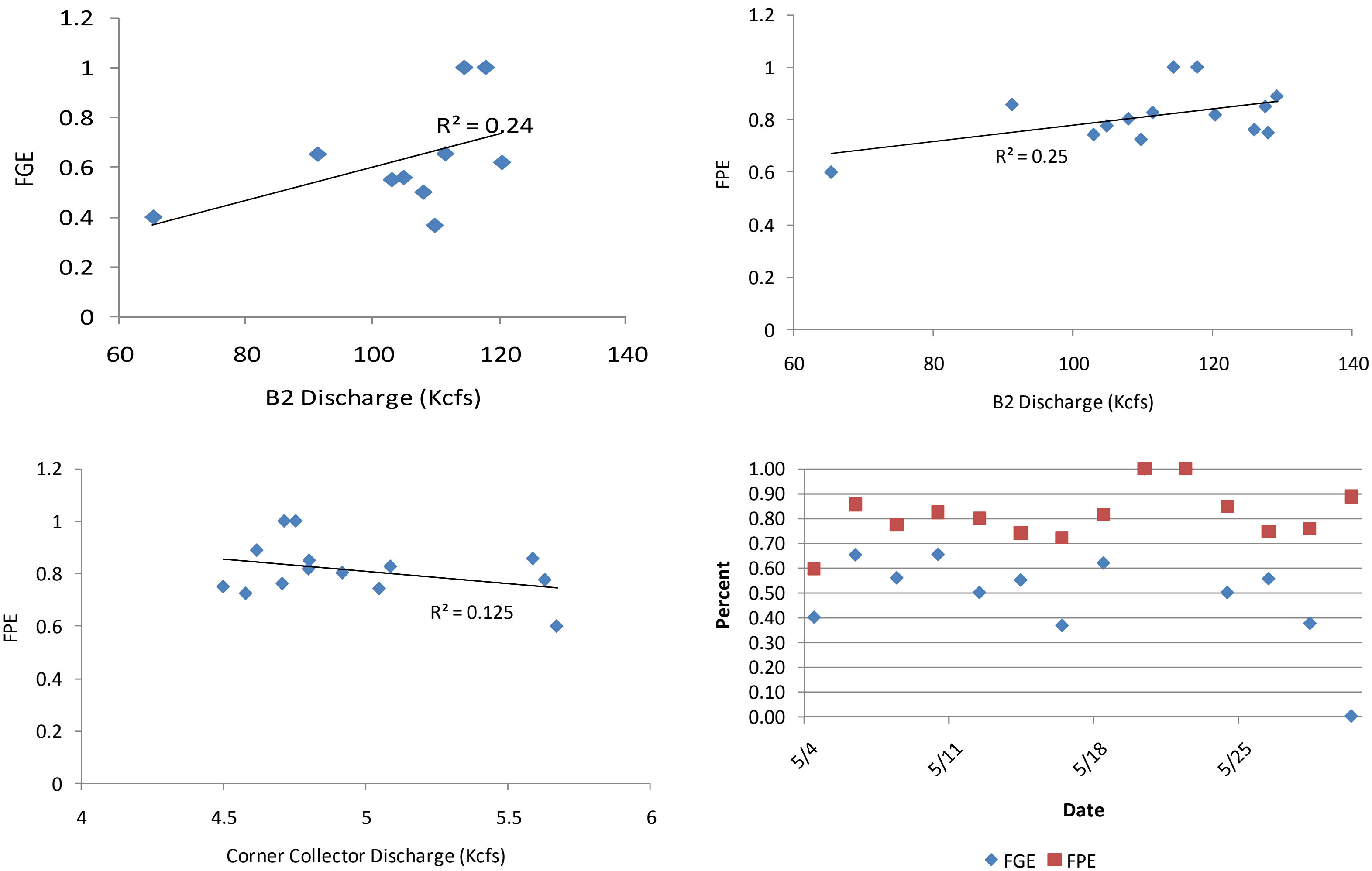


Figure 4.24. Scatter Plots of Nighttime FGE and FPE Estimates Compared to Average Discharge for Steelhead During the Pooled Sample. Nighttime FGE and FPE were plotted in relation to total B2 discharge (upper left and upper right respectively). Nighttime FPE was plotted against the average daily corner collector discharge (lower left). Nighttime estimates of FGE and FPE were also plotted over time (lower right). The displayed R-squared values were calculated using linear regression of passage metrics compared to average discharge. Dates associated with nighttime values are the beginning date for a continual night.

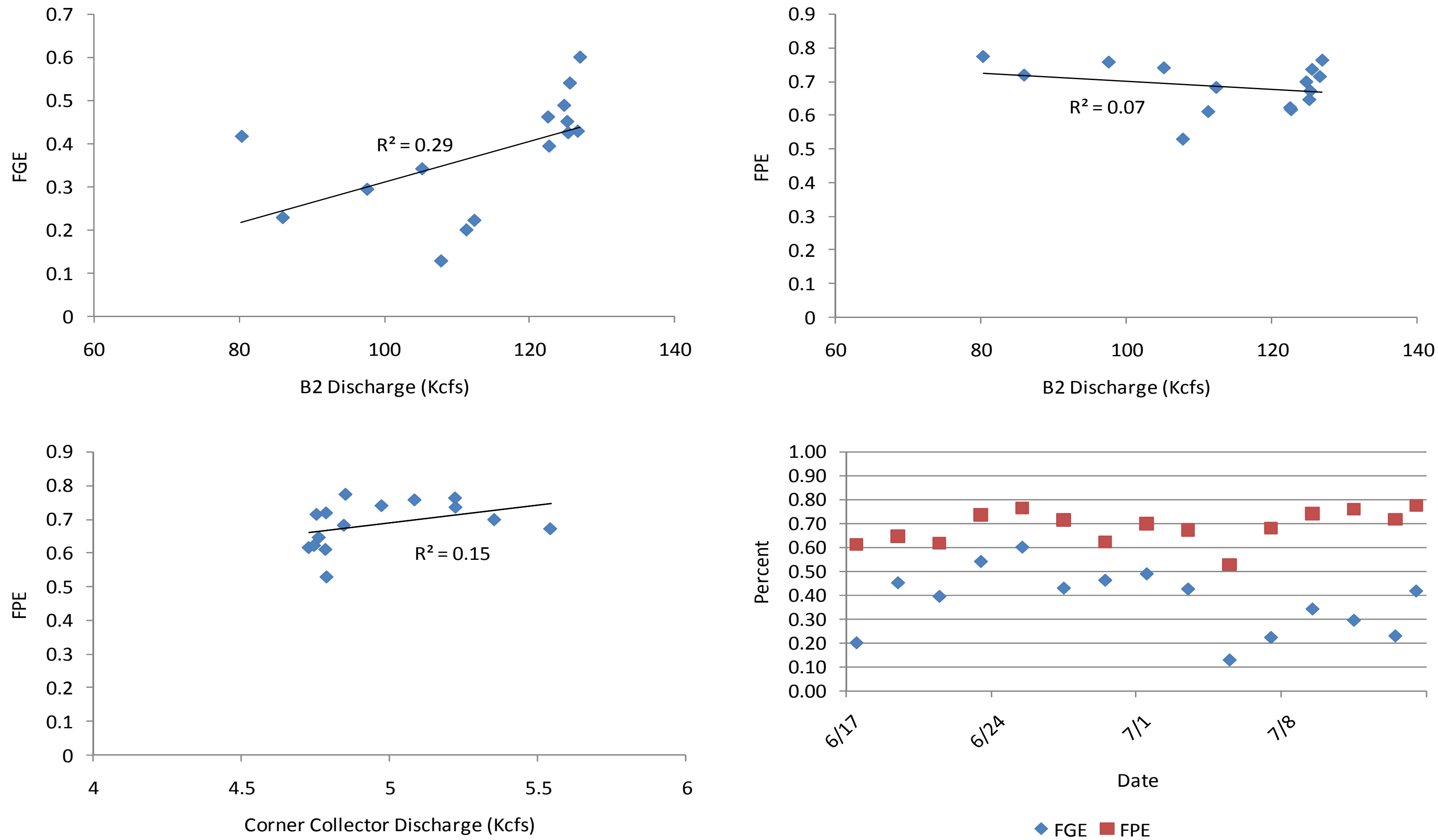


Figure 4.25. Scatter Plots of Daytime FGE and FPE Estimates Compared to Average Daily Discharge for Subyearling Chinook Salmon. Daytime FGE and FPE were plotted in relation to total B2 discharge (upper left and upper right respectively). Daytime FPE was plotted against the average daily corner collector discharge (lower left). Daytime estimates of FGE and FPE were also plotted over time (lower right). The displayed R-squared values were calculated using linear regression of passage metrics compared to average discharge.

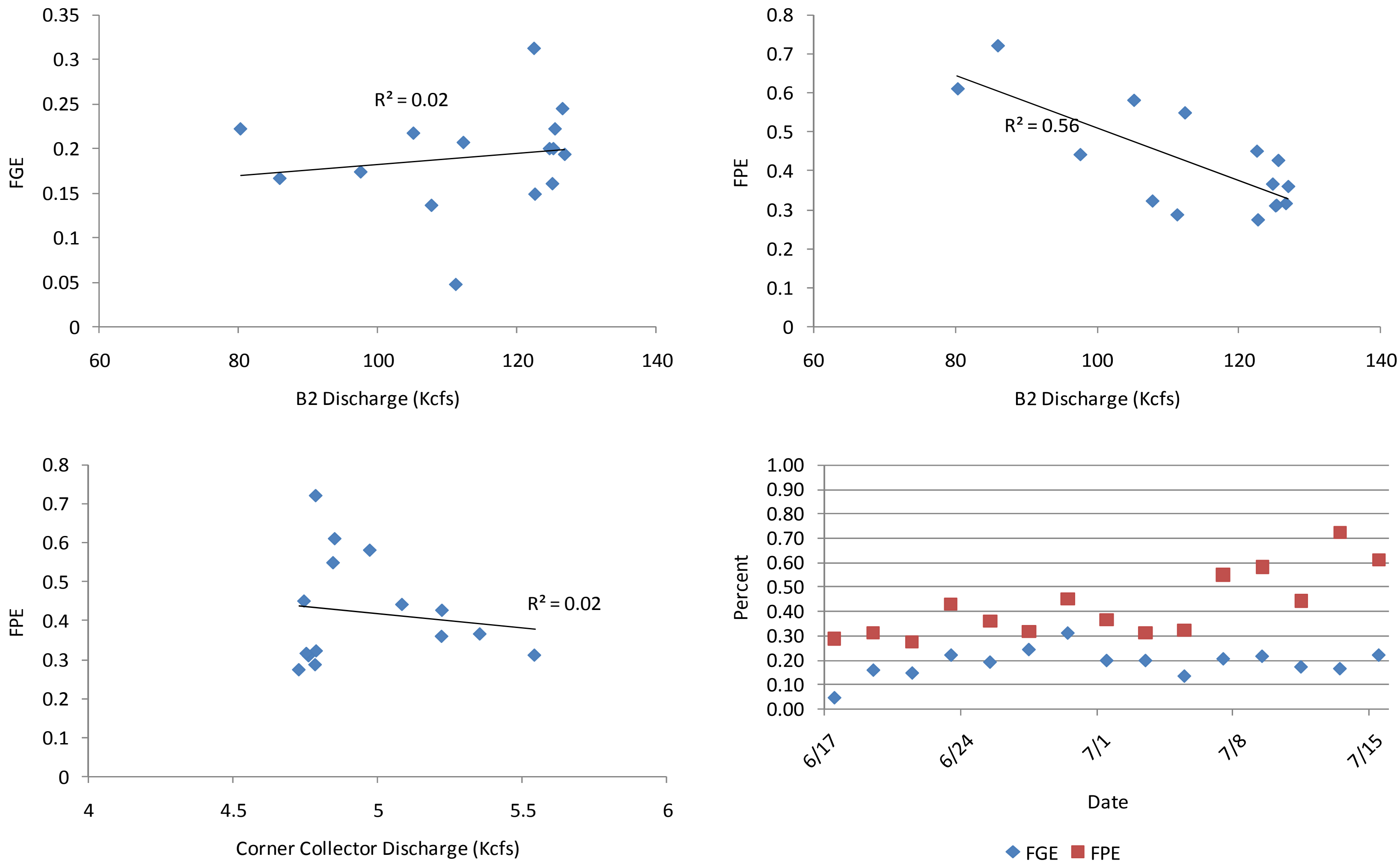


Figure 4.26. Scatter Plots of Nighttime FGE and FPE Estimates Compared to Average Discharge for Subyearling Chinook Salmon. Nighttime FGE and FPE were plotted in relation to total B2 discharge (upper left and upper right respectively). Nighttime FPE was plotted against the average daily corner collector discharge (lower left). Nighttime estimates of FGE and FPE were also plotted over time (lower right). The displayed R-squared values were calculated using linear regression of passage metrics compared to average discharge. Dates associated with nighttime values are the beginning date for a continual night.

4.12 Forebay and Passage Distribution Relative to BGS Deployment

Figures 4.27 through 4.30 and Tables 4.40 through 4.42 presented in this section show the relative distribution of passage for tagged fish approaching the BGS and eventually passing through B2 routes. Fish that approached were classified as either passing through the 'North Gap' near the Washington shoreline, where no BGS sections were deployed; 'Under,' where tagged fish were observed passing under the BGS; and 'Guided,' where fish were observed passing between the downstream edge of the BGS and Cascade island. All classifications of tagged fish were based upon the last detection of fish on hydrophones that specifically monitored the North Gap, Under, or Guided routes. Two-dimensional positioning was then used to create following figures to show the approach patterns of fish as they encountered the BGS. In general, Guided fish passed in greater proportions through the B2CC, North Gap and Under fish passed in greater proportions through the turbines. More detailed descriptions are provided in the figure and table captions.

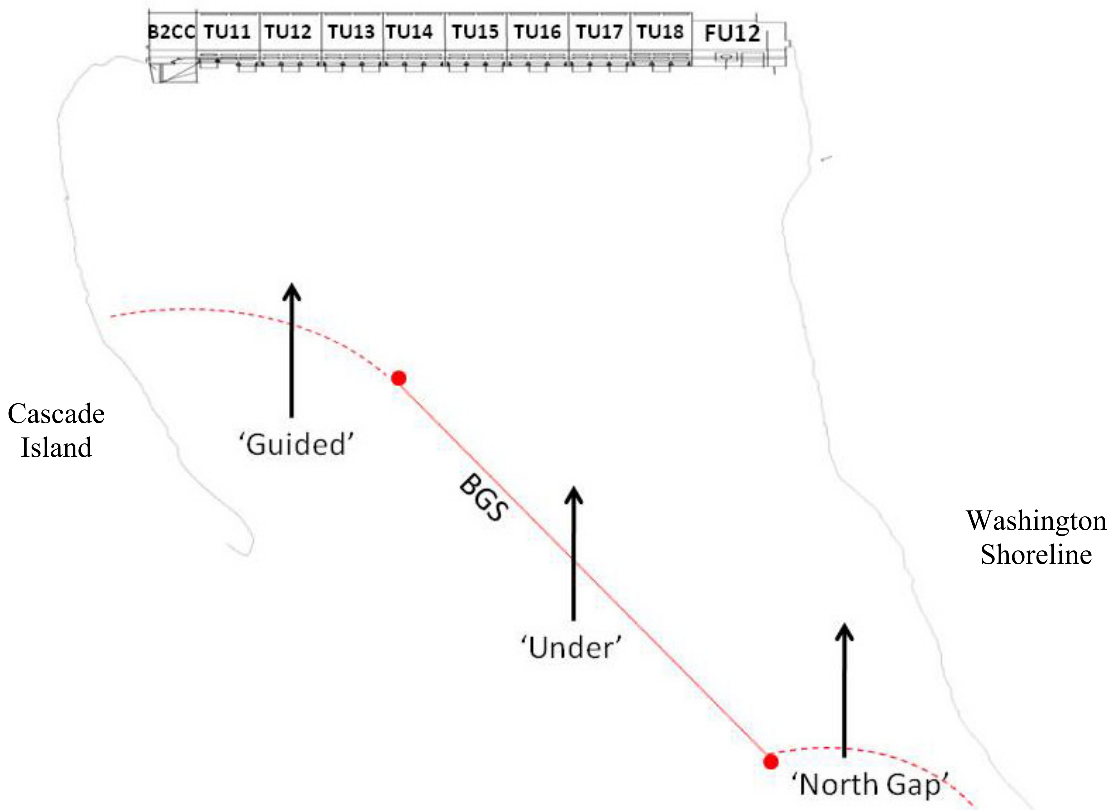


Figure 4.27. Diagram Showing the Approach Classification of Juvenile Salmon and Steelhead that Passed Downstream Through B2. Fish that first passed through the South Gap between the trailing edge of the BGS and Cascade Island were considered Guided. Fish that were first observed passing under the BGS were considered Under, and fish that first passed through the north gap between the leading edge of the BGS and the Washington shoreline were classified as North Gap.

Table 4.16. Tagged Yearling Chinook Passage by Approach and Subsequent Route of Passage. Yearling Chinook in this table were grouped during periods of consistant hydrophone array performance (May 2 to 8, 2008) and do not reflect all yearling Chinook that passed through B2 routes. The fish presented were only those who's aproach route was known.

	Approach					
Unit	North Gap (N)	Under (N)	BGS Guided (N)	North Gap (%)	Under (%)	BGS Guided (%)
B2CC	12	23	80	36%	25%	63%
TU11	0	0	0	0%	0%	0%
TU12	4	0	7	12%	0%	6%
TU13	0	2	5	0%	2%	4%
TU14	2	7	5	6%	8%	4%
TU15	5	20	23	15%	22%	18%
TU16	0	1	1	0%	1%	1%
TU17	4	22	3	12%	24%	2%
TU18	4	15	3	12%	16%	2%
FU2	2	2	0	6%	2%	0%

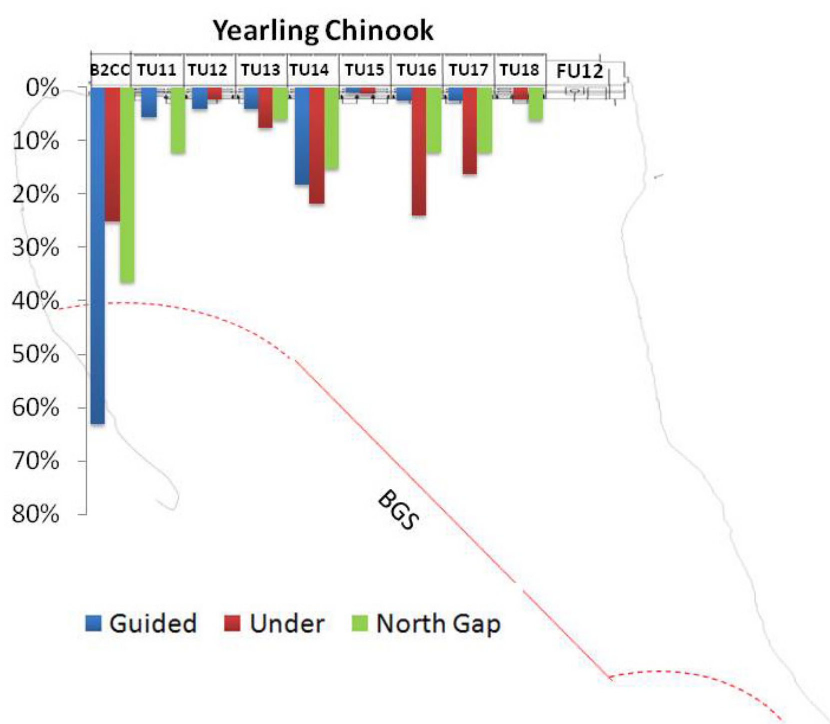


Figure 4.28. Tagged Yearling Chinook Passage by Approach and Subsequent Route of Passage. Fish represented in this figure were grouped during periods of consistant hydrophone array performance (May 2 to 8, 2008) and do not reflect all tagged yearling Chinook that passed through B2 routes.

Table 4.17. Tagged Juvenile Steelhead Passage by Approach and Subsequent Route of Passage. Juvenile steelhead in this table were grouped during periods of consistant hydrophone array performance (May 2 to 8, 2008) and do not reflect all juvenile steelhead that passed through B2 routes. The fish presented were only those who's aproach route was known.

	Approach					
Unit	North Gap (N)	Under (N)	BGS Guided (N)	North Gap (%)	Under (%)	BGS Guided (%)
B2CC	6	27	160	55%	39%	76%
TU11	0	1	1	0%	1%	0%
TU12	0	3	5	0%	4%	2%
TU13	0	0	4	0%	0%	2%
TU14	0	7	12	0%	10%	6%
TU15	1	17	27	9%	25%	13%
TU16	0	0	0	0%	0%	0%
TU17	3	9	1	27%	13%	0%
TU18	1	2	0	9%	3%	0%
FU2	0	3	0	0%	4%	0%

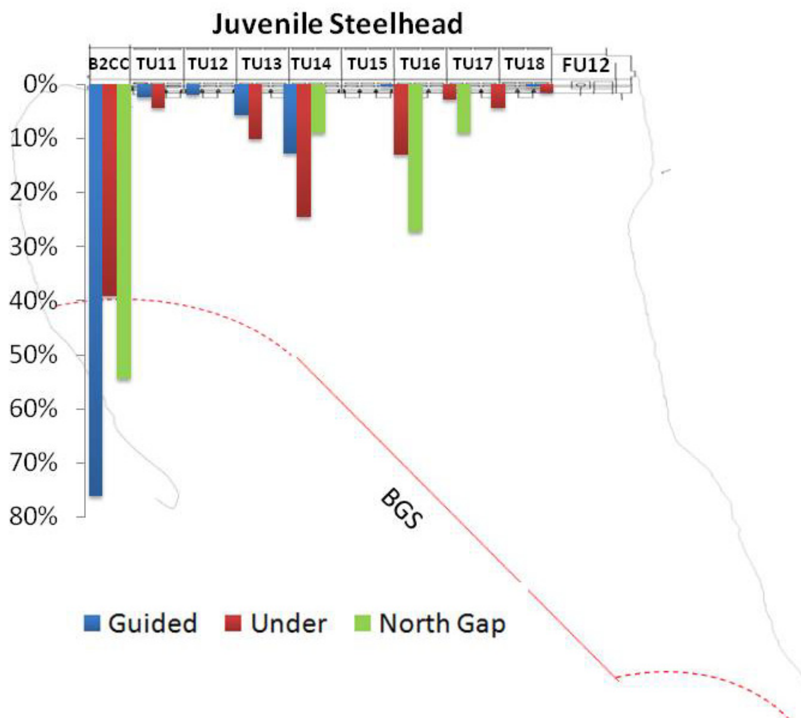


Figure 4.29. Tagged Juvenile Steelhead Passage by Approach and Subsequent Route of Passage. Fish represented in this figure were grouped during periods of consistant hydrophone array performance (May 2 to 8, 2008) and do not reflect all tagged juvenile steelhead that passed through B2 routes.

Table 4.18. Tagged Subyearling Chinook Passage by Approach and Subsequent Route of Passage. Subyearling Chinook in this table were grouped during periods of consistant hydrophone array performance (June 25 to July 17, 2008) and do not reflect all subyearling Chinook that passed through B2 routes. The fish presented were only those who's aproach route was known.

.

	Approach			
Unit	North Gap (n)	BGS Guided (n)	North Gap (%)	BGS Guided (%)
B2CC	193	379	29%	64%
TU11	8	8	1%	1%
TU12	40	45	6%	8%
TU13	41	49	6%	8%
TU14	35	15	5%	3%
TU15	85	30	13%	5%
TU16	126	18	19%	3%
TU17	75	23	11%	4%
TU18	52	24	8%	4%
FU2	44	22	7%	4%

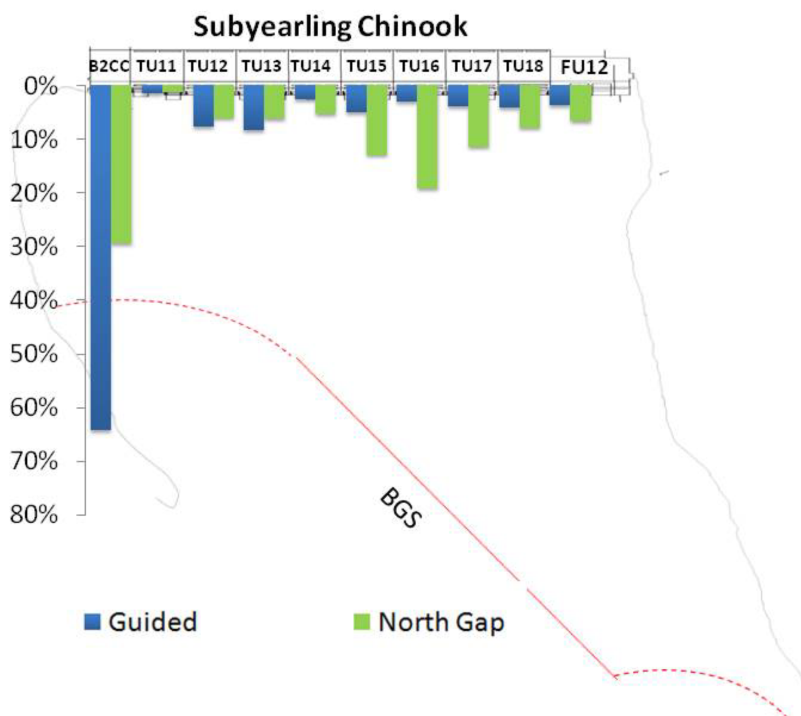


Figure 4.30. Tagged Subyearling Chinook Passage by Approach and Subsequent Route of Passage. Fish represented in this figure were grouped during periods of consistant hydrophone array performance (June 25 to July 17, 2008) and do not reflect all tagged subyearling Chinook that passed through B2 routes.

4.13 Forebay Distribution of Outmigrating Smolts

Figures 4.31 through 4.37 show the relative distribution of tagged smolts as they approached and passed through B2 routes, as derived from their 2D positions.

Figure 4.31. The Minimum 2-Dimensional Tracking Coverage. The coverage was estimated based upon measurements of hydrophone range in the field. The area where hydrophone ranges on three separate hydrophones overlap defined the minimum area that tagged fish could be positioned. The true extent of tracking area could not be thoroughly measured due to access restrictions in the B2 forebay during corner collector operations. The area to the north of the BGS likely had poorer 2D coverage than represented due to a malfunctioning cable to one of the hydrophones monitoring that area. However, fish passage through the North Gap was monitored as presence/absence from the remaining hydrophones.

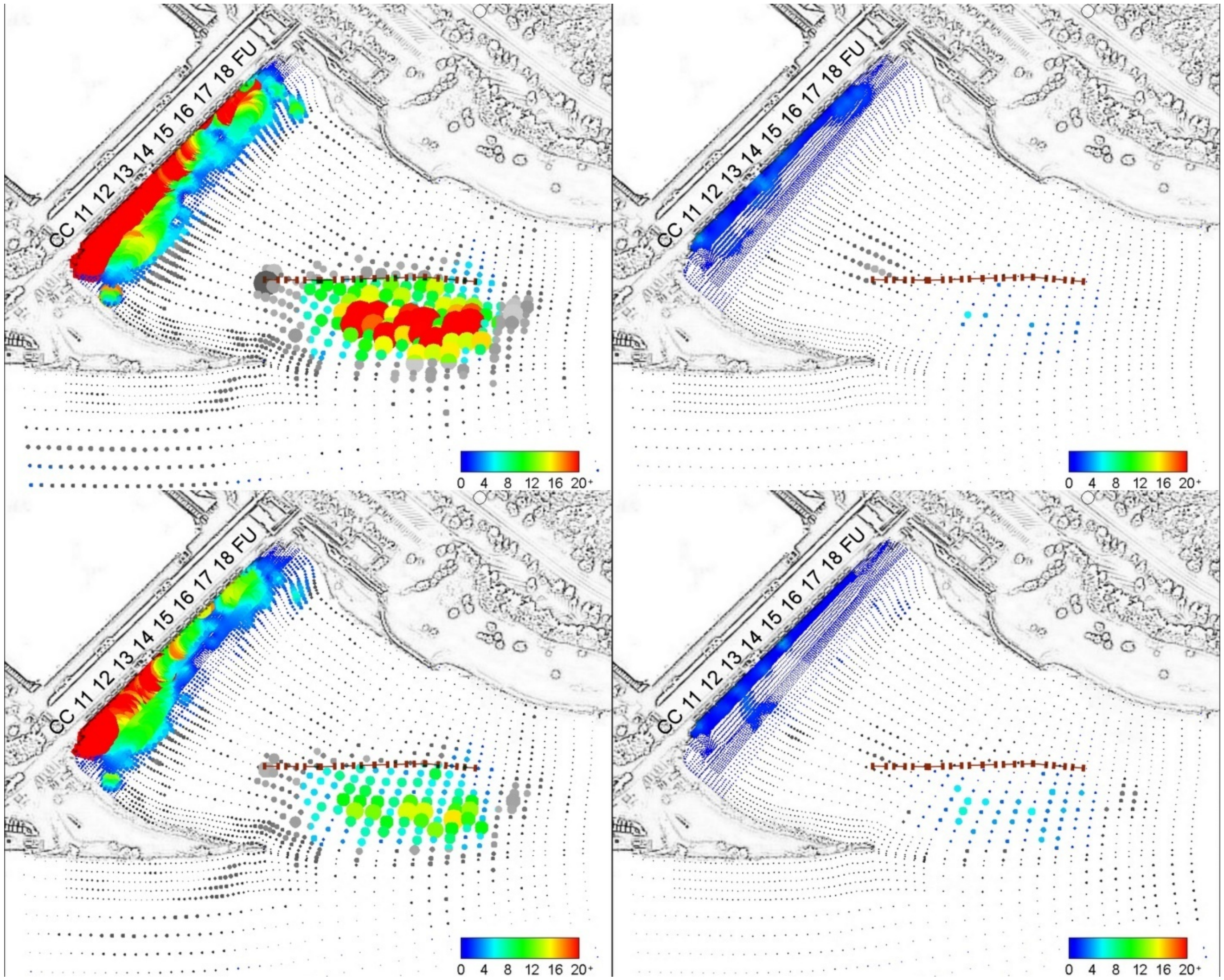


Figure 4.32. Pathways of Juvenile Steelhead that Were Positioned Adjacent to the BGS and B2 Between May 2 and May 8, 2008. Graph displays the distribution of all tracked steelhead (upper left), steelhead that passed through the JBS (upper right), steelhead that passed through the B2CC (lower left), and steelhead that passed through the turbines (lower right). Fish were grouped into 10-m x 10-m bins, whereby individual fish were represented only once if they passed through a bin. Scatter size and color were weighted by the number of fish passing through each bin; 'grey' areas were those that had poor or no coverage for the positioning of fish.

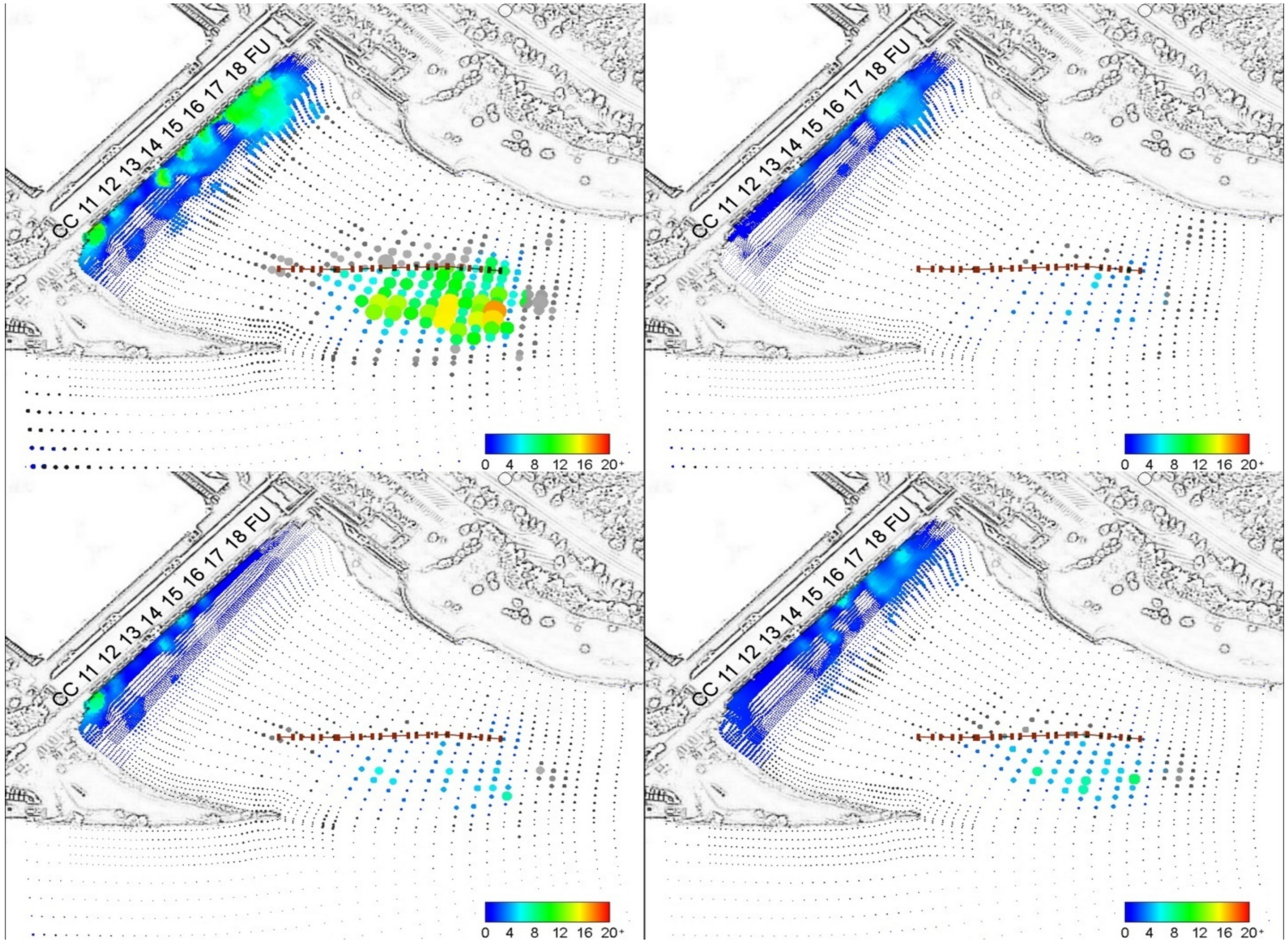


Figure 4.33. Pathways of Yearling Chinook that Were Positioned Adjacent to the BGS and B2 Between May 2 and May 8, 2008. Graph displays the distribution of all tracked yearling Chinook (upper left), yearling Chinook that passed through the JBS (upper right), yearling Chinook that passed through the B2CC (lower left), and yearling Chinook that passed through the turbines (lower right). Fish were grouped into 10-m x 10-m bins, whereby individual fish were represented only once if they passed through a bin. Scatter size and color were weighted by the number of fish passing through each bin; 'grey' areas were those that had poor or no coverage for the positioning of fish.

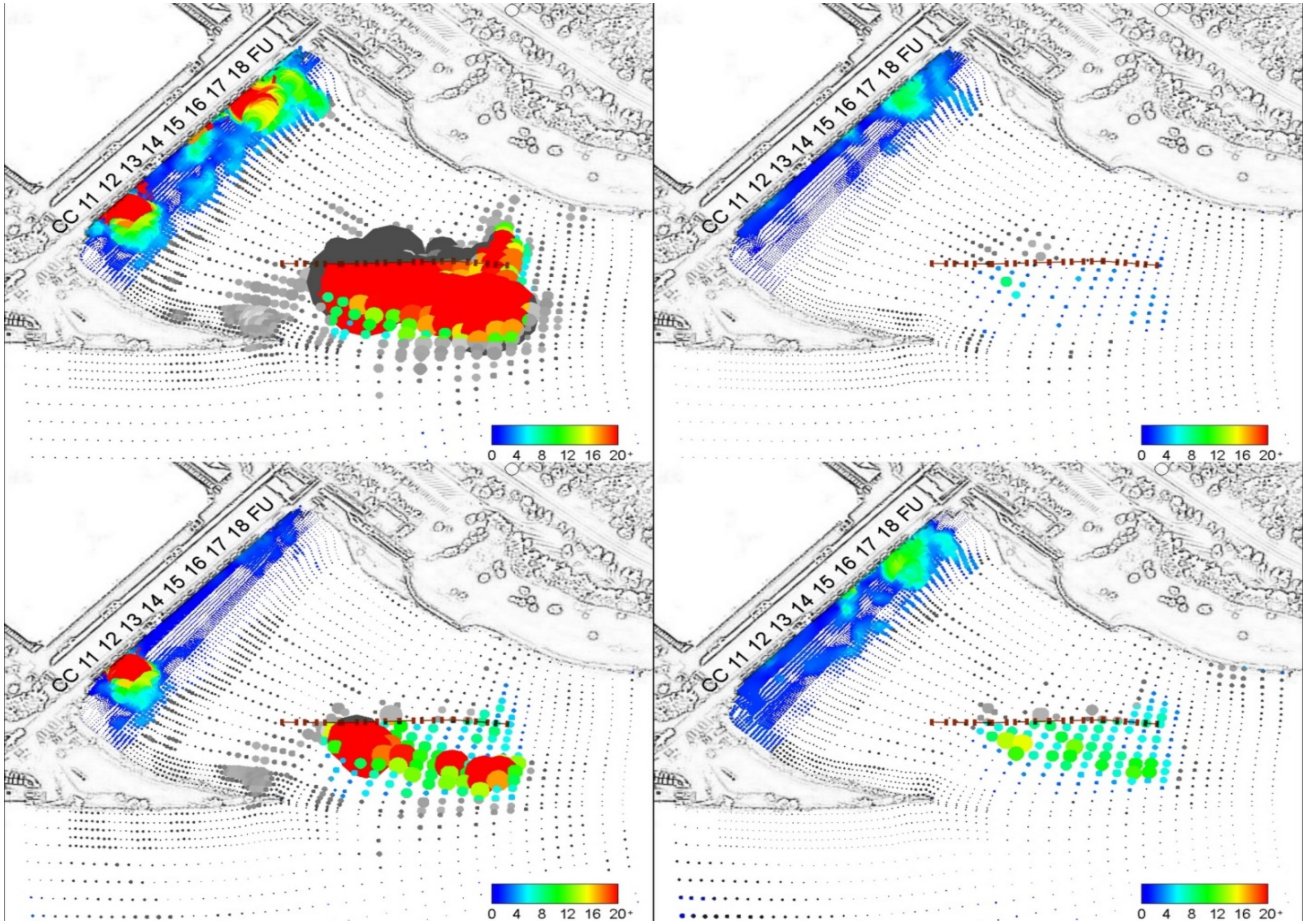


Figure 4.34. Pathways of Subyearling Chinook that Were Positioned Adjacent to the BGS and B2 Between June 25 and July 17, 2008. Graph displays the distribution of all tracked subyearling Chinook (upper left), subyearling Chinook that passed through the JBS (upper right), subyearling Chinook that passed through the B2CC (lower left), and subyearling Chinook that passed through the turbines (lower right). Fish were grouped into 10-m x 10-m bins, whereby individual fish were represented only once if they passed through a bin. Scatter size and color were weighted by the number of fish passing through each bin; 'grey' areas were those that had poor or no coverage for the positioning of fish.

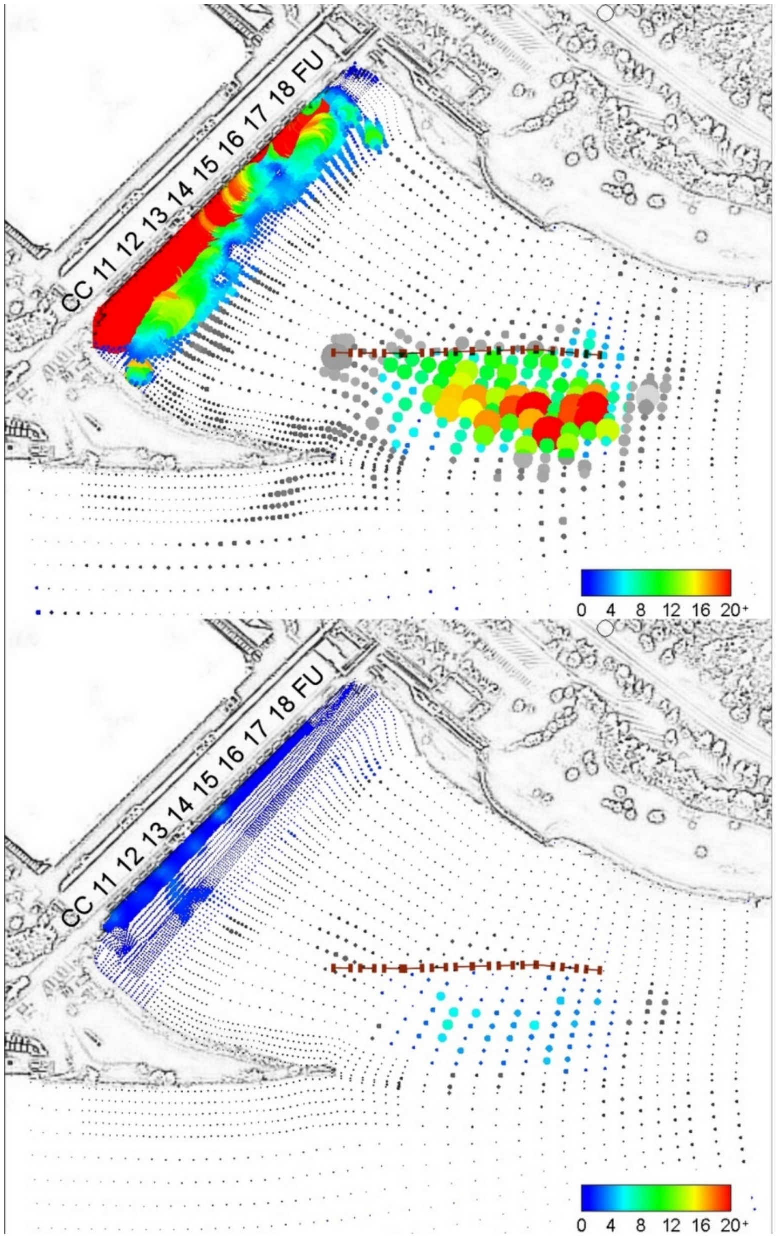


Figure 4.35. Pathways of Juvenile Steelhead that Were Positioned Adjacent to the BGS and B2 Between May 2 and May 8, 2008. Graph displays the distribution of tracked steelhead during daytime (upper) and nighttime (lower). Fish were grouped into 10-m x 10-m bins, whereby individual fish were represented only once if they passed through a bin. Scatter size and color were weighted by the number of fish passing through each bin; 'grey' areas were those that had poor or no coverage for the positioning of fish.

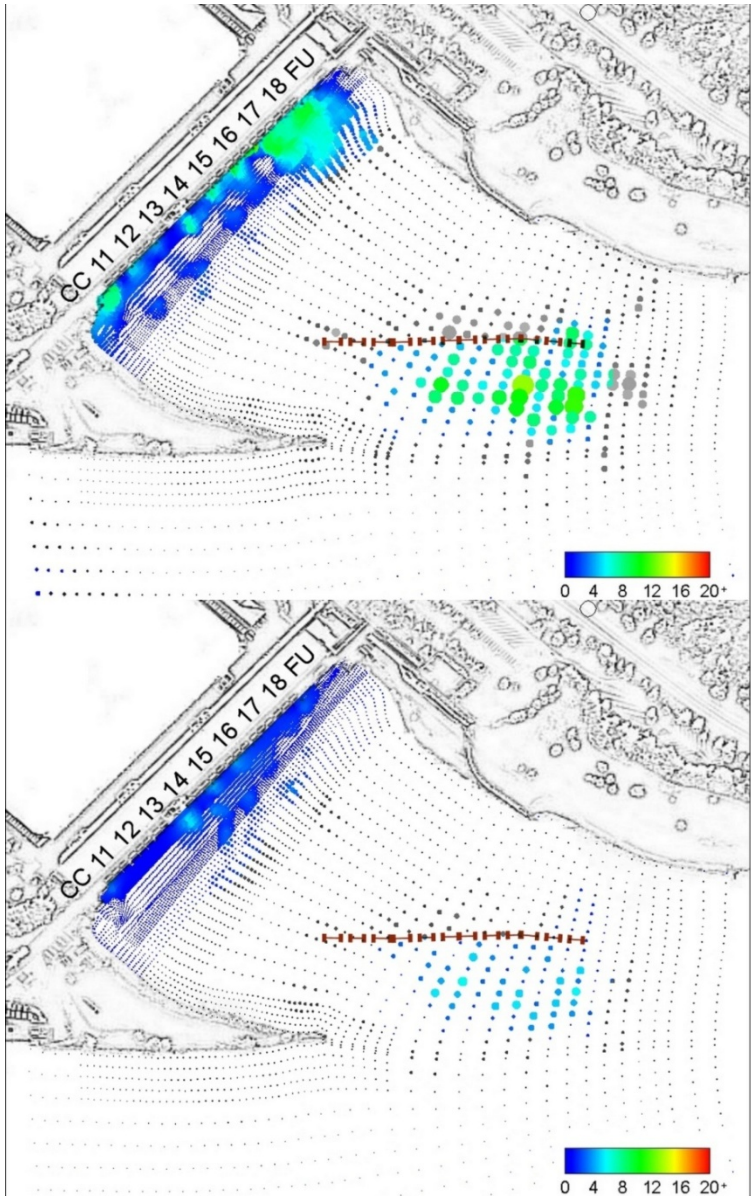


Figure 4.36. Pathways of Yearling Chinook that Were Positioned Adjacent to the BGS and B2 Between May 2 and May 8, 2008. Graph displays the distribution of tracked yearling Chinook during daytime (upper), and nighttime (lower). Fish were grouped into 10-m x 10-m bins, whereby individual fish were represented only once if they passed through a bin. Scatter size and color were weighted by the number of fish passing through each bin; 'grey' areas were those that had poor or no coverage for the positioning of fish.

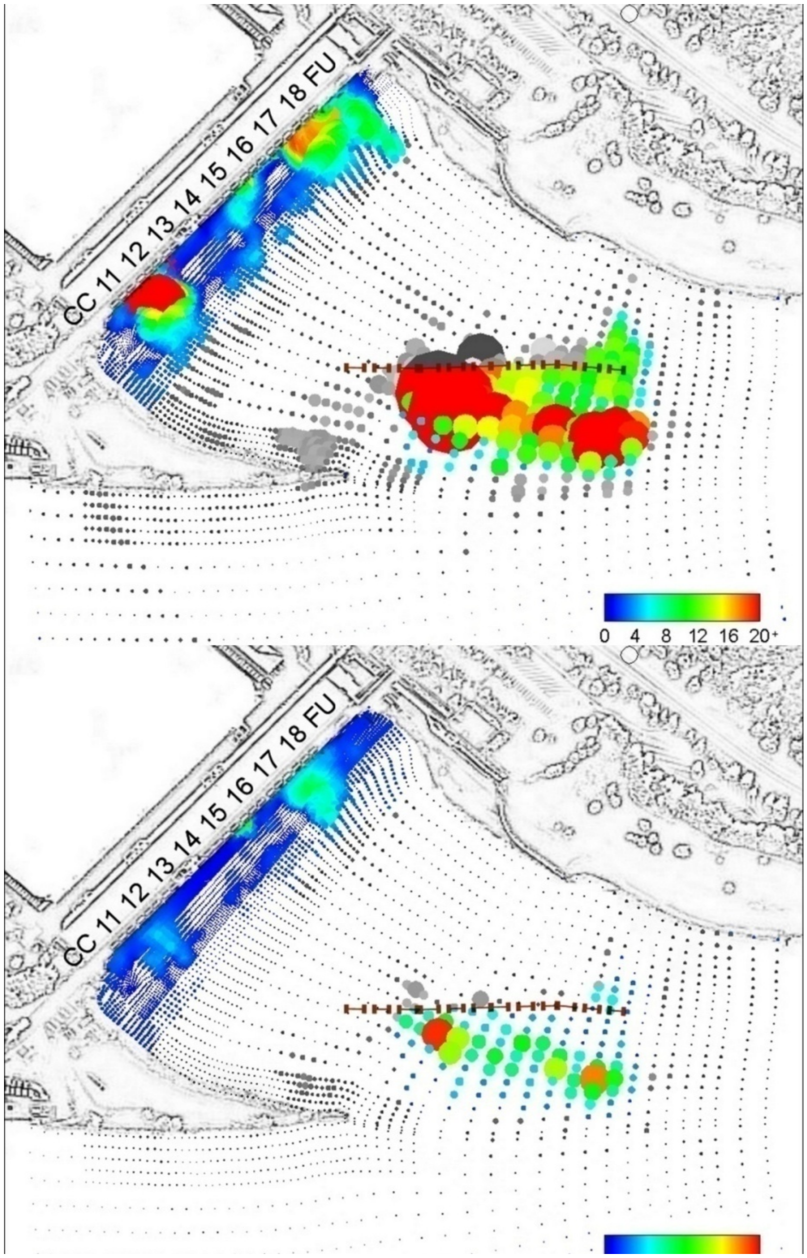


Figure 4.37. Pathways of Subyearling Chinook that Were Positioned Adjacent to the BGS and B2 Between June 25 and July 17, 2008. Graph displays the distribution of tracked subyearling Chinook during daytime (upper) and nighttime (lower). Fish were grouped into 10-m x 10-m bins, whereby individual fish were represented only once if they passed through a bin. Scatter size and color were weighted by the number of fish passing through each bin; 'grey' areas were those that had poor or no coverage for the positioning of fish.

4.14 Data Continuity

Some of the cabled hydrophones malfunctioned during the data collection period, which resulted in gaps in the 2D tracking detection field in spring (Figure 4.38) and summer (Figure 4.39).

Figure 4.38. Data Continuity Chart for All Hydrophones in the Spring. Green indicates data were collected, and black indicates that data were not collected due to a malfunctioning hydrophone or cable break. Listed from top to bottom are hydrophones located on B2 piers, hydrophones monitoring the North Gap and South Gap, hydrophones deployed on buoys upstream of the BGS, and hydrophones located on the upstream and downstream side of BGS. Red boxes indicate the time periods that fish were positioned in two dimensions.

Figure 4.39. Data Continuity Chart for All Hydrophones in the Summer. Green indicates data were collected, and black indicates that data were not collected due to a malfunctioning hydrophone or cable break. Listed from top to bottom are hydrophones located on B2 piers, hydrophones monitoring the North Gap and South Gap, hydrophones deployed on buoys upstream of the BGS, and hydrophones located on the upstream and downstream side of BGS. Red boxes indicate the time periods that fish were positioned in two dimensions.

In most cases, only one hydrophone node was out at a time and accompanying redundant hydrophones were still functional to monitor all routes. However, there was one day in spring (May 4) where three routes were not monitored due to equipment failure. For this day, 2D fish tracking, instead of the last hydrophone detection, was used to assign passage route. In designing deployments, we spaced nodes closely enough to provide some overlap in fields of detection, and this is reflected in the high percentage of multiple-hydrophone detections. Two-dimensional positioning of tagged fish in the vicinity of the BGS was only done when enough hydrophones were functioning with sufficient overlapping detection ranges. This included the time period in spring from May 2 to May 8, 2008, and in summer from June 26 to July 17, 2008. Positioning of tagged fish in the immediate vicinity of B2 was possible for all of the spring and summer sampling periods.

4.15 Historic Survival and Passage Data

The results of survival and passage estimates for 2008 were compared to survival and passage results from research conducted in 2004 and 2005. The U.S. Geological Survey (USGS) conducted back-to-back paired-release survival studies at B2 using radio telemetry in 2004 and 2005, which included dam passage of yearling Chinook, juvenile steelhead ,and subyearling Chinook through the JBS, B2CC, and turbines (Counihan et al. 2006a). Point estimate survivals were similar for yearling Chinook between years and followed similar trends for both yearling and subyearling Chinook. The B2CC had the highest survival rate followed by the JBS and turbines with the lowest survival for all years. There were no significant differences in survival for all routes between-years for yearling Chinook. However, the subyearling Chinook survival rate did show a significant difference between turbine-passed fish when comparing 2004 and 2005 confidence intervals to 2008 survival estimates. The survival rate of radio-telemetry tagged fish passing through turbines in 2004 and 2005 was much lower than the survival rate of JSATS-tagged fish passing through turbines in 2008. It should be mentioned that during the spring and summer outmigration season, flow was about 50% greater during 2008 than in 2004 or 2005 (Figures 4.40 and 4.41).

Passage of fish through the B2CC, JBS, and turbines was also measured for each year (Figures 4.42–4.44). The results for passage between years were very similar for juvenile steelhead and subyearling Chinook; however, yearling Chinook showed some differences. In 2008, the B2CC efficiency was 49% for yearling Chinook released in the lower Columbia River, compared to 35% and 29% B2CC efficiency in 2004 and 2005, respectively (Figure 4.42). Turbine passage percent for yearling Chinook was also lower in 2008 than 2004 or 2005. This shift in efficiency for yearling Chinook likely resulted in greater survival rates, because the B2CC has consistently had the best paired survival estimate when comparing survival among possible B2 routes and the turbine survival rate was lowest between routes for all years.

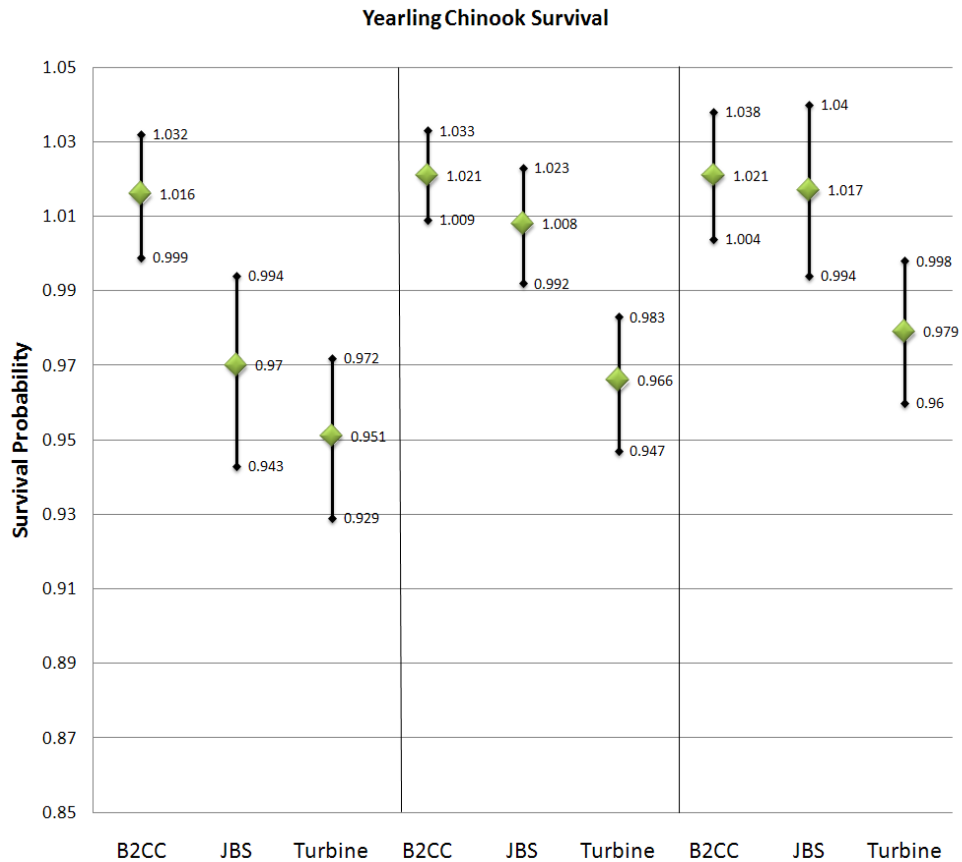


Figure 4.40. Paired-Release Survival Estimates for Yearling Chinook in 2004, 2005, and 2008 by Route of Passage Through B2. Graph shows the survival point estimate (diamond) and standard errors for each point estimate.

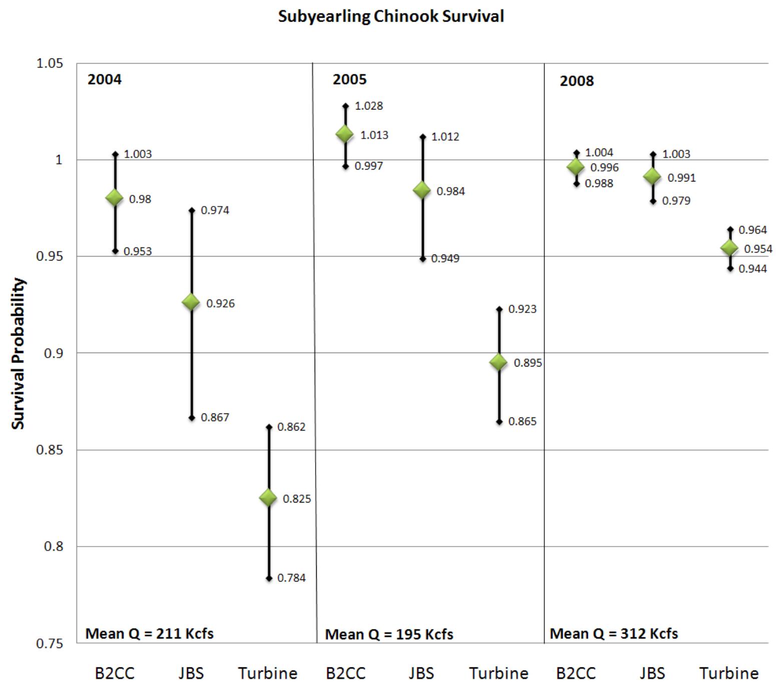


Figure 4.41. Paired Release Survival Estimates for Subyearling Chinook in 2004, 2005, and 2008 by Route of Passage at B2. Graph shows the survival point estimate (diamond) and standard errors for each point estimate.

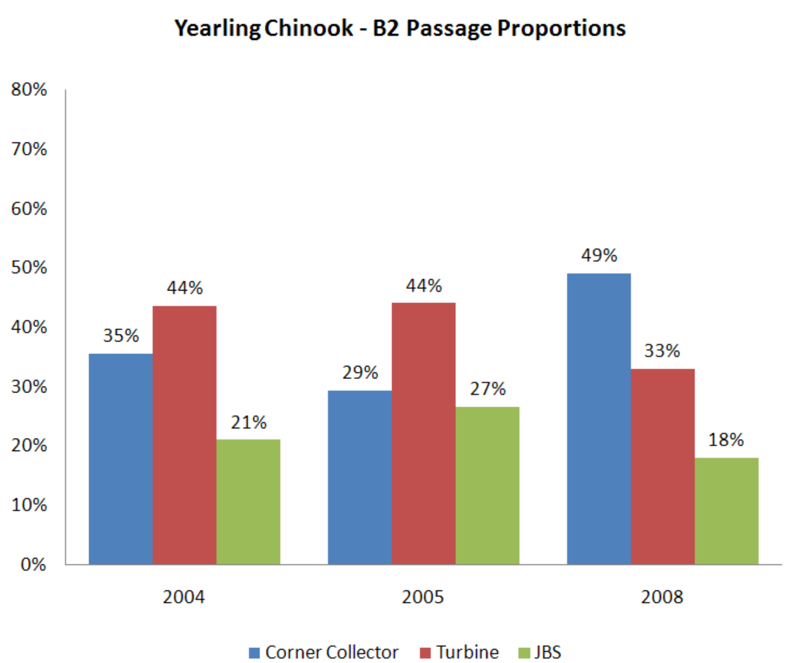


Figure 4.42. Total Proportions of Tagged Yearling Chinook Salmon Passing Through B2 in 2004, 2005, and 2008. Possible routes of passage included through the B2CC, JBS, and turbines. In 2004 and 2005, USGS monitored radio-tagged fish passing through these routes, and in 2008 we monitored the routes using dual JSATS- and PIT-tagged fish.

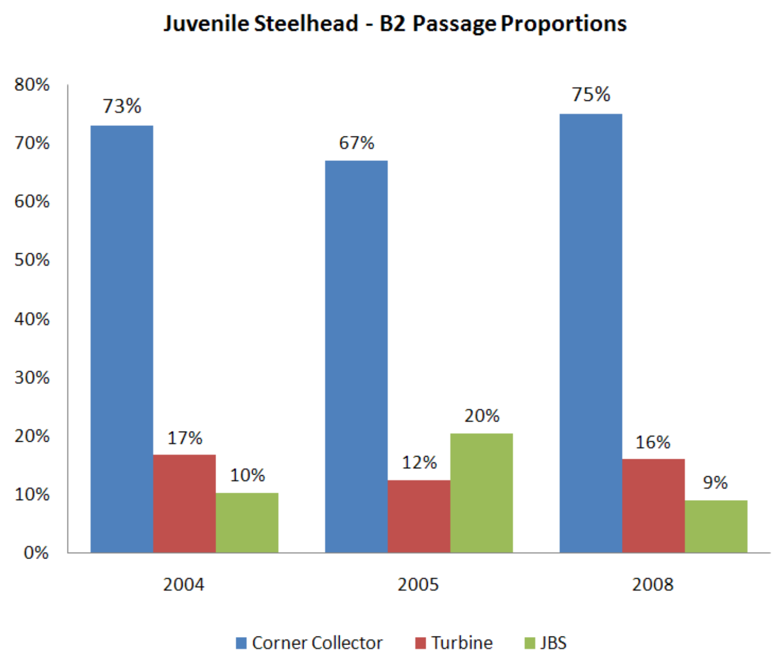


Figure 4.43. Total Proportions of Tagged Juvenile Steelhead Passing Through B2 in 2004, 2005, and 2008. Possible routes of passage included through the B2CC, JBS, and turbines. In 2004 and 2005, USGS monitored radio-tagged fish passing these routes, and in 2008 we monitored the routes using dual JSATS and PIT-tagged fish.

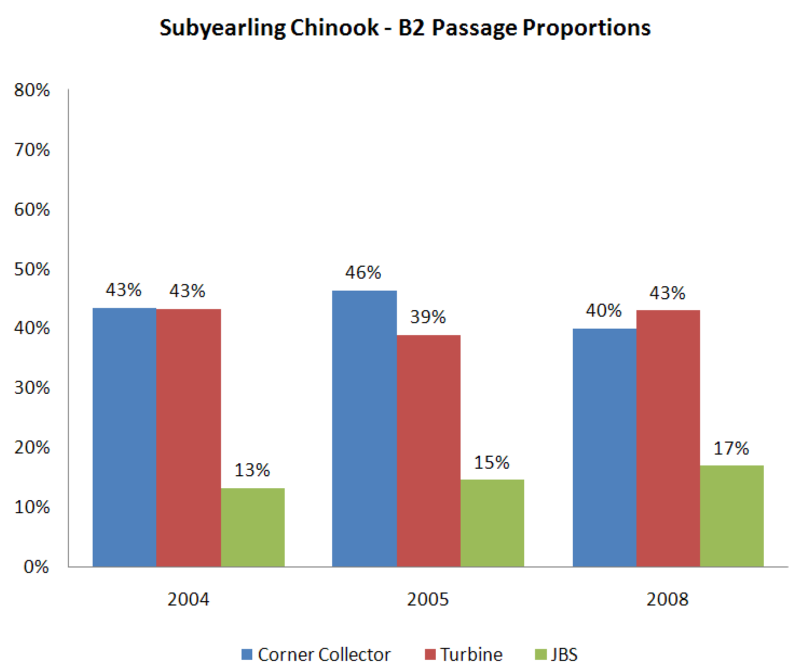


Figure 4.44. Total Proportions of Tagged Subyearling Chinook Salmon Passing Through B2 in 2004, 2005, and 2008. Possible routes of passage included through the B2CC, JBS, and turbines. In 2004 and 2005, USGS monitored radio-tagged fish passing these routes, and in 2008 we monitored the routes using dual JSATS and PIT-tagged fish.

4.16 B2CC PIT-Tag Detector Performance

We evaluated the performance of the PIT-tag detector located in the B2CC based upon the number of dual-tagged (acoustic- and PIT-tagged) fish observed entering the corner collector. Using data from the cabled JSATS deployed in the forebay, we determined that fish entered the corner collector. In the spring, 69% of the fish observed entering the B2CC (788 fish of 1135) were detected by the PIT-tag reader in the corner collector and 70% of the dual-tagged fish were detected in the B2CC by the PIT-tag reader during the summer (521 of 741).

5.0 Discussion

The results described in the previous section are discussed here, including environmental conditions, tests of assumptions, the tag-life study, calculations of survival estimates, and the detection and survival of yearling Chinook and juvenile steelhead in the spring and subyearling Chinook salmon in the summer. Discussion of travel times and rates, passage distribution, outmigrant use of the BGS, data continuity, and the influence of the river environment on survival and passage follows.

5.1 Environmental Conditions

Observations of environmental conditions fall under dam discharge and water temperature relative to 10-year averages and the run timing of smolts.

5.1.1 Project Discharge and Temperature

Project discharge in 2008 was greater than the 10-year average from May10 to July 14. This occurred throughout the majority of our spring and summer release periods (April 30 to May 28 and June 14 to July 12). Water temperatures were also below the 10-year average during our release periods. Observed water temperatures were below critical levels for juvenile Chinook salmon (Brett 1952), but higher water temperatures may increase susceptibility to disease (Tiffin et al. 2000) and be an additional stressor on young Chinook salmon, particularly those that are not well fed (Cobleigh 2003). Cooler water temperatures along with higher flows could be the reason for high survival rates.

5.1.2 Run Timing of Juvenile Salmonids

The spring tagging season ran from April 30 to May 28, 2008 and encompassed the peak of targeted steelhead, which ran from May 11 to May 22 and the majority of yearling Chinook, which ran from May 8 to May 28, 2008. The summer tagging season ran from June 14 to July 12, 2008, and, as in spring, encompassed the peak of the migration of the targeted subyearling Chinook run, which occurred around July 10, 2008. Collection was in conjunction with normal collection at the JDA SMF to reduce the amount of bycatch and handling of in-stream migrants.

5.2 Tests of Assumptions

Testing our assumptions about length frequency and the detection of dead fish by the survival arrays derived a number of observations and recommendations.

5.2.1 Fish Rejection Rates and Length Frequencies during Tagging

A 95-mm minimum length limitation on tagging did not restrict the lengths of fish that could be tagged in the spring, although length frequency distributions of tagged and untagged fish clearly indicate that fish less than 125 mm were not selected for tagging in proportion to their abundance in the run in spring. We suspect that the smallest yearlings were unintentionally sampled less frequently because they were not as visible to collectors as were larger individuals. We recommend placing additional emphasis on finding smaller yearlings to fully represent these length classes in the sample of tagged fish.

The 95-mm minimum length limitation clearly excluded most subyearlings less than 100 mm long in the summer sample (Figure 4.4), and tagging must include 80- to 100-mm subyearlings to be fully representative of the run-of-river population. Only 1% of the subyearling fish tagged were smaller than 100 mm. The 95-mm minimum tagging length effectively eliminated about 8% of the run-of-river subyearlings from the sample because they were too small. Tagging subyearlings 80 mm long will require much smaller tags and reduction in tag weight, according to results of a 2006 tag-effects study.

5.2.2 Detection of Dead Fish by Survival Arrays

The detection of one dead tagged yearling Chinook salmon smolt at the primary, secondary, and Kalama arrays violated the assumption that dead fish could not be detected on the survival arrays downstream of Bonneville Dam. The lack of detection of dead fish on arrays upstream of Bonneville suggest that the river conditions upstream may contribute to rapid assimilation of dead fish into the reservoirs either by settling or by predation. The free-flowing river environment downstream of Bonneville has now shown the possibility that dead fish can occasionally drift freely even for hundreds of kilometers downstream, and in a manner consistent with detection of tagged live fish. However, since 2007 only two such fish have been detected in downstream arrays of the 159 dead fish released in the Bonneville tailrace. This small probability of dead fish detection (0.0126) supports our assumption that that the survival models are performing well at detecting live fish. To better estimate the probability of dead fish detection, particularly downstream of Bonneville Dam, we suggest that more dead fish releases be conducted during future studies. The resulting data will provide input into a modeling framework in an effort to remove any bias associated with dead fish detections.

5.2.3 Tag-Life Study Correction

The tag-life study verified that most tags lasted about as long as expected. The majority of 5-s tags (95%) and 3-s tags (94%) lasted to their expected tag life of 30 and 23 days, respectively. However, over 99% tags implanted in fish for the Lower Columbia River study and 96% of the tags implanted in the fish released from Lower Granite Dam were expected to be operational at the time they were last detected on the Bonneville tertiary survival array (BTW3; the last detection for survival purposes [see Appendix B]). Given the possibility that a tag failure could occur before a tagged fish could reach downstream survival arrays, a tag–life correction procedure was necessary to account for this potential negative bias on survival rates. We used these "tag-life corrected" survival results to summarize the survival of fish passing through all B2 routes.

5.2.4 Assessment of Mixing

We assessed the mixing of fish to addresses the assumption that tagged fish were independent and identically distributed throughout the population as a whole. This assumption would be violated if upstream passage routes of juvenile salmon influenced downstream detections or survival. We showed with Burnham (1987) tests that this was not the case for the great majority of pooled single-release survival estimates. Presumably this was because our acoustic arrays covered the breadth of the river at a sufficient distance downstream so that tagged fish were well mixed and survival was not influenced by upstream detection histories or route. Burnham's Test 2 assessed whether detections at B2 and downstream arrays may have affected downstream capture at the three Bonneville survival arrays. Ten of 150 tests (7%) were significant to the α=0.10 level. This rate of rejection is less than the expected rate of rejection by chance alone, e.g., 10%, further supporting the notion that upstream detections did not affect downstream detections.

Visual inspection of the paired mixing graphs showed consistency in tailrace releases throughout the day and they comported well with virtual releases throughout the study period. In addition to visual inspection, Burnham (1987) Tests 2 and 3 were conducted to examine whether upstream detections affected downstream detections and/or survival rates for paired-release survival estimates. Paired-release models assume that treatment and control release groups pass through the common river reach at about the same time of day and under similar conditions. The results of these tests showed homogeneous capture and/or detection rates and survival for juvenile steelhead and subyearling Chinook (1 of 22 pairs significant α=0.05). However, for yearling Chinook, detection was not homogeneous with regard to capture history for the majority of Test 2 results (three of five pairings). This did not appear to affect survival, because Test 3 was not significant for any yearling Chinook route pairing. For whatever reason, the capture histories were not as homogeneous for yearling Chinook as they were for subyearling Chinook and juvenile steelhead. It is possible that the strong diel component of yearling Chinook passing through the turbines and B2CC may have influenced this outcome, although this hypothesis was not explored. As noted by Counihan et al. (2006a), the utility of these tests to discern whether independence assumptions have been met is limited by the high capture probabilities. Because detection arrays span the entire river channel, the possibility that this assumption could be violated if downstream detections were influenced by upstream passage routes is minimized, and the lack of handling following initial release of fish also minimizes the risk that upstream detections affect survival (Skalski 1998).

5.3 Survival Estimate Calculations

Calculations related to tag-life correction and weighting survival estimates, as described below.

5.3.1 Tag-Life Correction

Downstream arrival times on study arrays had the potential to be affected by tag life. To remove this potential source of bias, a tag-life correction was performed on the survival data. Examination of the tag-life curve and arrival distributions of fish to downstream detection arrays (Appendix B) indicated that the vast majority of fish arrived before the time of the first tag failure. This was especially true for the survival arrays upstream of Bonneville Dam where the probability of tag failure was much less than 1%. However, the arrays furthest downstream of Bonneville may not have received tag signals due to tag failure in greater proportions, especially for the fish released at Lower Granite Dam. The fish released from Lower Granite Dam had an average 4% chance that their tags were inactive at the time they crossed the array. In contrast, the probability of tag failure for Arlington-released fish was much smaller (<1%), nevertheless necessitating a correction for all tagged fish used for survival estimates. We only reported survival estimates that had a tag-life correction applied, and followed methods described by Townsend et al. (2006).

5.3.2 Weighting Survival Estimates

All summary paired- and triple-release survival estimates were pooled and then weighted by the number of fish in each pooling. This was necessary because capture histories were not homogeneous and some variance estimates approached zero for pooled estimates, which overly weights high survival estimates. For every route at B2 a chi-square goodness-of-fit test was significant ($\alpha = 0.05$) when testing for homogeneity in pooled survival estimates. We therefore exclusively reported the N-weighted mean for survival of fish passing through B2 routes.

Potential biases are associated with reporting the N-weighted mean if releases do not follow similar patterns as the run at large. These estimates can exclude or amplify seasonal differences in mortality if release groups are grouped disproportionately to the density of fish in the river at the time of release. Our release strategy was to release equal proportions of fish throughout the 10-year average of smolt outmigration to address this issue. However, the early and late releases may have influenced the final survival estimate by weighting the early and late runs equally to the peak of the run. For yearling Chinook and juvenile steelhead, use of the N-weighting method was not likely to influence the survival estimate for the population, because there were no evident seasonal trends (Figures 4.8 and 4.9). However, subyearling Chinook survival estimates were likely negatively biased when using this method, because survival declined prior to and past the peak outmigration but releases of fish remained equal (Figures 4.10 and 4.3). Compensating for this bias in the experimental design would be difficult *a priori* because of the variability in run timing. The negative bias associated with this method is in the favor of fish conservation.

5.4 Detection and Survival of Yearling Chinook Salmon in Spring

Spring detection and survival of all yearling Chinook release groups along with and Bonneville route-specific survivals of fish passing through the dam and tests of assumptions are discussed below.

5.4.1 Lower Granite Release Group

Survival estimates were generated for yearling Chinook salmon released in the Lower Granite tailrace as a part of a separate study. These fish were regrouped passing through Bonneville Dam, and their survival was estimated passing through the dam as a whole. Individual routes through B2 were not evaluated for this group, because fish were removed at the JBS and this removal would negatively bias survival estimates due to the number of B2 fish passing through the JBS in comparison to total B2 passage. However, whole dam survival was estimated from the forebay entrance array 2 km upstream through the dam and into the tailrace. The proportion of fish passing into the JBS (therefore removed) is much lower in comparison to the two combined powerhouses and spillway. Despite the negative bias associated with removing JBS fish from the virtual releases at Bonneville Dam, the Lower Granite yearling Chinook survival was not significantly different than the survival of yearling Chinook released in the Lower Columbia River. Fish released at Lower Granite had paired-release survival estimates of 99.8% (95% CI = 104.3, 96.3), and those released in the Lower Columbia River passing through Bonneville Dam had a survival estimate of 100% (95% CI = 102.5, 97.5).

5.4.2 Lower Columbia Release Group

The majority of route-specific B2 survival estimates were generated using fish released in the Lower Columbia River at or downstream of Arlington, Oregon (rkm 390), as a part of joint studies that were evaluating Bonneville spillway survival and survival of juvenile salmon passing through John Day and The Dalles dams, all funded by the USACE-Portland District. Fish released as a part of these studies were tracked into the B2 forebay, where virtual release groups were generated at an array 2 km upstream of Bonneville Dam (rkm 237) and at a B2 dam face array where we monitored fish passing through the BGS, and entering the B2CC, the turbines, or the JBS.

5.4.3 Bonneville Tailrace and B2CC-Specific Releases

Tailrace releases below Bonneville Dam were used as controls for B2 survival estimates, including route-specific survival for fish passing through the turbines, B2CC, and JBS at B2. An additional control release into the B2CC for yearling Chinook allowed for the compensation of any post-release handling effect of tagging that may have expressed itself after the tailrace control release. We found no evidence of post-handling mortality of control fish when we compared paired- and triple-release survival estimates for yearling Chinook. These estimates did not differ significantly, as evidenced by overlapping 95% confidence limits (paired-release estimate 100.5%, 95% CI = 104.5, 97.5, and triple-release estimate 99.4%, 95% CI = 102.4, 96.4).

5.4.4 Bonneville Project Passage Survivals

The passage survival estimate for Bonneville Dam using the forebay array for a virtual release and Bonneville tailrace fish as control fish was 100.0% (95% CI =102.5, 97.5). This estimate was significantly (4.9% higher) than a Bonneville project survival estimate of 95.1% (95% CI =96.4, 93.8) for 2004 by Counihan et al. (2006a) and similar to a Bonneville project estimate of 96.7% (95% CI = 99.3, 94.1) for 2005 (Counihan et al. 2006b). Cooler spring water temperatures and high flows likely contributed to the high survivals observed at Bonneville Dam in 2008, in comparison to the 2004 results. Also, the increased passage through the corner collector would benefit the survival of yearling Chinook because the corner collector has consistently proven to be the most benign route of passage at the dam.

5.4.5 Tests of Assumptions

Significant events were associated with three of the nine assumptions that were addressed with regard to yearling Chinook salmon passing through B2. Assumptions 1, 7, and 8 (defined in Section 2.8.1.1.1) focused upon population representation, dead fish detections, and mixing, respectively. There were deviations from adherence to these assumptions after analyzing the data.

In spite of intended random sampling of yearling Chinook >95 mm, the yearlings from 100 to 125 mm in length were not tagged in proportion to their relative abundance in the run at large. On average, the yearling Chinook tagged were on the order 5 to 10 mm larger than the bulk of the run. This was likely due to the larger fish being more visible at the SMF and being sampled in greater proportions. It is recommended that for future studies that the smaller fish be sought out so the sample is more representative.

One known-dead yearling Chinook was also detected at two survival arrays downstream of Bonneville Dam that were used to calculate dam survival at Bonneville (rkm 202 and rkm 193). This detection violated the assumption that dead fish could not be detected on downstream arrays. However, during the last 3 years of telemetry studies, only 2 of 159 dead fish released downstream of Bonneville Dam have been detected at these three arrays. This gives a detection probability (D) of 0.0126. It is likely that flow conditions downstream of Bonneville contribute to the rapid transport of some fish, even when dead, sometimes hundreds of kilometers downstream. To account for such events, it is recommended that more dead fish be released downstream of Bonneville so that an accurate probability can be calculated for inclusion in survival models.

The final assumption that showed a deviation from the model parameter was that of mixing. The paired-release model for yearling Chinook tested significant ($\alpha = 0.05$) for the majority of pooled results when examining the homogeneity of capture at downstream arrays. We attempted to properly mix fish with our experimental design by examining past travel times to the dam from upstream locations, and releasing control fish at these expected time intervals. However, it is likely that the strong diel component of yearling Chinook percentage confounded these efforts, thereby affecting the mixing assumptions of the model when yearling Chinook were passing through B2. Nevertheless, survival was not significantly affected. In addition, survival processes were stable throughout the spring season so significant mixing deviations are not of great concern.

All other assumptions were not violated and showed adherence to the model structure, for single-, paired-, and triple-release models with respect to yearling Chinook survival estimates.

5.4.6 Bonneville Route-Specific Survival

Regrouping fish as they passed through B2, the B2 JBS, B2 turbines, and the B2CC was accomplished to calculate route-specific survival for all yearling Chinook released in the Lower Columbia River.

We could not distinguish between the survival rates of yearling Chinook passing through the B2 JBS, the B2 turbines, or the B2CC for single-, paired-, or triple-release survival estimates because of overlapping 95% confidence intervals. All survival estimates were high, giving point estimates near 100% survival of fish passing through the B2CC and B2 JBS. Turbine survival was consistently lower and around 97% (paired 97.9%, 95% CL = 94.2, 101.6, triple 96.9%, 95%CL= 92.7, 101.1). The patterns of survival of fish passing through those routes were consistent with prior survival studies at B2 (Counihan 2006a, 2006b). There was no significant difference between radio telemetry results from 2004 and 2005 studies and those from acoustic-telemetry in 2008 for any route through B2 given the overlapping 95% CI. Again, the pattern of point estimate survival was identical with the B2CC consistently showing the highest survival, followed by the JBS and B2 turbines. The 3 years of survival studies for yearling Chinook passing through B2 showed consistently high survival rates that would meet today's BiOp standard of 96% survival.

5.5 Detection and Survival of Juvenile Steelhead in Spring

We did not conduct control releases for juvenile steelhead into the tailrace, or into the B2CC, so single-release survival probabilities were only generated for this run of fish. These estimates incorporated tailrace survival of fish passing through downstream routes and are almost always lower than paired-release estimates. This is particularly true at Bonneville Dam due to extended tailrace distance between survival arrays. Spring steelhead passage survivals at Bonneville Dam along with route-specific survivals of fish passing through the dam and tests of assumptions are discussed below.

5.5.1 Bonneville Project Passage Survivals

The Bonneville Dam passage single-release survival estimate that includes tailrace survival was 97.2% (95% CL = 96.2, 98.2) for juvenile steelhead. The most recent survival estimates for steelhead were paired-release estimates in 2004 and 2005. These estimated survival of fish passing through the dam at 99.1% and 96.3%, respectively. These estimates are consistent with 2008 results using acoustic telemetry. The reach survival of juvenile steelhead between the primary and secondary downstream survival arrays was 95.9% (95%CL = 92.7, 99.3). When using the B2CC as a surrogate paired release (because of its consistently high survival), the relative survival of juvenile steelhead passing through Bonneville Dam would be near 99%. Overall, dam passage survival for juvenile steelhead at Bonneville Dam was high in 2008.

5.5.2 Bonneville Route-Specific Survival

Virtual releases of fish as they passed through B2, the B2 JBS, the B2 turbines, and the B2CC were used to estimate single-release survival estimates for these routes. We could not distinguish between survival estimates for these routes, or for any route combined or otherwise for fish passing through B2. All single-release survivals were near 98% (B2CC 98.4%, JBS 98.4%, turbines 98.2%, B2 98.2%; see Table 4.59). The high survival of juvenile steelhead passing through B2 was strongly influenced by the large passage proportion of fish going through the B2CC (70–80%). The prolific use of this benign passage route could only benefit juvenile steelhead as they navigated through B2, minimizing dam-induced mortality.

5.5.3 Tests of Assumptions

Only assumption 1 could be questioned with regard to juvenile steelhead; it addresses the representation of the population by the tagged sample. As was the case with yearling Chinook, juvenile steelheads that were tagged were slightly larger than the population of inference. This under-represented the smaller fish in the population and could have influenced survival estimates if mortality caused by passing through dams was influenced by the size of fish. Nevertheless, survival estimates for Bonneville Dam and all routes passing through B2 were consistent with past estimates (Counihan 2006a, 2006b), and evidence of any effect on survival was not evident. All other assumptions were satisfactorily addressed for the single-release estimates of juvenile steelhead survival past Bonneville Dam.

5.6 Detection and Survival of Subyearling Chinook in Summer

Summer Bonneville Dam passage survivals of subyearling Chinook salmon along with Bonneville route-specific survivals of fish passing through the dam and tests of assumptions are discussed below.

5.6.1 Bonneville Project Passage Survivals

The Bonneville Dam passage survival estimate using the forebay array for a virtual release and Bonneville tailrace as control fish was 97% (95% CL= 95.6, 98.4). This estimate was significantly higher than the 2004 estimate of 89.1% (95% CL= 87.1, 91.1), and similar to the 2005 estimate of 93.8% (95%CL = 91.1, 96.5). The 2008 estimate would have passed survival criteria outlined in the NOAA Fisheries BiOp (2008). The cooler-than-average water temperatures in addition to higher flows (mean Q = 312kcfs) may have contributed to this elevated survival estimate for subyearling Chinook, in comparison to the lower flow year in 2004 (Q=211kcfs) and 2005 (Q=195kcfs).

5.6.2 Bonneville Route-Specific Survival

Virtual releases of fish passing through B2, the B2 JBS, B2 turbines, and B2CC were evaluated using simple-, paired-, and triple-release models. Route-specific survival differences were only observed when comparing the 95% CL of B2CC and the B2 turbines for single- and paired-release survival estimates. All other combinations were not significantly different. However, the point estimate of survival followed consistent patterns as observed in spring fish as well as for prior years' results. As in these cases, the highest survival rate was for fish passing through the B2CC, followed by those passing through the B2 JBS, with turbine routes consistently showing the lowest survival estimates.

When comparing paired-and triple-release survival estimates, there was no significant difference between estimates using the two methods. This was consistent with paired-and triple-release combinations for yearling Chinook, which suggests no post-handling mortality. In fact, for subyearling Chinook the triple-release estimate was calculated higher (Table 1.3), presumably due to higher survival of B2CC control fish in the downstream reaches compared to the virtual release fish.

5.6.3 Tests of Assumptions

Only assumption 1 deviated from model requirements; it assumes that the tagged simple is representative of the run at large. The fish tagged were on average larger than the run at large. This was mainly due to limits on the minimum size of fish that could be tagged without significantly affecting behavior or survival of the individual with the current acoustic-telemetry tag size of 0.43g. The length of fish that can be tagged must exceed 95 mm. Approximately 5% (Figure 4.4) of the run at large were less than 95 mm. Using this criterion, our sample was an average 5 mm larger than the outmigrating population of subyearling Chinook. There were no other significant departures from model assumptions regarding subyearling Chinook salmon survival estimates.

5.7 Travel Time and Rate

Travel times and rates were calculated for all fish released from Lower Granite, John Day forebay, John Day tailrace, and The Dalles and Bonneville tailraces, as well as for virtual releases at Bonneville and The Dalles dams. These results are published in a separate report by Ploskey et al. (2009).

5.8 Passage Distribution

The passage distribution of fish was noticeably influenced by the BGS showing peaks in distribution near the center of the powerhouse and at the B2CC. The flow conditions created by the BGS likely contributed to the observed passage distributions, especially when comparing passage at the dam to previous radio-telemetry and hydroacoustic studies (Ploskey 2007a). Those studies showed a strong southerly preference for passage highly skewed toward turbine units 11–12 at the peak, with the tail of the distribution extending toward unit 18. This was not the case in 2008, where all species showed bimodal distribution for B2 passage, one mode near the B2CC and the other near unit 15. This pattern was noticeably similar to the surface flow conditions trailing the BGS into the powerhouse.

An additional factor that influenced B2 passage was that several unit outages occurred during the spring and summer study periods. Turbine unit 15 was offline during all of the spring study period, and turbine unit 11 was offline during the summer study period. The B2CC passage in 2008 was compared to passage percentages for 2004 and 2005 to look for improvement in the B2CC efficiency, because the ultimate goal of the BGS was to increase B2CC efficiency. This comparison only showed an improvement for yearling Chinook of about 10%. However, steelhead passage at the B2CC was exceedingly high for all years and between 70%–75%, gains from which would be difficult detect. The subyearling Chinook passage percentage was similar for all years. However, turbine unit 11 was operational for 2004 and 2005 (Reagan 2006), and was not in 2008. Because of the proximity of turbine unit 11 to the B2CC, it is likely that the loss of this source of attracting flow influenced the overall passage percentage in 2008 for subyearling Chinook, which may have been lower as a result of this outage. The effect of the BGS on fish passage at increasing the B2CC efficiency should be investigated with all turbine units operational to assess whether the design criteria were met for the BGS.

5.8.1 Yearling Chinook

Yearling Chinook showed a preference for passing through the B2CC, which was successful at passing 49% of the yearling Chinook through B2. The yearling Chinook salmon passage distribution rate was 33% through the turbines and 18% through the JBS. There was strong diel component to passage distribution, which showed that yearling Chinook strongly preferred the B2CC during daylight hours, and during nighttime their passage distribution shifted to favor turbine passage. This is consistent with prior research on surface bypass (Faber 2000; Cash 2004) near powerhouses, where there is more directed movement with the flow during nighttime, but during daytime hours fish are less likely to sound and pass through turbines. Passage timing also had a strong diel component, whereby yearling Chinook passed through the B2CC primarily during the waxing and waning of sunlight, and turbine passage peaked at 2 a.m. This did not comport with their arrival time in the forebay, which showed no distinct peaks for all hours. This suggests that yearling Chinook were delaying in the forebay before finally passing through the dam during one of the observed peaks. The B2CC had very high collection effectiveness—eleven times as many yearling Chinook entered the B2CC proportional to the flow passing through the entire B2. This boosted FPE for yearling Chinook at B2 to 67%, which was an improvement from the radio-telemetry studies conducted in 2004 and 2005 that showed the FPE was 56% and 56%, and B2CC collection efficiency at 35% and 29% for 2004 and 2005, respectively.

5.8.2 Juvenile Steelhead

Juvenile steelhead strongly preferred the B2CC over any other route of passage. In fact, survival estimates for steelhead passing through turbines had larger standard errors because so few tagged steelhead chose turbines as a route of passage at B2. In total, 75% of tagged steelhead passed through the B2CC, followed by 9% through the JBS and 16% through the turbines. Passage distribution also had a strong diel component with the majority of fish passing through during the day and peaking just the hours before sunset. Similar to yearling Chinook, juvenile steelhead preferred the B2CC in greater proportions (80%) during daylight hours than during nighttime hours (60%). However, FGE was better for yearling Chinook during nighttime than for juvenile steelhead at night. FPE for juvenile steelhead was exceedingly high, with 84% of fish traveling through fish-specific passage routes, mostly due to the large proportion of fish passing the B2CC. These passage estimates are comparable to 2004 and 2005 radio-telemetry results, which showed 73% and 67% B2CC passage, and FPE was 83% and 87% respectively.

5.8.3 Subyearling Chinook

A large proportion of subyearling Chinook passed through the B2CC, but they passed in smaller proportions than the yearling Chinook and juvenile steelhead. Approximately 40% of the total number of subyearling Chinook passed through the B2CC compared to 43% passing through turbines and 18% through the JBS. However, the lesser passage proportion could have been due to a major operational difference that existed in the summer compared to the spring. Turbine unit 11 was not operational for the entire summer season, but was operational in spring. The hydraulic conditions of the forebay were clearly different because of this outage. For instance, the higher velocity flow that trails the downstream tip of the BGS would typically intersect the powerhouse at unit 12, but with turbine unit 11 offline, this flow was shifted toward unit 14. The different forebay hydraulic conditions likely had an impact on the passage distribution of subyearling Chinook salmon, especially for those entering the B2CC. Notwithstanding hydraulic differences, the B2CC passage efficiency and FPE were comparable to the radio-telemetry results in 2004 and 2005 when turbine unit 11 was operational. For instance, the FPE in 2004 and 2005 was 56% and 61%, which compares well with the 2008 FPE of subyearling Chinook at 57%. Similarly, the B2CC passage efficiency was 43% and 46% in 2004 and 2005, compared to 40% in 2008. The diel pattern of subyearling Chinook passing through B2 was close to that of yearling Chinook salmon. There were peaks in passage just after sunrise and just prior to sunset at the B2CC, and nighttime peak in turbine passage at 2 a.m. Subyearling Chinook passage was not coincident with their arrival distribution on the forebay array, which suggests a delay in the forebay.

5.9 Outmigrant Use of the BGS

In the spring and summer of 2008, smolts that passed through the South Gap between the BGS and Cascade Island entered the B2CC in much greater proportions than fish traveling under the BGS or passing through the North Gap. Presumably, this was due to a much better discovery efficiency of the B2CC opening for South Gap fish compared to the fish passing through the North Gap or fish passing under the BGS. Unfortunately, due to equipment failures, high flow events, and GPS hardware issues, we were unable to position fish upstream of the BGS for the much of spring and summer outmigration periods. However, from May 1 to May 8 in spring period and June 26 to July 17 in summer period, the majority of hydrophones located upstream of the BGS were functional and allowed the 2D positioning of tagged smolts for a subset of the study. We were able to 2D-position many fish upstream of the BGS although the resolution of fish positions was somewhat poor. The positions were therefore aggregated to the nearest 10-m grid position for the examination of trends in the data.

When examining distributions of fish relative to the BGS position, it was evident that the majority of smolts were intersecting the BGS proportional to the distribution of water velocity in the thalweg, and in the center-left of the BGS. This was particularly true during the springtime where the peak distribution of fish was skewed toward the center of the river and toward the southern gap but away from the North Gap (Figures 4.32 and 4.33). This was also reflected in the relative passage distribution of fish moving passed through the BGS, where we observed very few fish passing through the North Gap in the springtime.

The forebay distribution of fish changed from spring to summer. There were evidently more fish traveling just inside the upstream North Gap (Figure 4.37). The distribution in the direction of the North Gap was likely more skewed than is represented in the figure, because an influential third hydrophone (B6, Table 2.5) located inside the North Gap was not functional. Tag receptions at this hydrophone in addition to tag receptions at the two shoreline hydrophones would have provided additional positions for fish near the Washington shore. Unfortunately, this hydrophone was not operating for much of the sample period (Figures 4.38 and 4.39). As a surrogate to 2D-positions, we used the last detection at deployed hydrophones to determine fish route (similar to radio-telemetry methods), where we found that a greater proportion of fish passed through the North Gap than was evident from the 2D tracks.

Smolts passing the through the South Gap, under the BGS or through the North Gap were used to define passage proportions at the dam (Figures 4.28–4.30). The percent of fish passing through the B2CC relative to the rest of B2 was always greater for fish navigating through the south gap than for fish passing under the BGS or through the North Gap, most probably because the B2CC was located on the south side of the powerhouse and more accessible to those fish. Similarly, fish passing through the north gap tended to pass through B2 in greater proportions through turbine units to the north of the powerhouse. This was especially evident when examining subyearling Chinook distribution at the dam. Fish that navigated under the BGS during springtime passed through the B2CC in similar proportions to the turbine units. The deep distribution of these fish could prevent the discovery of the relatively shallow corner collector entrance; whereas the turbine units would be easily reached relatively quickly after the fish passed under the BGS. Unfortunately, we were unable to determine whether fish were navigating under the BGS in the summer because hydrophones monitoring the back-side of the BGS were damaged. Regardless, we were able to determine that the BGS did increase B2CC efficiency for fish that navigated to the south gap. However, the overall efficiency of the B2CC only increased for yearling Chinook when comparing 2008 results to those from 2004 and 2005 (Counihan et. al 2006), suggesting forebay distribution of juvenile steelhead or subyearling Chinook may not have been significantly altered from prior years without a BGS present. However, differing turbine unit priorities and varying unit outages, including turbine unit 15 in spring and priority unit 11 in summer may confound this conclusion.

5.10 Data Continuity

The most challenging aspect of this study was preserving the continuity of data for hydrophones located on and upstream of the BGS. Due to legitimate safety concerns for operating boats upstream of the BGS, we had limited access for maintenance of hydrophones and hydrophone cables that were subsequently damaged due to high flow conditions and floating debris. This caused significant loss of data and the ability to 2D-position fish in this area for the majority of spring and for a week in summer.

However, we maintained enough shoreline hydrophones in the spring and summer to adequately monitor the north and south gaps in relation to the BGS deployment, so that movement of tagged fish could be determined without 2D tracking. As mentioned previously, we used techniques similar to the use of radio telemetry where we used the known positions of hydrophones and known hydrophone detection ranges to monitor the detection history of tagged fish to determine the route of passage relative to the BGS. Using this method, we could determine whether fish passed the North Gap or South Gap, where hydrophones were easily maintained and data were continuous for both spring and summer. We were also able to use this method for determining if a fish passed under the BGS for the spring when hydrophones were functional on the backside of the BGS. Unfortunately, a large floating tree dislodged the hydrophones monitoring the backside of the BGS during the summer, so we could only monitor the North Gap and South Gap during summer and were unable to confirm that a fish passed under the BGS in the summer.

In contrast to the hydrophones deployed at the BGS, the B2 hydrophones and cables were easily maintained and we encountered no appreciable loss of data at any one route through the dam. This was in part due to redundant deployments of hydrophones, whereby if one hydrophone was incapacitated, then another was monitoring the same route until a replacement could be made. We recommend that for any future study at B2 that seeks to monitor the use of the BGS that researchers deploy equipment that is easily and safely accessible for maintenance, or that is sufficiently rugged to maintain functionality throughout each of the seasons when the forebay is inaccessible to personnel.

5.11 Influence of River Environment on Survival and Passage

Several relationships were evident between river condition and survival and passage after examining the data. The most striking and significant was the strong decline in survival that was observed in subyearlings over the summer season for all routes passing through B2. As noted by Ploskey et al. in 2007b, the loss of fish to residualization (reverse smoltification) in summer could produce such a trend. However, Ploskey et al. also found the survival correlation with B2 discharge was significant, as was found in the summer of 2008 ($r^2 = 0.64$). This had the potential to impact survival. Another correlate with the dropping discharge was the rising river temperature. Dropping flows and rising temperatures could have synergistic effects on subyearling Chinook survival, because travel rate and an increasing physiological stressor (temperature) have shown to increase mortality (Cada 1997; Tiffan 2000). Discharge, temperature, and residualization could highly influence the tailrace survival of subyearling Chinook, but discerning the most influential of these variables and their synergies would be difficult from this study alone.

Operational conditions at B2 also appeared to affect survival. For instance, single-release survival of yearling Chinook was worse when B2 turbines passed more water. This is intuitive because turbine routes consistently had the lowest survival estimate, and passed more fish proportionally when flow through the turbines was higher. Again, travel rates and discharge have shown to benefit juvenile salmon survival (Raymond 1979; Sims and Ossiander 1981; Cada 1997). Discharge and increasing forebay elevation (therefore B2CC discharge) also seemed to benefit survival for yearling Chinook and subyearling Chinook when examining correlations between these variables, but was not significant for steelhead survival.

Finally, collection efficiencies and effectiveness were also impacted by B2 flow. The FPE decreased for yearling Chinook and subyearling Chinook as discharge increased. This relationship is expected because increasing flow into the turbines decreases the proportion of flow passing through B2 into the relatively fixed discharge of the B2CC. This effect may be mitigated by strictly adhering to unit priority for flows that benefit B2CC passage, but when full capacity of the powerhouse is reached there are no obvious options available to keep FPE at those high levels.

6.0 Recommendations

The following recommendations are derived from the study results:

1. To better address the dead-fish assumption downstream of Bonneville, release at least 100 dead fish each season during the next survival study at this dam. A low incidence of detection of dead tagged fish has been observed in two radio-telemetry studies and this acoustic-telemetry study, and although the probability appears to be low ($D \leq 0.017$), studies to date have not released enough dead tagged fish to accurately quantify the rate. Detection of dead tagged fish implanted with tags results in a positive bias in estimates of survival that can be corrected if researchers have precise estimates of D.
2. Assure that the methods for sampling fish for tagging reflect the run at large. This may require methods that seek out smaller fish to better represent their size classes.
3. Examine alternatives to Burnham tests to better address concerns regarding survival models. Because the Burnham tests were created to predict survival for smaller sample sizes and poorer detection probabilities, they may not adequately address the mixing assumptions for techniques using acoustic telemetry.
4. Develop a hydrodynamic model for B2 that includes the BGS. It is apparent that flow conditions along the BGS face may greatly influence the use of the BGS by outmigrant smolts, but this relationship cannot be determined without a hydrodynamic model for B2 that includes the BGS. Unit outages and unit priorities may have a significant impact on the passage of fish into the B2CC, which is the ultimate goal of the BGS. In addition, the characteristics of flow through the North Gap are of particular interest for subyearling Chinook; better understanding them will enable us to ascertain how to direct more of these fish toward the south powerhouse and into the B2CC Extend the BGS. During the summertime it appears that the subyearlings passing through the North Gap may do so very close to the upstream tip of the BGS. If it is possible to extend the BGS by one to two panels upstream, the higher water velocities of the surface flow may be diverted southward and under the BGS rather than through the North Gap.
5. Assure that turbine unit 11 is operational. It is essential that turbine unit 11 be operational for the BGS to meet the design criteria. This unit is effective at directing flow toward the B2CC, making discovery of the corner collector more attainable for outmigrating smolt.

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Appendix A

Tables on Tagging, Release, BON Virtual Release, Dam Operations Data, and Capture History (at or Below BON)

Appendix A

Tables on Tagging, Release, BON Virtual Release, Dam Operations Data, and Capture History (at or Below BON)

Table A.1. List of Comma-Separated-Variable (CSV) Files on an Accompanying Compact Disc.[a] Variables in the first row of CSV files are defined in Tables A.1 through A.5 below.

File	Description
Appendix A1.csv	BON Virtual Releases, Reference Releases, Hourly Dam Operations Data, and Capture History at or below Bonneville Dam (All Species)
Appendix A2.csv	Tagging, Release, and Capture History Data for Steelhead
-0Appendix A3.csv	Tagging, Release, and Capture History Data for Spring Chinook Salmon Released in the John Day and The Dalles Pools
Appendix A4.csv	Tagging, Release, and Capture History Data for Fall Chinook Salmon Released in the John Day, The Dalles, and Bonneville Pools
Appendix A5.csv	Tagging, Release, and Capture History Data for Spring Chinook Salmon Released in the Lower Granite Tailrace

(a) The compact disc accompanying this report contains a Portable Document Format (PDF) file of this report and CSV/Excel files with tagging, release, virtual release, and capture-history data. Included are appendix_a_bon_B2 CSV/Excel Files, which contain data only of fish that passed B2.

Table A.2. Variable Names and Definitions in Appendix 2.csv

Variable	Definition
SEASON	Spring or Summer
TAGGER	Name of Surgeon Implanting Tags
SP	Species Name
SPP	PTAGIS Species Code
LENGTH	Fork Length (mm)
WEIGHT	Fish weight (g)
MORT	0=Alive; > 0 = Dead
ACTAGCODE	Acoustic Tag Code
PRI	Pulse Repetition Interval of Acoustic Tag
PIT	PIT Tag Code
ADATETIME	Acoustic Tag Activation Date and Time (mm/dd/yyyy hh:mm)
TDATETIME	Tagging Date and Time (mm/dd/yyyy hh:mm)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
REL_LOC	Release Location
rkm	Release River Kilometer (km)
A4BFB	Regrouped at BON Forebay Entrance Array (1 or 0)
DATE	Date Released (if REL_LOC=BON_T) or Date of Forebay Virtual Release (if A4BFB=1), or Date of B2 Virtual Release (if BROUTE='B2')
HOUR	Hour Released (if REL_LOC=BON_T) or Hour of Forebay Virtual Release (if A4BFB=1), or Hour of B2 Virtual Release (if BROUTE='B2')
BROUTE	Route of Passage (B2 or Blank)
BSUB_ROUTE	Sub Route of Passage (BCC = B2CC, JBS, Turbine, or blank)
FU_01	Fish Unit 1 Discharge (cfs x 1,000)
FU_02	Fish Unit 2 Discharge (cfs x 1,000)
SP_01	Spill bay 1 Discharge (cfs x 1,000)
SP_02	Spill bay 2 Discharge (cfs x 1,000)
SP_03	Spill bay 3 Discharge (cfs x 1,000)
SP_04	Spill bay 4 Discharge (cfs x 1,000)
SP_05	Spill bay 5 Discharge (cfs x 1,000)
SP_06	Spill bay 6 Discharge (cfs x 1,000)
SP_07	Spill bay 7 Discharge (cfs x 1,000)
SP_08	Spill bay 8 Discharge (cfs x 1,000)
SP_09	Spill bay 9 Discharge (cfs x 1,000)
SP_10	Spill bay 10 Discharge (cfs x 1,000)
SP_11	Spill bay 11 Discharge (cfs x 1,000)
SP_12	Spill bay 12 Discharge (cfs x 1,000)
SP_13	Spill bay 13 Discharge (cfs x 1,000)
SP_14	Spill bay 14 Discharge (cfs x 1,000)
SP_15	Spill bay 15 Discharge (cfs x 1,000)
SP_16	Spill bay 16 Discharge (cfs x 1,000)
SP_17	Spill bay 17 Discharge (cfs x 1,000)
SP_18	Spill bay 18 Discharge (cfs x 1,000)
TU_01	Turbine 1 Discharge (cfs x 1,000)

Table A.2. (contd)

Variable	Definition
TU_02	Turbine 2 Discharge (cfs x 1,000)
TU_03	Turbine 3 Discharge (cfs x 1,000)
TU_04	Turbine 4 Discharge (cfs x 1,000)
TU_05	Turbine 5 Discharge (cfs x 1,000)
TU_06	Turbine 6 Discharge (cfs x 1,000)
TU_07	Turbine 7 Discharge (cfs x 1,000)
TU_08	Turbine 8 Discharge (cfs x 1,000)
TU_09	Turbine 9 Discharge (cfs x 1,000)
TU_10	Turbine 10 Discharge (cfs x 1,000)
TU_11	Turbine 11 Discharge (cfs x 1,000)
TU_12	Turbine 12 Discharge (cfs x 1,000)
TU_13	Turbine 13 Discharge (cfs x 1,000)
TU_14	Turbine 14 Discharge (cfs x 1,000)
TU_15	Turbine 15 Discharge (cfs x 1,000)
TU_16	Turbine 16 Discharge (cfs x 1,000)
TU_17	Turbine 17 Discharge (cfs x 1,000)
TU_18	Turbine 18 Discharge (cfs x 1,000)
SPILL_Q	Spillway Discharge (cfs x 1,000)
B1_Q	Powerhouse 1 Discharge (cfs x 1,000)
B2_Q	Powerhouse 2 Discharge (cfs x 1,000)
B2CC_Q	B2CC Discharge (cfs x 1,000)
BON_Q	Bonneville Project Discharge (cfs x 1,000)
P_SPILL	Percent Spill
HEAD	Difference in forebay and tailrace water surface elevations
FB_EL	Forebay Water Surface Elevation (ft)
TR_EL	Tailrace Water Surface Elevation (ft)
A5BT1	Tag Detected at Primary Array = 1; Not Detected = 0
A6BT2	Tag Detected at Secondary Array = 1; Not Detected = 0
A7BT3	Tag Detected at Tertiary Array = 1; Not Detected = 0
A5BT1_A	Date and Time of Detection on Primary Array
A6BT2_A	Date and Time of Detection on Secondary Array
A7BT3_A	Date and Time of Detection on Tertiary Array

Table A.3. Variable Names and Definitions in Appendix A3.csv

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (SPR_STH = steelhead)
REL_LOC	Release Location (ARLINGTON=Arlington, OR; JDA_TW = upper end of the John Day Tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive Integrated Transponder tag code
ACTAGCODE	Acoustic tag code
A1JFB	Detection indicator for the JDA Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the JDA Dam-Face Array (1 = detected; 0 = not detected; blank = missing)
A2JTW	Detection indicator for the JDA Tailwater Array (1 = detected; 0 = not detected; blank = missing)
A3TFB	Detection indicator for The Dalles Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
A4BFB	Detection indicator for the Bonneville Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Powerhouse 2 Dam-Face Array (1 = detected; 0 = not detected; blank = missing)
BSPILL_ARRAY	Detection indicator for the Bonneville Spillway Array (1 = detected; 0 = not detected; blank = missing)
A5BT1	Detection indicator for the first Bonneville Tailwater Array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6BT2	Detection indicator for the second Bonneville Tailwater Array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7BT3	Detection indicator for the third Bonneville Tailwater Array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1JFB_TIME	Date and time of arrival at the JDA Forebay Entrance Array
JDATETIME	Date and time of arrival at the JDA Dam-Face Array
A2JTW_TIME	Date and time of arrival at the JDA Tailwater Array
A3TFB_TIME	Date and time of arrival at The Dalles Forebay Entrance Array
A4BFB_TIME	Date and time of arrival at the Bonneville Dam Forebay Entrance Array
B2DATETIME	Date and time of last detection on the Bonneville Powerhouse 2 Array
BSDATETIME	Date and time of last detection on the Bonneville Spillway Array
A5BT1_TIME	Date and time of arrival at the first Bonneville Tailwater Array at Reed Island
A6BT2_TIME	Date and time of arrival at the second Bonneville Tailwater Array at Lady Island
A7BT3_TIME	Date and time of arrival at the third Bonneville Tailwater Array at Oak Point
JROUTE	Route of passage through John Day Dam (Powerhouse or Spillway)
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill) , NonTSW (spill), Turbine, JBS]
JHOLE	Specific route of passage (Spill bays S1-S20; Turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)

Table A.3. (contd)

Variable Name	Definition
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; Turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (Spill bays = SB1-SB18; Turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at JDA for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with variable J above
J_NON_TSW	Assigned pool of dates for virtual releases at non-TSW spill bays at JDA
J_NON_TSW_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_NON_TSW above
J_TSW	Assigned pool of dates for virtual releases at JDA TSW spill bays (bays 15 and 16 in 2008)
J_TSW_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_TSW above
J_TUR	Assigned pool of dates for virtual releases at JDA turbines
J_TUR_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_TUR above
J_JBS	Assigned pool of dates for virtual releases at the JDA JBS
J_JBS_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_JBS above
T_FB	Assigned pool of dates for virtual releases at The Dalles Forebay Entrance Array
B_FB	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_TUR above
B2	Assigned pool of dates for virtual releases at Bonneville Powerhouse 2
B2CC	Assigned pool of dates for virtual releases at the BON B2CC
B2_JBS	Assigned pool of dates for virtual releases at the BON B2 JBS
B2_TUR	Assigned pool of dates for virtual releases at BON B2 Turbines
BSPILL	Assigned pool of dates for virtual releases at the BON Spillway
BS_END	Assigned pool of dates for virtual releases at end bays (1-3 and 16-18) at the BON Spillway
BS_MID	Assigned pool of dates for virtual releases at middle spill bays at the BON Spillway

Table A.4. Variable Names and Definitions in Appendix A4.csv

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (SPR_CHN = spring Chinook salmon)
REL_LOC	Release Location (ARLINGTON=Arlington, OR; JDA_TW = upper end of the John Day Tailwater; BON_T = the upper end of the Bonneville Tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive Integrated Transponder tag code
ACTAGCODE	Acoustic tag code
A1JFB	Detection indicator for the JDA Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the JDA Dam-Face Array (1 = detected; 0 = not detected; blank = missing)
A2JTW	Detection indicator for the JDA Tailwater Array (1 = detected; 0 = not detected; blank = missing)
A3TFB	Detection indicator for The Dalles Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
A4BFB	Detection indicator for the Bonneville Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Powerhouse 2 Dam-Face Array (1 = detected; 0 = not detected; blank = missing)
BSPILL_ARRAY	Detection indicator for the Bonneville Spillway Array (1 = detected; 0 = not detected; blank = missing)
A5BT1	Detection indicator for the first Bonneville Tailwater Array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6BT2	Detection indicator for the second Bonneville Tailwater Array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7BT3	Detection indicator for the third Bonneville Tailwater Array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1JFB_TIME	Date and time of arrival at the JDA Forebay Entrance Array
JDATETIME	Date and time of arrival at the JDA Dam-Face Array
A2JTW_TIME	Date and time of arrival at the JDA Tailwater Array
A3TFB_TIME	Date and time of arrival at The Dalles Forebay Entrance Array
A4BFB_TIME	Date and time of arrival at the Bonneville Dam Forebay Entrance Array
B2DATETIME	Date and time of last detection on the Bonneville Powerhouse 2 Array
BSDATETIME	Date and time of last detection on the Bonneville Spillway Array
A5BT1_TIME	Date and time of arrival at the first Bonneville Tailwater Array at Reed Island
A6BT2_TIME	Date and time of arrival at the second Bonneville Tailwater Array at Lady Island
A7BT3_TIME	Date and time of arrival at the third Bonneville Tailwater Array at Oak Point
JROUTE	Route of passage through John Day Dam (Powerhouse or Spillway)

Table A.4. (contd)

Variable Name	Definition
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill) , NonTSW (spill), Turbine, JBS]
JHOLE	Specific route of passage (Spill bays S1-S20; Turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; Turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (Spill bays = SB1-SB18; Turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at JDA for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with variable J above
J_NON_TSW	Assigned pool of dates for virtual releases at non-TSW spill bays at JDA
J_NON_TSW_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_NON_TSW above
J_TSW	Assigned pool of dates for virtual releases at JDA TSW spill bays (bays 15 and 16 in 2008)
J_TSW_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_TSW above
J_TUR	Assigned pool of dates for virtual releases at JDA turbines
J_TUR_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_TUR above
J_JBS	Assigned pool of dates for virtual releases at the JDA JBS
J_JBS_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_JBS above
T_FB	Assigned pool of dates for virtual releases at The Dalles Forebay Entrance Array
B_FB	Assigned pool of dates for virtual releases at the BON Forebay Entrance Array for estimating BON Dam survival
B_FB_TW	Assigned pool of date for reference releases for pairing with B_FB above
B2	Assigned pool of dates for virtual releases at Bonneville Powerhouse 2
B2_TW	Assigned pool of dates for reference releases for pairing with B2 above
B2CC	Assigned pool of dates for virtual releases at the BON B2CC
B2CC_TW	Assigned pool of dates for reference releases for pairing with B2 above
B2CC_R	Assigned pool of dates for releases directly into the B2CC
B2CC_R_TW	Assigned pool of dates for reference releases in the BON Tailwater for pairing with B2CC_R
B2_JBS	Assigned pool of dates for virtual releases at the BON B2 JBS
B2_JBS_TW	Assigned pool of dates for reference releases in the BON Tailwater for pairing with B2_JBS above
B2_TUR	Assigned pool of dates for virtual releases at BON B2 Turbines
B2_TUR_TW	Assigned pool of dates for reference releases in the BON Tailwater for pairing with B2_TUR above
BSPILL	Assigned pool of dates for virtual releases at the BON Spillway
BSPILL_TW	Assigned pool of dates for references releases in the BON Tailwater for pairing with BSPILL above

Table A.4. (contd)

Variable Name	Definition
BS_END	Assigned pool of dates for virtual releases at end bays (1-3 and 16-18) at the BON Spillway
BS_END_TW	Assigned pool of dates for references releases in the BON Tailwater for pairing with BS_END above
BS_MID	Assigned pool of dates for virtual releases at middle spill bays at the BON Spillway
BS_MID_TW	Assigned pool of dates for references releases in the BON Tailwater for pairing with BS_MID above

Table A.5. Variable Names and Definitions in Appendix A5.csv

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (FALL_CHN = fall Chinook salmon)
REL_LOC	Release Location (ARLINGTON=Arlington, OR; JDA_TW = upper end of the John Day Tailwater; TDA_TW = the upper end of The Dalles Tailwater; BON_T = the upper end of the Bonneville Tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive Integrated Transponder tag code
ACTAGCODE	Acoustic tag code
A1JFB	Detection indicator for the JDA Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the JDA Dam-Face Array (1 = detected; 0 = not detected; blank = missing)
A2JTW	Detection indicator for the JDA Tailwater Array (1 = detected; 0 = not detected; blank = missing)
A3TFB	Detection indicator for The Dalles Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
A4BFB	Detection indicator for the Bonneville Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Powerhouse 2 Dam-Face Array (1 = detected; 0 = not detected; blank = missing)
BSPILL_ARRAY	Detection indicator for the Bonneville Spillway Array (1 = detected; 0 = not detected; blank = missing)
A5BT1	Detection indicator for the first Bonneville Tailwater Array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6BT2	Detection indicator for the second Bonneville Tailwater Array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7BT3	Detection indicator for the third Bonneville Tailwater Array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1JFB_TIME	Date and time of arrival at the JDA Forebay Entrance Array
JDATETIME	Date and time of arrival at the JDA Dam-Face Array

Table A.5. (contd)

Variable Name	Definition
A2JTW_TIME	Date and time of arrival at the JDA Tailwater Array
A3TFB_TIME	Date and time of arrival at The Dalles Forebay Entrance Array
A4BFB_TIME	Date and time of arrival at the Bonneville Dam Forebay Entrance Array
B2DATETIME	Date and time of last detection on the Bonneville Powerhouse 2 Array
BSDATETIME	Date and time of last detection on the Bonneville Spillway Array
A5BT1_TIME	Date and time of arrival at the first Bonneville Tailwater Array at Reed Island
A6BT2_TIME	Date and time of arrival at the second Bonneville Tailwater Array at Lady Island
A7BT3_TIME	Date and time of arrival at the third Bonneville Tailwater Array at Oak Point
JROUTE	Route of passage through John Day Dam (Powerhouse or Spillway)
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill) , NonTSW (spill), Turbine, JBS]
JHOLE	Specific route of passage (Spill bays S1-S20; Turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; Turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (Spill bays = SB1-SB18; Turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at JDA for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with variable J above
J_NON_TSW	Assigned pool of dates for virtual releases at non-TSW spill bays at JDA
J_NON_TSW_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_NON_TSW above
J_TSW	Assigned pool of dates for virtual releases at JDA TSW spill bays (bays 15 and 16 in 2008)
J_TSW_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_TSW above
J_TUR	Assigned pool of dates for virtual releases at JDA turbines
J_TUR_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_TUR above
J_JBS	Assigned pool of dates for virtual releases at the JDA JBS
J_JBS_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with J_JBS above
T_FB	Assigned pool of dates for virtual releases at The Dalles Forebay Entrance Array
T_FB	Assigned pool of dates for reference releases in the upper tailwater of The Dalles Dam
B_FB	Assigned pool of dates for virtual releases at the BON Forebay Entrance Array for estimating BON Dam survival
B_FB_TW	Assigned pool of date for reference releases for pairing with B_FB above
B2	Assigned pool of dates for virtual releases at Bonneville Powerhouse 2
B2_TW	Assigned pool of dates for reference releases for pairing with B2 above
B2CC	Assigned pool of dates for virtual releases at the BON B2CC
B2CC_TW	Assigned pool of dates for reference releases for pairing with B2 above

Table A.5. (contd)

Variable Name	Definition
B2CC_R	Assigned pool of dates for releases directly into the B2CC
B2CC_R_TW	Assigned pool of dates for reference releases in the BON Tailwater for pairing with B2CC_R
B2_JBS	Assigned pool of dates for virtual releases at the BON B2 JBS
B2_JBS_TW	Assigned pool of dates for reference releases in the BON Tailwater for pairing with B2_JBS above
B2_TUR	Assigned pool of dates for virtual releases at BON B2 Turbines
B2_TUR_TW	Assigned pool of dates for reference releases in the BON Tailwater for pairing with B2_TUR above
BSPILL	Assigned pool of dates for virtual releases at the BON Spillway
BSPILL_TW	Assigned pool of dates for references releases in the BON Tailwater for pairing with BSPILL above
BS_END	Assigned pool of dates for virtual releases at end bays (1-3 and 16-18) at the BON Spillway
BS_END_TW	Assigned pool of dates for references releases in the BON Tailwater for pairing with BS_END above
BS_MID	Assigned pool of dates for virtual releases at middle spill bays at the BON Spillway
BS_MID_TW	Assigned pool of dates for references releases in the BON Tailwater for pairing with BS_MID above

Table A.6. Variable Names and Definitions in Appendix A6.csv.

Variable Name	Definition
SEASON	Spring or summer outmigration season defined by type of fish and release date
SP	Species or run of juvenile salmon (SPR_CHN = spring Chinook salmon)
REL_LOC	Release Location (LGR=Lower Granite Tailwater; JDA_TW = upper end of the John Day Tailwater; BON_T = the upper end of the Bonneville Tailwater)
RDATETIME	Release date and time (mm/dd/yyyy hh:mm)
ADATETIME	Acoustic tag activation date and time (mm/dd/yyyy hh:mm)
PIT	Passive Integrated Transponder tag code
ACTAGCODE	Acoustic tag code
A1JFB	Detection indicator for the JDA Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
JDA_ARRAY	Detection indicator for the JDA Dam-Face Array (1 = detected; 0 = not detected; blank = missing)
A2JTW	Detection indicator for the JDA Tailwater Array (1 = detected; 0 = not detected; blank = missing)
A3TFB	Detection indicator for The Dalles Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
A4BFB	Detection indicator for the Bonneville Forebay Entrance Array (1 = detected; 0 = not detected; blank = missing)
B2_ARRAY	Detection indicator for the Bonneville Powerhouse 2 Dam-Face Array (1 = detected; 0 = not detected; blank = missing)

Table A.6. (contd)

Variable Name	Definition
BSPILL_ARRAY	Detection indicator for the Bonneville Spillway Array (1 = detected; 0 = not detected; blank = missing)
A5BT1	Detection indicator for the first Bonneville Tailwater Array at Reed Island (1 = detected; 0 = not detected; blank = missing)
A6BT2	Detection indicator for the second Bonneville Tailwater Array at Lady Island (1 = detected; 0 = not detected; blank = missing)
A7BT3	Detection indicator for the third Bonneville Tailwater Array at Oak Point (1 = detected; 0 = not detected; blank = missing)
A1JFB_TIME	Date and time of arrival at the JDA Forebay Entrance Array
JDATETIME	Date and time of arrival at the JDA Dam-Face Array
A2JTW_TIME	Date and time of arrival at the JDA Tailwater Array
A3TFB_TIME	Date and time of arrival at The Dalles Forebay Entrance Array
A4BFB_TIME	Date and time of arrival at the Bonneville Dam Forebay Entrance Array
B2DATETIME	Date and time of last detection on the Bonneville Powerhouse 2 Array
BSDATETIME	Date and time of last detection on the Bonneville Spillway Array
A5BT1_TIME	Date and time of arrival at the first Bonneville Tailwater Array at Reed Island
A6BT2_TIME	Date and time of arrival at the second Bonneville Tailwater Array at Lady Island
A7BT3_TIME	Date and time of arrival at the third Bonneville Tailwater Array at Oak Point
JROUTE	Route of passage through John Day Dam (Powerhouse or Spillway)
JSUB_ROUTE	Sub-route of passage through John Day Dam [TSW (spill) , NonTSW (spill), Turbine, JBS]
JHOLE	Specific route of passage (Spill bays S1-S20; Turbines T1-T16; blank = missing)
BROUTE	Route of passage through Bonneville Dam (B2 or SPILL)
BSUB_ROUTE	Sub-route of passage through Bonneville Dam (SP_MID = spill bays 4-15; SP_END = spill bays 1-3 or 16-18; BCC = B2CC; Turbine = B2 turbines; JBS = juvenile bypass system)
BHOLE	Specific route of passage through Bonneville Dam (Spill bays = SB1-SB18; Turbines = TU11-TU18 or Unknown Turbine = UnkTurb; B2CC=BCC; Juvenile Bypass System = JBS)
J	Assigned pool of dates for virtual releases at JDA for estimating dam survival
J_TW	Assigned pool of dates for reference releases in the upper JDA Tailwater for pairing with variable J above
B_FB	Assigned pool of dates for virtual releases at the BON Forebay Entrance Array for estimating BON Dam survival
B_FB_TW	Assigned pool of date for reference releases for pairing with B_FB above

Table A.7. Definitions of Variables in Headings of Appendix A CSV files on the Accompanying Compact Disc. Original units of elevation (ft) and discharge (cfs x 1,000) were retained in this appendix.

Variable	Definition
SEASON	Fish Released season Spring/Summer
ReleaseDate	Fish released date
ReleaseTime	Fish released time
TagCode	PIT tag code
AcousticTagCode	Acoustic Tag Code
ActivationDate	Acoustic Tag Activated date
ForkLength	Fish length
Weight	Fish weight
Mortality	MORT/NO MORT
ReleaseLoc	Fish Release Location
FB	Forebay Elevation, ft above mean sea level
TW	Tailwater Elevation, ft above mean sea level
N_Units	Number of operating turbines
PH1_Q	Powerhouse 1 Discharge (cfs x 1000)
PH2_Q	Powerhouse 2 Discharge (cfs x 1000)
Spill_Q	Spillway Discharge (cfs x 1000)
Total_Q	Total Project Discharge (cfs x 1000)
T1	Turbine 1 Discharge (cfs x 1000)
T2	Turbine 2 Discharge (cfs x 1000)
T3	Turbine 3 Discharge (cfs x 1000)
T4	Turbine 4 Discharge (cfs x 1000)
T5	Turbine 5 Discharge (cfs x 1000)
T6	Turbine 6 Discharge (cfs x 1000)
T7	Turbine 7 Discharge (cfs x 1000)
T8	Turbine 8 Discharge (cfs x 1000)
T9	Turbine 9 Discharge (cfs x 1000)
T10	Turbine 10 Discharge (cfs x 1000)
T11	Turbine 11 Discharge (cfs x 1000)
T12	Turbine 12 Discharge (cfs x 1000)
T13	Turbine 13 Discharge (cfs x 1000)
T14	Turbine 14 Discharge (cfs x 1000)
T15	Turbine 15 Discharge (cfs x 1000)
T16	Turbine 16 Discharge (cfs x 1000)
T17	Turbine 17 Discharge (cfs x 1000)
T18	Turbine 18 Discharge (cfs x 1000)
T19	Turbine 19 Discharge (cfs x 1000)

Table A.7. (contd)

Variable	6Definition
T20	Turbine 20 Discharge (cfs x 1000)
T21	Turbine 21 Discharge (cfs x 1000)
T22	Turbine 22 Discharge (cfs x 1000)
S1	Spill Bay 1
S2	Spill Bay 2
S3	Spill Bay 3
S4	Spill Bay 4
S5	Spill Bay 5
S6	Spill Bay 6
S7	Spill Bay 7
S8	Spill Bay 8
S9	Spill Bay 9
S10	Spill Bay 10
S11	Spill Bay 11
S12	Spill Bay 12
S13	Spill Bay 13
S14	Spill Bay 14
S15	Spill Bay 15
S16	Spill Bay 16
S17	Spill Bay 17
S18	Spill Bay 18
S19	Spill Bay 19
S20	Spill Bay 20
S21	Spill Bay 21
S22	Spill Bay 22

Table A.8. Release Groups of Fish that were Used to Estimate Survival of Juvenile Salmon and Steelhead that Passed B2 During the Spring Outmigration

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
4/30/2008	5/1/2008	240	Arlington	Steelhead	120	1
				Yearling Chinook	120	1
5/1/2008	5/2/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/2/2008	5/3/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/3/2007	5/4/2008	246	Arlington	Steelhead	87	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0
5/4/2008	5/5/2008	249	Arlington	Steelhead	90	0
				Yearling Chinook	87	0
			JDA Tailwaters	Steelhead	36	1
				Yearling Chinook	36	1
5/5/2008	5/6/2008	123	Arlington	Steelhead	45	0
				Yearling Chinook	48	1
			JDA Tailwaters	Steelhead	15	0
				Yearling Chinook	15	0
5/6/2008	5/7/2008	254	Arlington	Steelhead	90	0
				Yearling Chinook	90	0
			JDA Tailwaters	Steelhead	37	0
				Yearling Chinook	37	0
5/7/2008	5/8/2008	252	Arlington	Steelhead	90	0
				Yearling Chinook	89	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	37	0
5/8/2008	5/9/2008	259	Arlington	Steelhead	89	0
				Yearling Chinook	92	1
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/9/2008	5/10/2008	256	Arlington	Steelhead	88	0
				Yearling Chinook	90	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/10/2008	5/11/2008	265	Arlington	Steelhead	97	0
				Yearling Chinook	90	2
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/11/2008	5/12/2008	264	Arlington	Steelhead	95	0
				Yearling Chinook	91	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0

Table A.8. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
5/12/2008	5/13/2008	186	Arlington	Steelhead	63	0
				Yearling Chinook	63	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	33	0
5/13/2008	5/14/2008	270	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	1
5/14/2008	5/15/2008	213	Arlington	Steelhead	72	0
				Yearling Chinook	72	0
			JDA Tailwaters	Steelhead	33	0
				Yearling Chinook	36	0
5/15/2008	5/16/2008	270	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	39	0
5/16/2008	5/17/2008	226	Arlington	Steelhead	78	0
				Yearling Chinook	78	0
			JDA Tailwaters	Steelhead	35	0
				Yearling Chinook	35	0
5/17/2008	5/18/2008	269	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	39	0
				Yearling Chinook	38	0
5/18/2008	5/19/2008	276	Arlington	Steelhead	96	0
				Yearling Chinook	96	0
			JDA Tailwaters	Steelhead	43	1
				Yearling Chinook	41	0
5/19/2008	5/20/2008	191	Arlington	Steelhead	69	0
				Yearling Chinook	66	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	29	0
5/20/2008	5/21/2008	281	Arlington	Steelhead	98	2[(a)]
				Yearling Chinook	99	0
			JDA Tailwaters	Steelhead	43	0
				Yearling Chinook	41	3[(a)]
5/21/2008	5/22/2008	223	Arlington	Steelhead	78	0
				Yearling Chinook	74	0
			JDA Tailwaters	Steelhead	37	0
				Yearling Chinook	34	0
5/22/2008	5/23/208	280	Arlington	Steelhead	104	0
				Yearling Chinook	104	0
			JDA Tailwaters	Steelhead	36	0
				Yearling Chinook	36	0

Table A.8. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
5/23/2008	5/24/2008	192	Arlington	Steelhead	68	1
				Yearling Chinook	72	0
			JDA Tailwaters	Steelhead	27	0
				Yearling Chinook	25	0
5/24/2008	5/25/2008	292	Arlington	Steelhead	100	0
				Yearling Chinook	106	0
			JDA Tailwaters	Steelhead	44	0
				Yearling Chinook	42	0
5/25/2008	5/26/2008	294	Arlington	Steelhead	104	1
				Yearling Chinook	107	0
			JDA Tailwaters	Steelhead	40	0
				Yearling Chinook	43	0
5/26/2008	5/27/2008	295	Arlington	Steelhead	108	0
				Yearling Chinook	108	1
			JDA Tailwaters	Steelhead	37	4[a]
				Yearling Chinook	42	4[a]
5/27/2008	5/28/2008	194	Arlington	Steelhead	56	0
				Yearling Chinook	60	0
			JDA Tailwaters	Steelhead	42	5[a]
				Yearling Chinook	36	3[a]
5/28/2008	5/29/2008	44	JDA Tailwaters	Steelhead	22	5[a]
				Yearling Chinook	22	2[a]
Totals	Totals	6902	Arlington	Steelhead	2453	5[b]
				Yearling Chinook	2451	6
			JDA Tailwaters	Steelhead	998	16 [c]
				Yearling Chinook	1000	14[d]

(a) sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(b) 2 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(c) 14 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(d) 12 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.

Table A.9. Release Groups of Subyearling Chinook Salmon that were Used to Estimate Survival of Subyearling Chinook Salmon that Passed B2 During the Summer Outmigration

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
6/14/2008	6/15/2008	117	Arlington	Sub-Yearling	81	1
			JDA Tailwaters	Sub-Yearling	36	0
6/15/2008	6/16/2008	124	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	37	1[a]
6/16/2008	6/17/2008	122	Arlington	Sub-Yearling	87	1
			JDA Tailwaters	Sub-Yearling	35	0
6/17/2008	6/18/2008	123	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	36	0
6/18/2008	6/19/2008	123	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	36	0

Table A.9. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
6/19/2008	6/20/2008	125	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	38	2[(a)]
6/20/2008	6/21/2008	121	Arlington	Sub-Yearling	87	2
			JDA Tailwaters	Sub-Yearling	34	0
6/21/2008	6/22/2008	123	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	36	0
6/22/2008	6/23/2008	123	Arlington	Sub-Yearling	87	1
			JDA Tailwaters	Sub-Yearling	36	0
6/23/2008	6/24/2008	123	Arlington	Sub-Yearling	86	0
			JDA Tailwaters	Sub-Yearling	37	1
6/24/2008	6/25/2008	123	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	36	0
6/25/2008	6/26/2008	123	Arlington	Sub-Yearling	88	0
			JDA Tailwaters	Sub-Yearling	35	0
6/26/2008	6/27/2008	123	Arlington	Sub-Yearling	86	0
			JDA Tailwaters	Sub-Yearling	37	1
6/27/2008	6/28/2008	123	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	36	0
6/28/2008	6/29/2008	132	Arlington	Sub-Yearling	87	0
			JDA Tailwaters	Sub-Yearling	36	0
6/29/2008	6/30/2008	123	Arlington	Sub-Yearling	88	0
			JDA Tailwaters	Sub-Yearling	35	0
6/30/2008	7/1/2008	123	Arlington	Sub-Yearling	86	0
			JDA Tailwaters	Sub-Yearling	37	1
7/1/2008	7/2/2008	84	Arlington	Sub-Yearling	57	0
			JDA Tailwaters	Sub-Yearling	27	0
7/2/2008	7/3/2008	164	Arlington	Sub-Yearling	119	0
			JDA Tailwaters	Sub-Yearling	45	1
7/3/2008	7/4/2008	122	Arlington	Sub-Yearling	90	0
			JDA Tailwaters	Sub-Yearling	32	0
7/4/2008	7/5/2008	123	Arlington	Sub-Yearling	90	0
			JDA Tailwaters	Sub-Yearling	33	0
7/5/2008	7/6/2008	126	Arlington	Sub-Yearling	92	0
			JDA Tailwaters	Sub-Yearling	34	1
7/6/2008	7/7/2008	124	Arlington	Sub-Yearling	88	0
			JDA Tailwaters	Sub-Yearling	36	2[(a)]
7/7/2008	7/8/2008	75	Arlington	Sub-Yearling	53	0
			JDA Tailwaters	Sub-Yearling	22	0
7/8/2008	7/9/2008	173	Arlington	Sub-Yearling	122	0
			JDA Tailwaters	Sub-Yearling	51	2

Table A.9. (contd)

Tag Date	Release Date	Number Tagged	Release Location	Species	Number Released	Mortalities
7/9/2008	7/10/2008	126	Arlington	Sub-Yearling	90	0
			JDA Tailwaters	Sub-Yearling	36	0
7/10/2008	7/11/2008	126	Arlington	Sub-Yearling	90	0
			JDA Tailwaters	Sub-Yearling	36	0
7/11/2008	7/12/2008	126	Arlington	Sub-Yearling	90	1
			JDA Tailwaters	Sub-Yearling	36	1
7/12/2008	7/13/2008	31	JDA Tailwaters	Sub-Yearling	31	1[a]
Totals	Totals	3485	Arlington	Sub-Yearling	2453	6
			JDA Tailwaters	Sub-Yearling	1032	14[b]

(a) sacrificed to reach a goal of tagging and releasing 40 dead fish in spring.
(b) 6 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 20 dead fish in spring.

Appendix B

Tag Life Appendix

Appendix B

Tag Life Appendix

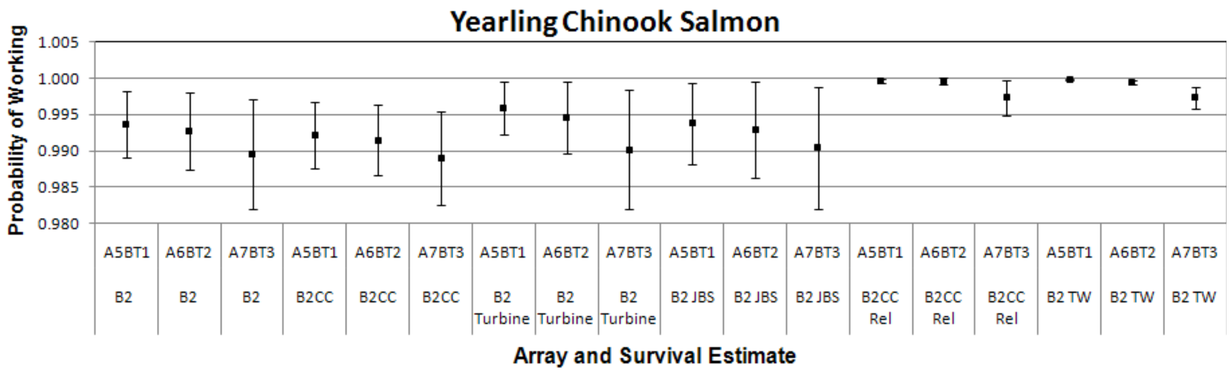

Figure B.1. Plot of the Probability of a Tag Implanted in Yearling Chinook Salmon Smolts Working by the Time Fish Arrived at Survival Arrays for Various Survival Estimates for the Bonneville Dam Second Powerhouse (B2). Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington). Survival abbreviations are as follows: B2CC = B2 Corner Collector; JBS = Juvenile Bypass System; B2CC Rel = Release into the B2CC; TW = Tailwater.

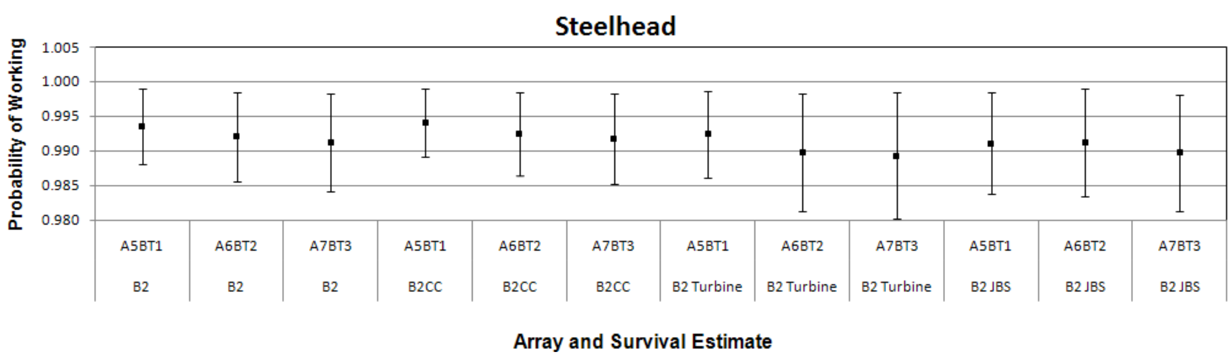

Figure B.2. Plot of the Probability of a Tag Implanted in Steelhead Smolts Working by the Time Fish Arrived at Survival Arrays for Various Survival Estimates for the Bonneville Dam Second Powerhouse (B2). Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington). Survival abbreviations are as follows: B2CC = B2 Corner Collector; JBS = Juvenile Bypass System; B2CC Rel = Release into the B2CC; TW = Tailwater.

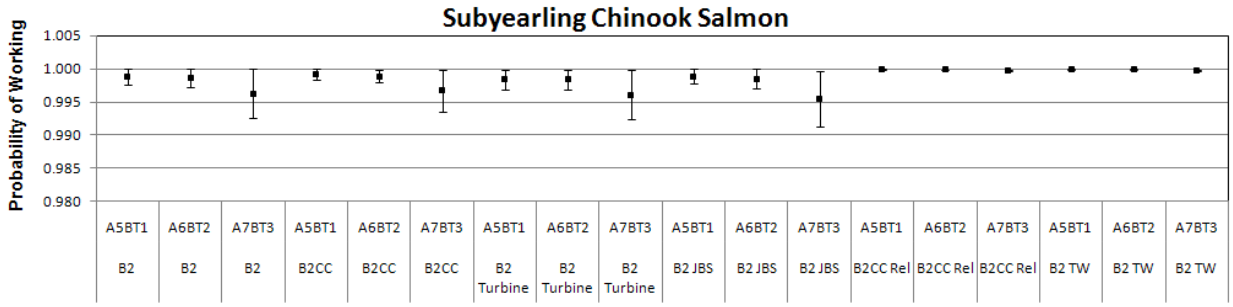

Figure B.3. Plot of the Probability of a Tag Implanted in Subyearling Chinook Salmon Smolts Working by the Time Fish Arrived at Survival Arrays for Various Survival Estimates for the Bonneville Dam Second Powerhouse (B2). Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington). Survival abbreviations are as follows: B2CC = B2 Corner Collector; JBS = Juvenile Bypass System; B2CC Rel = Release into the B2CC; TW = Tailwater.

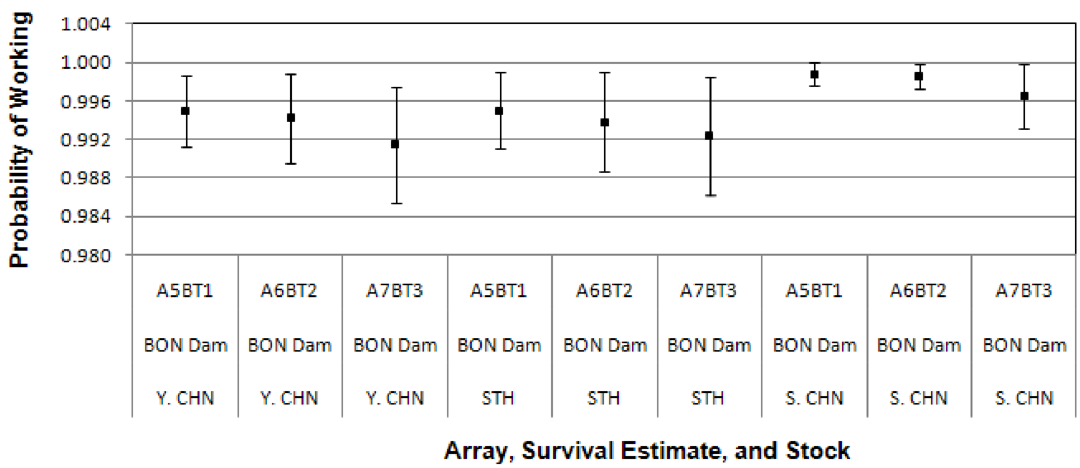

Figure B.4. Plot of the Probability of a Tag Implanted in Juvenile Salmonid Smolts Working by the Time Fish Arrived at Survival Arrays for Bonneville Dam Survival Estimates. Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington). Fish stock abbreviations include Y. CHN = yearling Chinook salmon; STH = steelhead; S. CHN = subyearling Chinook salmon.

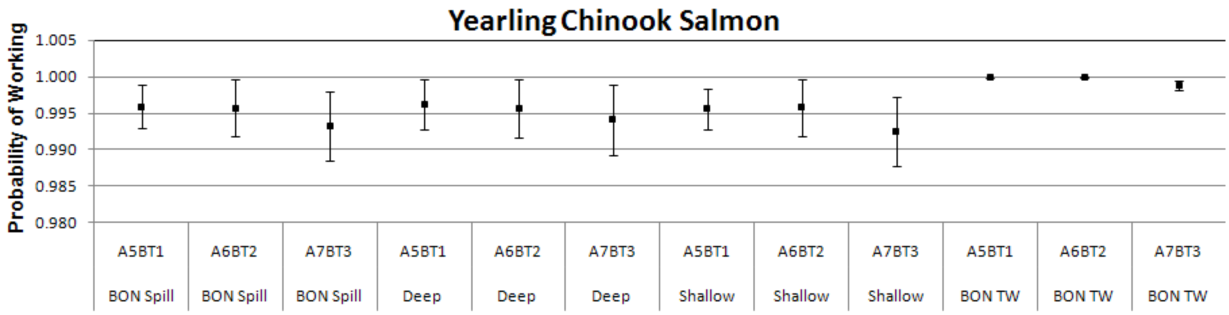

Figure B.5. Plot of the Probability of a Tag Implanted in Yearling Chinook Salmon Smolts Working by the Time Fish Arrived at Survival Arrays for Estimating Bonneville Spillway and Tailwater (TW) survivals. Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington). Survival abbreviations by passage route are as follows: BON Spill = Bonneville Spillway; Deep = spill bays with deep flow deflectors (Bays 1-3 and 16-18); Shallow = spill bays with shallow flow deflectors (Bays 4-15); BON TW = Bonneville Tailwater.

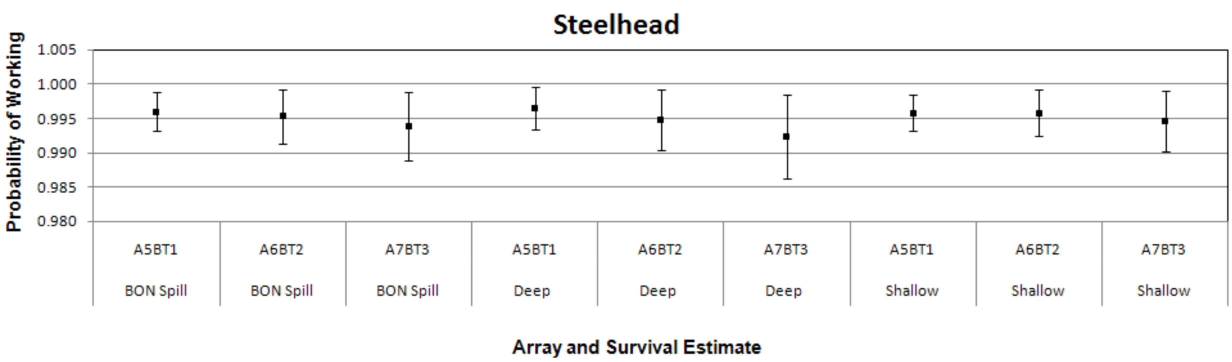

Figure B.6. Plot of the Probability of a Tag Implanted in Steelhead Smolts Working by the Time Fish Arrived at Survival Arrays for Estimating Bonneville Spillway Survivals. No steelhead were released in the Bonneville Tailwater in 2008. Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington). Survival abbreviations by passage route are as follows: BON Spill = Bonneville Spillway; Deep = spill bays with deep flow deflectors (Bays 1-3 and 16-18); Shallow = spill bays with shallow flow deflectors (Bays 4-15); BON TW = Bonneville Tailwater.

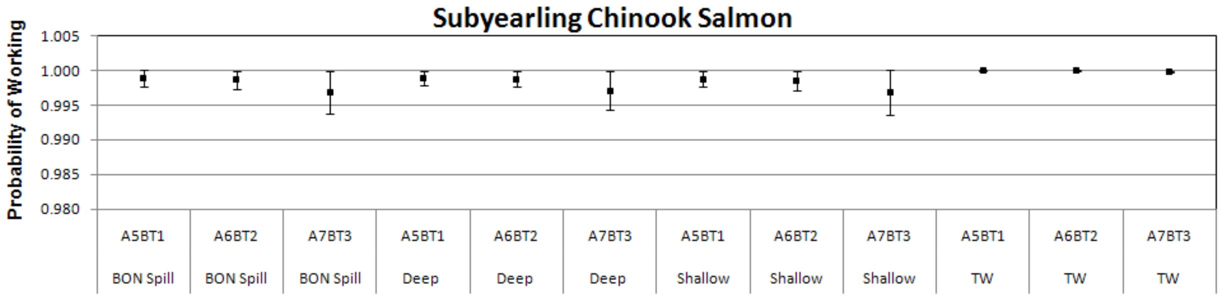

Figure B.7. Plot of the Probability of a Tag Implanted in Subyearling Chinook Salmon Smolts Working by the Time Fish Arrived at Survival Arrays for Estimating Bonneville Spillway Survivals. Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington). Survival was estimated for fish passing four routes: BON Spill = Bonneville Spillway; Deep = spill bays with deep flow deflectors (Bays 1-3 and 16-18); Shallow = spill bays with shallow flow deflectors (Bays 4-15); BON TW = Bonneville Tailwater.

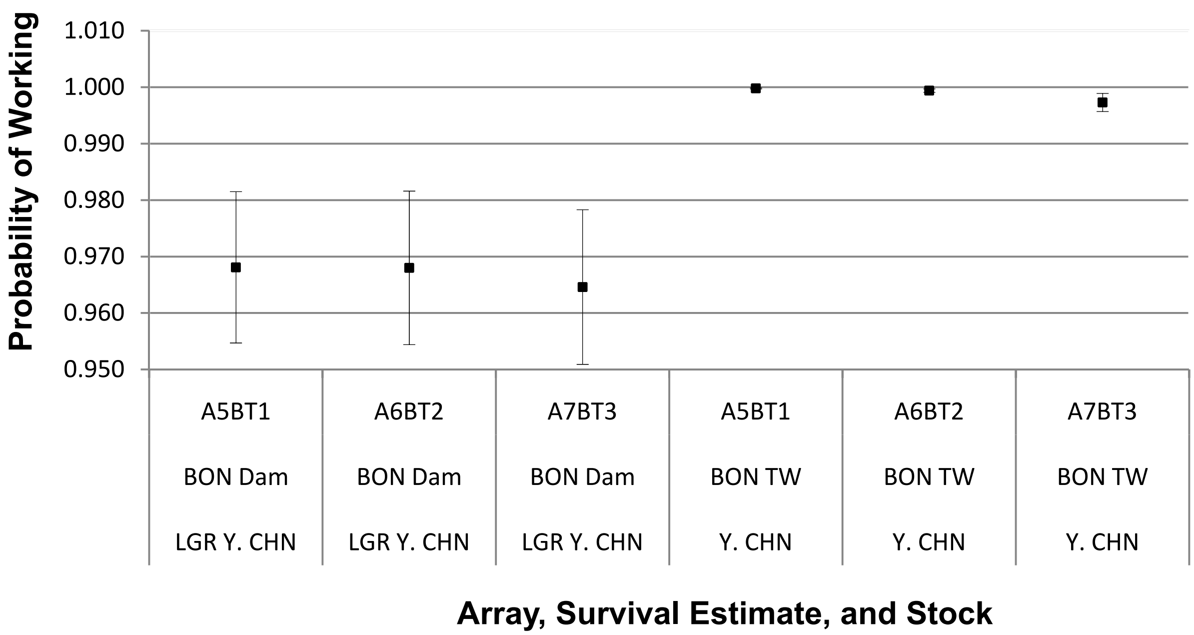

Figure B.8. Plot of the Probability of a Tag Implanted in Yearling Chinook Salmon Smolts Working by the Time Fish Arrived at Survival Arrays for Estimating Bonneville Dam and Tailwater Survivals. These tagged yearlings were released at Lower Granite Dam on the Snake River and in the Bonneville Tailwater. Array abbreviations are as follows: A5BT1 = Bonneville Tailwater 1 (Primary at Reed Island), A6BT2 = Bonneville Tailwater 2 (Secondary at Camas, Washington), A6BT3 = Bonneville Tailwater 3 (Tertiary at Oak Point, Washington).

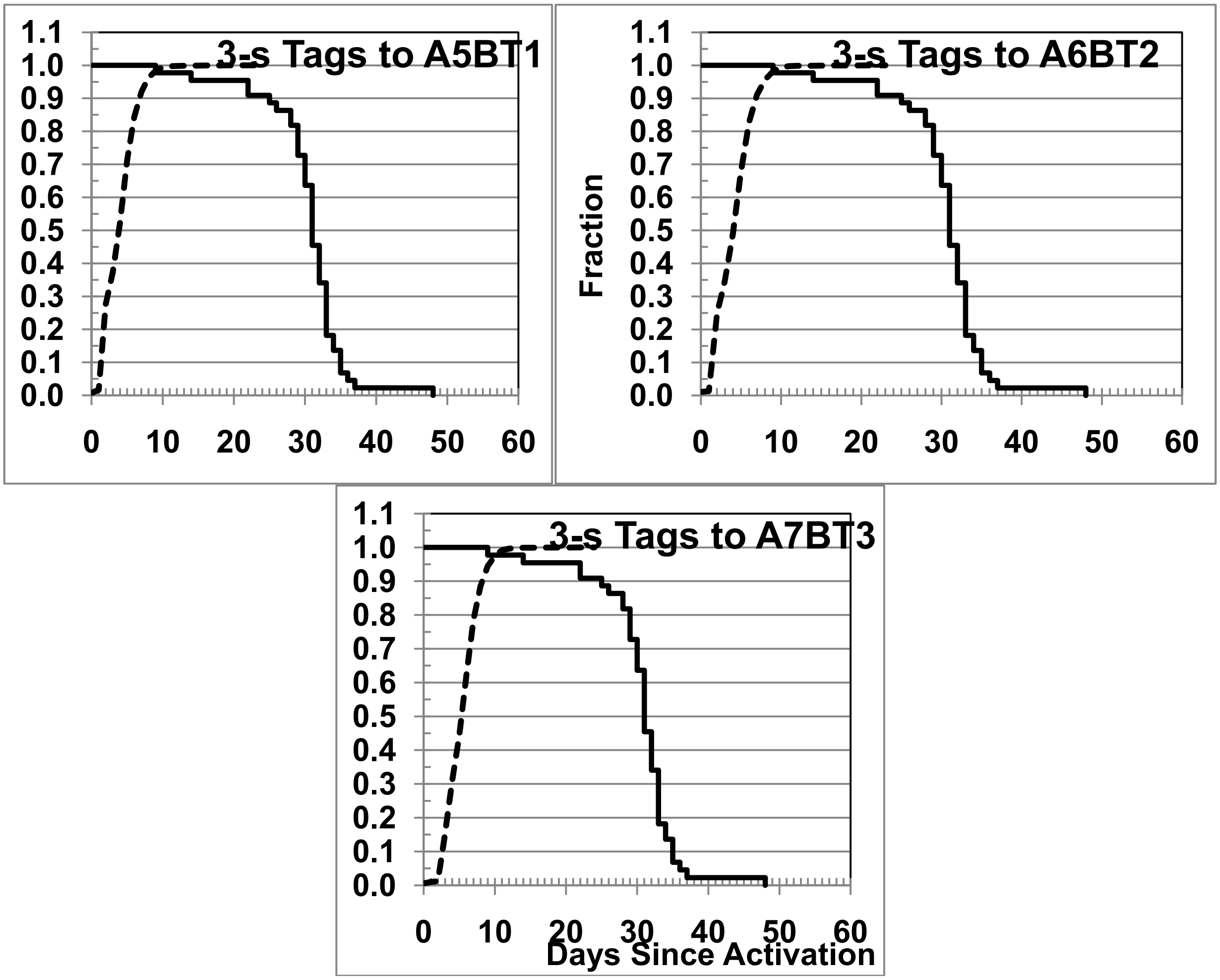

Figure B.9. Fraction of Tag-Life Study Tags Transmitting (Solid Lines) and the Cumulative Fraction of Tagged Subyearling Chinook Salmon Smolts Arriving at the Bonneville Dam Primary, Secondary, and Tertiary Survival Arrays (Dashed Lines) as a Function of Days Since Tag Activation. Arrays were as follows: A5BT1 in the Bonneville Tailwater near Reed Island, A6BT2 in the tailwater near Lady Island at Camas, Washington, and A7BT3 near Oak Point, Washington.

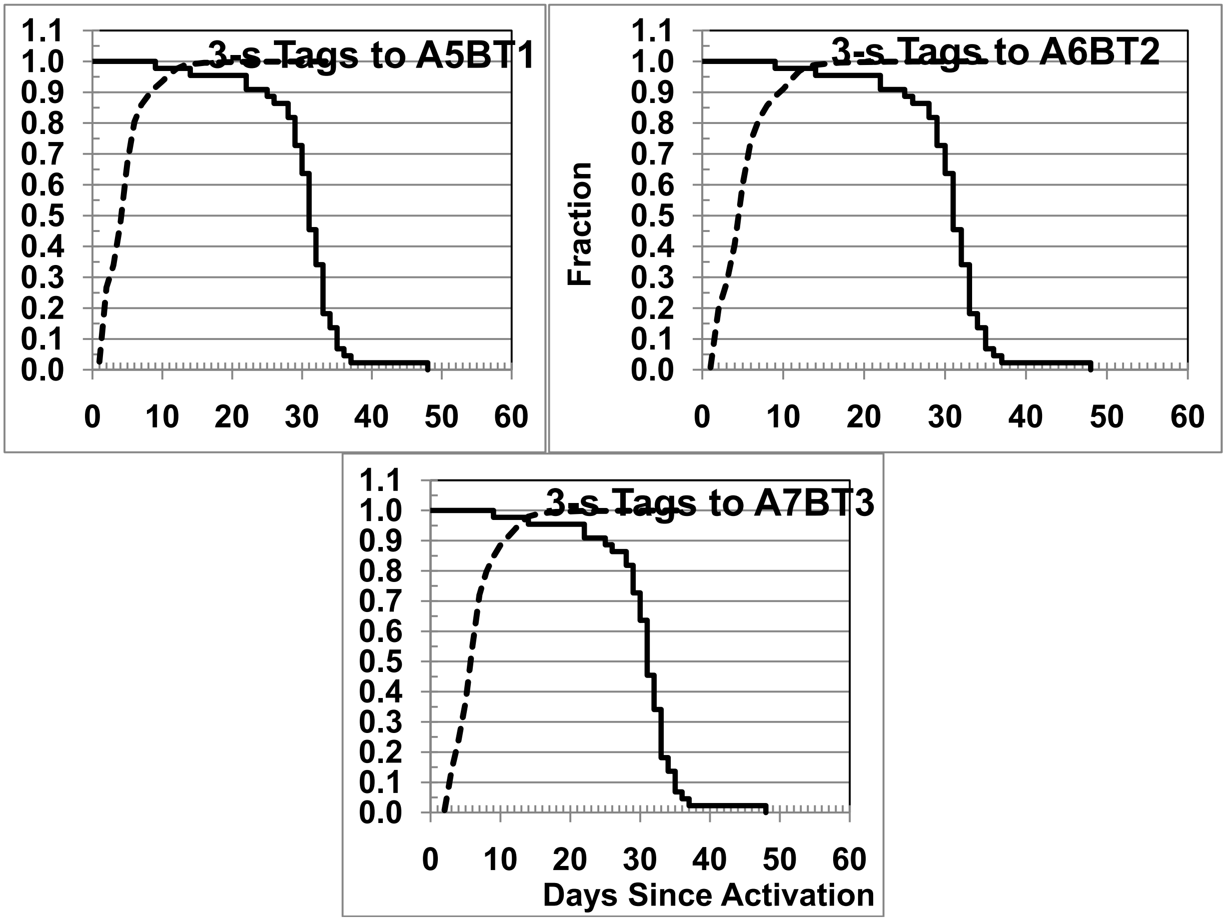

Figure B.10. Fraction of Tag-Life Study Tags Transmitting (Solid Lines) and the Cumulative Fraction of Tagged Yearling Chinook Salmon Smolts Arriving at the Bonneville Dam Primary, Secondary, and Tertiary Survival Arrays (Dashed Lines) as a Function of Days Since Tag Activation. Arrays were as follows: A5BT1 in the Bonneville Tailwater near Reed Island, A6BT2 in the tailwater near Lady Island at Camas, Washington, and A7BT3 near Oak Point, Washington.

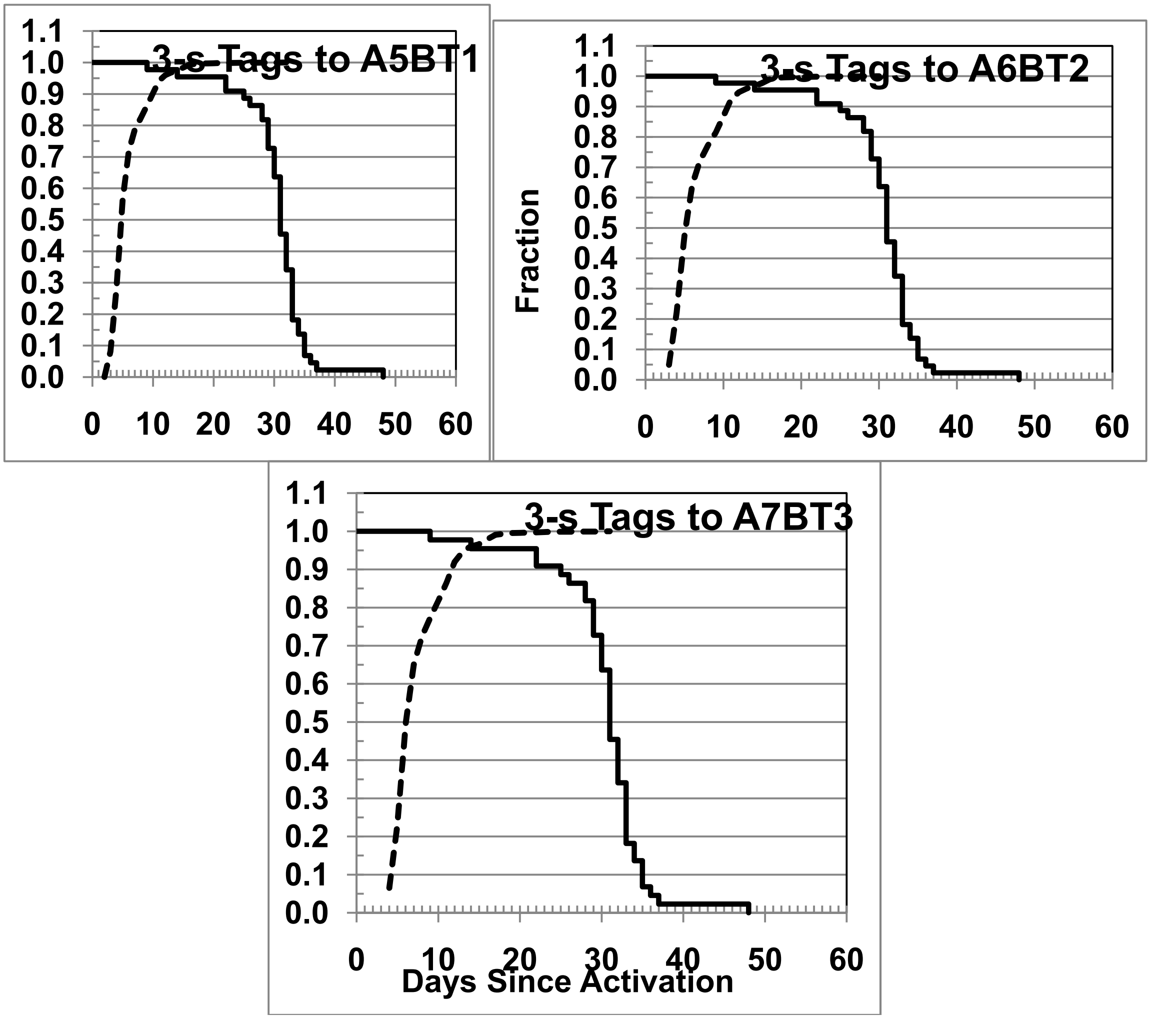

Figure B.11. Fraction of Tag-Life Study Tags Transmitting (Solid Lines) and the Cumulative Fraction of Tagged Steelhead Smolts Arriving at the Bonneville Dam Primary, Secondary, and Tertiary Survival Arrays (Dashed Lines) as a Function of Days Since Tag Activation. Arrays were as follows: A5BT1 in the Bonneville Tailwater near Reed Island, A6BT2 in the tailwater near Lady Island at Camas, Washington, and A7BT3 near Oak Point, Washington.

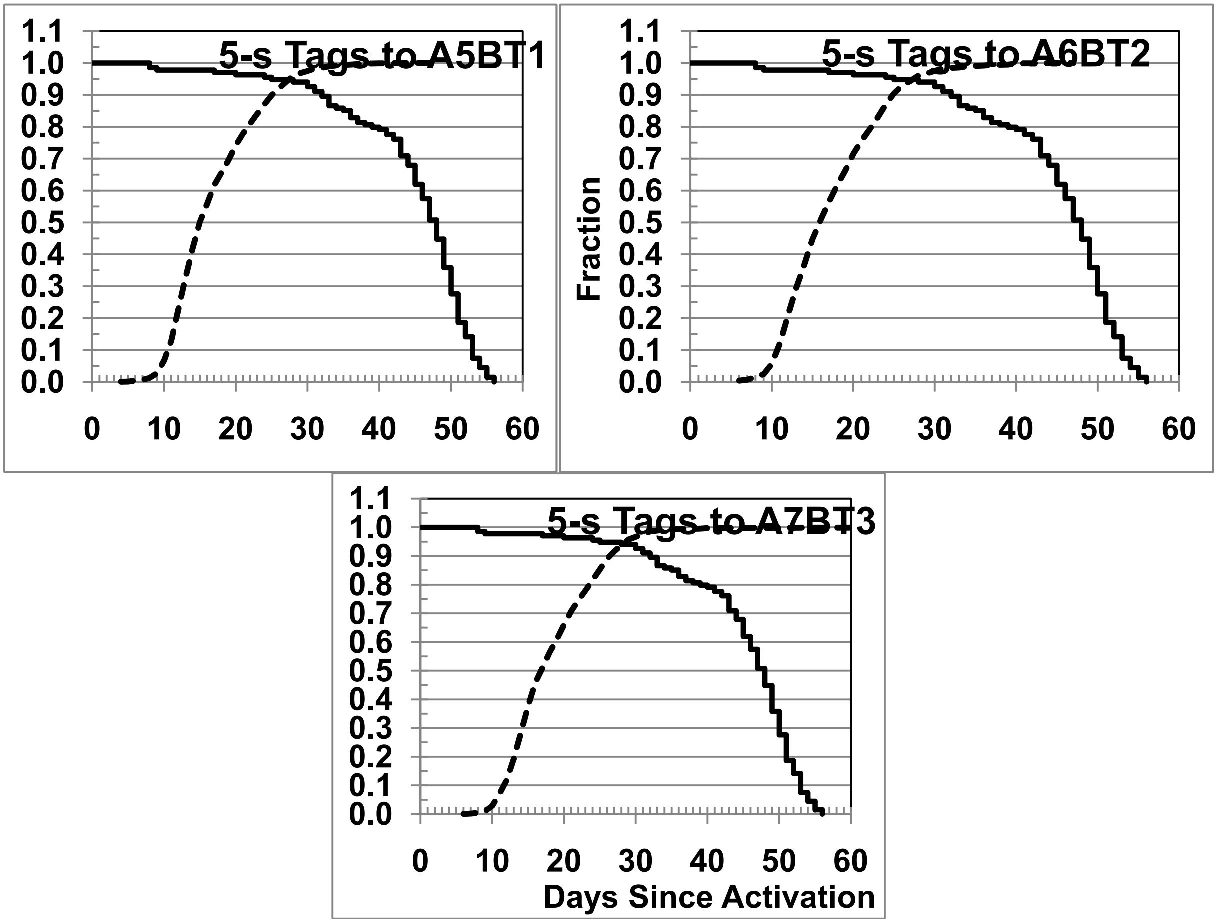

Figure B.12. Fraction of Tag-Life Study Tags Transmitting (Solid Lines) and the Cumulative Fraction of Tagged Lower Granite Yearling Chinook Salmon Smolts Arriving at the Bonneville Dam Primary, Secondary, and Tertiary Survival Arrays (Dashed Lines) as a Function of Days Since Tag Activation. Arrays were as follows: A5BT1 in the Bonneville Tailwater near Reed Island, A6BT2 in the tailwater near Lady Island at Camas, Washington, and A7BT3 near Oak Point, Washington.

Appendix C

Survival Calculation Tables

Appendix C

Survival Calculation Tables

This appendix includes detailed capture histories and associated survival rates for juvenile Chinook salmon and steelhead passing Bonneville Dam and B2.

C.1 Lower Granite Releases

C.1.1 Bonneville Dam Survival

Table C.1. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Lower Granite Released Yearling Chinook Salmon in Virtual Releases at the Bonneville forebay array Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/07-5/14	0.92	0.063	1	0.012	0.937	0.063	0.748	0.012	0.6686	0.084
5/15-5/16	0.911	0.057	1	0.001	0.898	0.057	0.698	0.001	0.6721	0.071
5/17-5/18	0.95	0.062	0.817	0.096	0.821	0.062	0.546	0.096	0.6886	0.093
5/19-5/20	0.972	0.057	0.986	0.174	0.794	0.057	0.318	0.174	0.4812	0.099
5/21-5/22	0.969	0.057	1	0.004	0.829	0.057	0.26	0.004	0.3669	0.055
5/23-5/24	0.954	0.061	1	0.006	0.774	0.061	0.383	0.006	0.4223	0.061
5/25-5/26	0.961	0.044	0.958	0.119	0.811	0.044	0.389	0.119	0.4553	0.069
5/27-5/28	1	0	1	0	0.837	0	0.297	0	0.412	0.057
5/29-5/30	0.942	0.092	0.882	0.417	0.878	0.092	0.163	0.417	0.538	0.271
5/31-6/04	0.976	0.088	1	0	0.796	0.088	0.273	0	0.5476	0.112
N-Wt Mean	0.96	0.015	0.968	0.035						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.2. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Lower Granite Released Yearling Chinook Salmon in Virtual Releases at the Bonneville forebay array based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/07-5/14	0.982	0.02	0.978	0.036	0.944	0.02	0.852	0.036	0.8055	0.062
5/15-5/16	1	0.013	0.962	0.097	0.958	0.013	0.65	0.097	0.8667	0.122
5/17-5/18	1	0.016	0.889	0.257	0.857	0.016	0.563	0.257	0.6429	0.251
5/19-5/20	1	0.089	1	0.046	0.686	0.089	0.259	0.046	0.5189	0.136
5/21-5/22	0.895	0.131	1	0.054	0.722	0.131	0.241	0.054	0.4988	0.142
5/23-5/24	0.888	0.115	1	0.059	0.84	0.115	0.389	0.059	0.4097	0.143
5/25-5/26	1	0	1	0.04	0.654	0	0.365	0.04	0.5	0.135
5/27-5/28	1	0.055	0.738	0.206	0.708	0.055	0.48	0.206	0.7059	0.217
5/29-5/30	0.854	0.142	1	0.046	0.829	0.142	0.268	0.046	0.4147	0.159
5/31-6/04	0.976	0.092	0.735	0.228	0.846	0.092	0.364	0.228	0.6667	0.218
N-Wt Mean	0.962	0.032	0.939	0.063						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

C.2 Detection and Survival of Lower Columbia Released Yearling Chinook salmon in spring

C.2.1 Bonneville Dam Survival

Table C.3. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Lower Columbia Released Yearling Chinook Salmon in Virtual Releases at the Bonneville forebay array Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	0.960	0.051	1.000	0.000	0.946	0.051	0.962	0.000	0.794	0.069
5/07-5/08	0.984	0.028	1.000	0.001	0.940	0.028	0.915	0.001	0.707	0.059
5/09-5/10	0.949	0.041	0.988	0.041	0.912	0.041	0.789	0.041	0.758	0.062

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.4. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Lower Columbia Released Yearling Chinook Salmon in Virtual Releases at the Bonneville forebay array based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	0.986	0.024	0.971	0.037	0.920	0.024	0.966	0.037	0.784	0.078
5/07-5/08	0.966	0.060	0.971	0.098	0.881	0.060	0.771	0.098	0.797	0.136
5/09-5/10	0.984	0.040	0.956	0.077	0.935	0.040	0.850	0.077	0.852	0.111
5/11-5/12	1.000	0.000	0.987	0.042	0.979	0.000	0.950	0.042	0.845	0.106
5/13-5/14	0.980	0.040	1.000	0.000	0.978	0.040	0.829	0.000	0.723	0.128
5/15-5/16	1.000	0.013	0.962	0.097	0.958	0.013	0.650	0.097	0.867	0.122
5/17-5/18	1.000	0.016	0.889	0.257	0.857	0.016	0.563	0.257	0.643	0.251
5/19-5/20	1.000	0.093	1.000	0.046	0.685	0.093	0.259	0.046	0.519	0.136
5/21-5/22	0.895	0.131	1.000	0.054	0.722	0.131	0.241	0.054	0.499	0.142
5/23-5/24	0.888	0.115	1.000	0.059	0.840	0.115	0.389	0.059	0.410	0.143
5/25-5/26	1.000	0.000	1.000	0.040	0.654	0.000	0.365	0.040	0.500	0.135
5/27-5/28	1.000	0.055	0.738	0.206	0.708	0.055	0.480	0.206	0.706	0.217
5/29-6/04	0.922	0.079	0.896	0.277	0.844	0.079	0.300	0.277	0.517	0.182
N-Wt Mean	0.965	0.023	0.952	0.038						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

C.2.2 Bonneville Second Powerhouse Specific Survival

Table C.5. Detection Histories for Yearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2 Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/06	50	4	1	1	13	0	0	3	72
5/07-5/08	49	3	6	1	23	1	2	0	85
5/09-5/10	46	3	16	2	17	0	8	9	101
5/11-5/12	71	1	8	1	13	1	4	0	99
5/13-5/14	53	3	6	1	30	0	5	0	98
5/15-5/16	57	3	14	0	18	1	4	2	99
5/17-5/18	42	5	14	1	11	2	8	4	87
5/19-5/20	6	1	11	3	8	1	9	6	45
5/21-5/22	10	1	2	3	7	1	5	2	31
5/23-5/24	10	2	1	1	9	2	6	0	31
5/25-5/26	9	1	3	1	16	2	6	4	42
5/27-5/28	8	2	15	2	9	2	10	6	54
5/29-6/04	8	2	7	6	5	1	8	7	44
Pooled	419	31	104	23	179	14	75	43	888

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant ($P < 0.0010$).

Table C.6. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Virtual Releases at B2 Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	0.976	0.055	1.000	0.000	0.927	0.055	0.971	0.000	0.812	0.093
5/07-5/08	1.000	0.000	1.000	0.000	0.941	0.000	0.894	0.000	0.703	0.099
5/09-5/10	0.931	0.062	0.976	0.080	0.941	0.062	0.731	0.080	0.745	0.106
5/11-5/12	1.000	0.009	0.978	0.042	0.970	0.009	0.889	0.042	0.839	0.078
5/13-5/14	1.000	0.000	0.988	0.055	0.959	0.000	0.889	0.055	0.653	0.101
5/15-5/16	0.983	0.028	1.000	0.000	0.957	0.028	0.813	0.000	0.763	0.085
5/17-5/18	0.966	0.046	0.943	0.083	0.893	0.046	0.758	0.083	0.786	0.104
5/19-5/20	0.916	0.116	1.000	0.000	0.827	0.116	0.388	0.000	0.510	0.159
5/21-5/22	0.978	0.105	0.912	0.236	0.792	0.105	0.688	0.236	0.579	0.222
5/23-5/24	1.000	0.016	0.866	0.176	0.839	0.016	0.857	0.176	0.523	0.205
5/25-5/26	0.926	0.094	1.000	0.115	0.875	0.094	0.720	0.115	0.360	0.153
5/27-5/28	0.930	0.096	1.000	0.040	0.837	0.096	0.418	0.040	0.538	0.143
5/29-6/04	0.955	0.149	0.930	0.306	0.690	0.149	0.435	0.306	0.615	0.233
N-Wt Mean	0.970	0.017	0.977	0.018						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.7. Detection Histories for Yearling Chinook Salmon Smolts Released in the Upper BON Tailwater as Reference Releases for B2 Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/06	80	5	2	1	21	3	4	2	118
5/07-5/08	24	3	6	2	7	0	3	2	47
5/09-5/10	31	3	6	0	6	0	3	1	50
5/11-5/12	37	1	2	0	7	0	1	0	48
5/13-5/14	27	1	6	0	11	0	2	1	48
5/15-5/16	24	2	14	0	4	0	4	0	48
5/17-5/18	8	1	4	3	5	0	7	0	28
5/19-5/20	5	1	15	7	5	3	12	6	54
5/21-5/22	3	3	17	6	7	1	15	13	65
5/23-5/24	6	1	11	2	10	2	14	9	55
5/25-5/26	7	1	11	7	7	4	9	6	52
5/27-5/28	7	5	9	4	5	0	13	5	48
5/29-6/04	11	4	30	5	13	1	37	16	117
Pooled	270	31	133	37	108	14	124	61	778

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.8. Tag-life Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2 Survival[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	0.986	0.024	0.971	0.037	0.920	0.024	0.966	0.037	0.784	0.078
5/07-5/08	0.966	0.060	0.971	0.098	0.881	0.060	0.771	0.098	0.797	0.136
5/09-5/10	0.984	0.040	0.956	0.077	0.935	0.040	0.850	0.077	0.852	0.111
5/11-5/12	1.000	0.000	0.987	0.042	0.979	0.000	0.950	0.042	0.845	0.106
5/13-5/14	0.980	0.040	1.000	0.000	0.978	0.040	0.829	0.000	0.723	0.128
5/15-5/16	1.000	0.013	0.962	0.097	0.958	0.013	0.650	0.097	0.867	0.122
5/17-5/18	1.000	0.016	0.889	0.257	0.857	0.016	0.563	0.257	0.643	0.251
5/19-5/20	1.000	0.093	1.000	0.046	0.685	0.093	0.259	0.046	0.519	0.136
5/21-5/22	0.895	0.131	1.000	0.054	0.722	0.131	0.241	0.054	0.499	0.142
5/23-5/24	0.888	0.115	1.000	0.059	0.840	0.115	0.389	0.059	0.410	0.143
5/25-5/26	1.000	0.000	1.000	0.040	0.654	0.000	0.365	0.040	0.500	0.135
5/27-5/28	1.000	0.055	0.738	0.206	0.708	0.055	0.480	0.206	0.706	0.217
5/29-6/04	0.922	0.079	0.896	0.277	0.844	0.079	0.300	0.277	0.517	0.182
N-Wt Mean	0.965	0.023	0.952	0.038						

(a) Releases were in the Upper BON Tailwater. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.9. Tag-life Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2 Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/06	0.990	0.061
5/07-5/08	1.035	0.064
5/09-5/10	0.945	0.074
5/11-5/12	1.000	0.009
5/13-5/14	1.020	0.042
5/15-5/16	0.983	0.031
5/17-5/18	0.966	0.049
5/19-5/20	0.916	0.144
5/21-5/22	1.093	0.199
5/23-5/24	1.127	0.148
5/25-5/26	0.926	0.094
5/27-5/28	0.930	0.108
5/29-6/04	1.035	0.184
N-Wt Mean	1.005	0.03

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant ($P < 0.0010$).

C.2.3 Bonneville Corner Collector Survival

Table C.10. Detection Histories for Yearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2CC Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/08	45	4	4	0	20	1	1	1	76
5/09-5/12	57	2	11	1	12	1	6	3	93
5/13-5/16	51	1	11	1	32	1	3	0	100
5/17-5/20	25	4	12	2	7	3	9	4	66
5/21-5/24	10	2	3	1	8	2	4	1	31
5/25-6/04	15	4	12	5	13	2	9	6	66
Pooled	203	17	53	10	92	10	32	15	432

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.11. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Virtual Releases at B2CC Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/08	1.000	0.031	1.000	0.018	0.932	0.031	0.933	0.018	0.709	0.104
5/09-5/12	0.981	0.040	0.958	0.060	0.952	0.040	0.831	0.060	0.821	0.089
5/13-5/16	1.000	0.009	1.000	0.013	0.970	0.009	0.850	0.013	0.641	0.094
5/17-5/20	0.969	0.065	0.905	0.127	0.830	0.065	0.674	0.127	0.746	0.138
5/21-5/24	1.000	0.001	0.948	0.198	0.808	0.001	0.750	0.198	0.546	0.208
5/25-6/04	0.969	0.080	1.000	0.000	0.781	0.080	0.547	0.000	0.579	0.128
N-Wt Mean	0.987	0.012	0.973	0.030						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.12. Detection Histories for Yearling Chinook Salmon Smolts Released in the Upper BON Tailwater as Reference Releases for B2CC Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/08	104	8	8	3	28	3	7	4	165
5/09-5/12	68	4	8	0	13	0	4	1	98
5/13-5/16	51	3	20	0	15	0	6	1	96
5/17-5/20	13	2	19	10	10	3	19	6	82
5/21-5/24	9	4	28	8	17	3	29	22	120
5/25-6/04	25	10	50	16	25	5	59	27	217
Pooled	270	31	133	37	108	14	124	61	778

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.13. Tag-life Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2CC Survival. Releases were in the Upper BON Tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/08	0.98	0.024	0.972	0.037	0.909	0.024	0.911	0.037	0.788	0.068
5/09-5/12	0.992	0.020	0.972	0.044	0.957	0.020	0.900	0.044	0.849	0.077
5/13-5/16	0.992	0.021	0.993	0.067	0.966	0.021	0.730	0.067	0.783	0.097
5/17-5/20	1	0.035	1.000	0.198	0.744	0.035	0.342	0.198	0.537	0.121
5/21-5/24	0.892	0.088	1.000	0.037	0.776	0.088	0.308	0.037	0.458	0.101
5/25-6/04	0.96	0.062	0.901	0.177	0.763	0.062	0.347	0.177	0.539	0.121
N-Wt Mean	0.966	0.030	0.962	0.035						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.14. Tag-life Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Virtual Releases for B2CC Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
Paired Release	S to Tailrace	1/2 95% CI
5/02-5/08	1.020	0.040
5/09-5/12	0.990	0.045
5/13-5/16	1.008	0.023
5/17-5/20	0.969	0.073
5/21-5/24	1.122	0.111
5/25-6/04	1.009	0.106
N-Wt Mean	1.021	0.034

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

C.2.4 Bonneville Second Powerhouse Turbine Survival

Table C.15. Detection Histories for Yearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2turbines Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/07	20	3	1	1	5	0	1	2	33
5/08-5/12	44	2	7	2	12	0	5	3	75
5/13-5/17	47	4	2	0	14	0	3	2	72
5/18-5/22	11	0	6	3	8	0	6	5	39
5/23-5/27	6	1	6	0	14	2	6	4	39
5/28-6/04	2	0	5	3	3	1	7	6	27
Pooled	130	10	27	9	56	3	28	22	285

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.16. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Virtual Releases at B2 turbines based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/07	0.960	0.089	0.977	0.076	0.867	0.089	0.920	0.076	0.825	0.142
5/08-5/12	0.970	0.046	0.960	0.070	0.940	0.046	0.836	0.070	0.799	0.105
5/13-5/17	0.976	0.038	0.963	0.052	0.940	0.038	0.962	0.052	0.788	0.100
5/18-5/22	0.891	0.110	0.996	0.263	0.893	0.110	0.550	0.263	0.580	0.222
5/23-5/27	0.922	0.102	1.000	0.000	0.892	0.102	0.641	0.000	0.363	0.159
5/28-6/04	0.894	0.229	1.000	0.083	0.704	0.229	0.249	0.083	0.414	0.217
N-Wt Mean	0.946	0.030	0.977	0.015						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.17. Detection Histories for Yearling Chinook Salmon Smolts Released in the Upper BON Tailwater as Reference Releases for B2 Turbine Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/07	92	6	3	2	24	3	5	2	137
5/08-5/12	80	6	13	1	17	0	6	3	126
5/13-5/17	57	4	24	3	20	0	11	1	120
5/18-5/22	10	4	32	13	12	4	29	19	123
5/23-5/27	15	5	27	10	22	6	28	18	131
5/28-6/04	16	6	34	8	13	1	45	18	141
Pooled	270	31	133	37	108	14	124	61	778

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant ($P < 0.0010$).

Table C.18. Tag-life Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2 Turbine Survival. Releases were in the Upper BON Tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambd a	1/2 95% CI
5/02-5/07	0.989	0.020	0.970	0.036	0.915	0.020	0.951	0.036	0.789	0.073
5/08-5/12	0.979	0.027	0.971	0.044	0.940	0.027	0.860	0.044	0.837	0.072
5/13-5/17	0.998	0.017	0.976	0.074	0.935	0.017	0.693	0.074	0.753	0.094
5/18-5/22	0.944	0.089	1.000	0.046	0.715	0.089	0.259	0.046	0.509	0.101
5/23-5/27	0.941	0.076	1.000	0.034	0.746	0.076	0.389	0.034	0.462	0.094
5/28-6/04	0.948	0.076	0.783	0.188	0.808	0.076	0.344	0.188	0.611	0.159
N-Wt Mean	0.966	0.020	0.947	0.068						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.19. Tag-life Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2 Turbine Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
Paired Release	S to Tailrace	1/2 95% CI
5/02-5/07	0.971	0.092
5/08-5/12	0.991	0.055
5/13-5/17	0.978	0.042
5/18-5/22	0.944	0.147
5/23-5/27	0.979	0.135
5/28-6/04	0.943	0.253
N-Wt Mean	0.979	0.037

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

C.2.5 Bonneville Juvenile Bypass Survival

Table C.20. Detection Histories for Yearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2 JBS Survival[a]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/16	72	1	15	1	23	0	4	4	120
5/17-6/04	14	3	9	3	8	1	11	2	51
Pooled	86	4	24	4	31	1	15	6	171

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.21. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Virtual Releases at B2 JBS Based on Three Downstream Arrays[a]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/16	0.976	0.036	1.000	0.021	0.982	0.036	0.827	0.021	0.770	0.078
5/17-6/04	1.000	0.032	0.870	0.182	0.824	0.032	0.586	0.182	0.654	0.183
N-Wt Mean	0.983	0.022	0.961	0.117						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.22. Detection Histories for Yearling Chinook Salmon Smolts Released in the Upper BON Tailwater as Reference Releases for B2 JBS Survival[a]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/16	223	15	36	3	56	3	17	6	359
5/17-6/04	47	16	97	34	52	11	107	55	419
Pooled	270	31	133	37	108	14	124	61	778

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.23. Tag-life Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2 JBS Survival. Releases were in the Upper BON Tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/16	0.987	0.014	0.976	0.027	0.938	0.014	0.859	0.027	0.804	0.045
5/17-6/04	0.948	0.044	0.977	0.146	0.763	0.044	0.325	0.146	0.500	0.087
N-Wt Mean	0.966	0.037	0.976	0.000						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.24. Tag-life Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2 JBS Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
5/02-5/16	0.989	0.039
5/17-6/04	1.055	0.060
N-Wt Mean	1.017	0.045

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

C.2.6 Bonneville Corner Collector Specific Release Survival

Table C.25. Detection Histories for Yearling Chinook Salmon Smolts Detected and Regrouped to Form Releases in Spring for Estimating B2CC Specific Survival[a]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
4/30-5/01	34	1	3	0	8	0	1	1	48
5/02-5/03	35	0	2	0	8	0	2	0	47
5/04-5/05	35	1	1	0	9	0	1	0	47
5/06-5/07	25	1	8	0	4	0	3	1	42
5/08-5/09	30	4	4	0	8	1	5	2	54
5/10-5/11	34	0	5	1	8	0	1	0	49
5/12-5/13	31	4	3	0	7	0	1	1	47
5/14-5/15	23	0	7	2	11	0	5	1	49
5/16-5/17	24	3	8	1	4	3	3	2	48
5/18-5/19	7	1	9	5	2	0	7	5	36
5/20-5/21	4	3	16	4	7	4	15	5	58
5/22-5/23	6	3	18	3	10	2	9	8	59
5/24-5/25	5	1	18	3	8	0	12	6	53
5/26-5/27	4	4	10	5	8	2	9	6	48
5/28-5/29	1	1	9	7	4	1	20	5	48
5/30-5/31	2	2	13	4	5	0	18	4	48
6/01-6/02	7	3	8	1	7	1	13	5	45
Pooled	307	32	142	36	118	14	125	52	826

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.26. Tag-life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Specific Releases at B2CC, Based on Three Downstream Arrays [(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
4/30-5/01	0.983	0.041	0.993	0.047	0.978	0.041	0.921	0.047	0.822	0.117
5/02-5/03	1.000	0.000	0.967	0.060	1.000	0.000	0.946	0.060	0.819	0.117
5/04-5/05	1.000	0.013	0.985	0.043	0.979	0.013	0.973	0.043	0.805	0.118
5/06-5/07	0.979	0.046	0.955	0.092	0.974	0.046	0.765	0.092	0.871	0.122
5/08-5/09	0.974	0.053	0.914	0.093	0.894	0.053	0.895	0.093	0.794	0.122
5/10-5/11	1.000	0.013	1.000	0.026	0.980	0.013	0.857	0.026	0.817	0.109
5/12-5/13	0.981	0.042	0.989	0.050	0.911	0.042	0.921	0.050	0.835	0.113
5/14-5/15	0.985	0.041	0.981	0.129	0.954	0.041	0.719	0.129	0.677	0.157
5/16-5/17	0.971	0.060	0.973	0.102	0.837	0.060	0.750	0.102	0.794	0.136
5/18-5/19	0.926	0.142	0.825	0.261	0.750	0.142	0.364	0.261	0.801	0.248
5/20-5/21	1.000	0.029	1.000	0.045	0.724	0.029	0.310	0.045	0.466	0.129
5/22-5/23	0.915	0.102	1.000	0.028	0.797	0.102	0.389	0.028	0.556	0.140
5/24-5/25	0.922	0.097	1.000	0.037	0.880	0.097	0.286	0.037	0.552	0.145
5/26-5/27	1.000	0.000	1.000	0.062	0.646	0.000	0.375	0.062	0.479	0.142
5/28-5/29	1.000	0.022	1.000	0.080	0.708	0.022	0.146	0.080	0.375	0.138
5/30-5/31	1.000	0.035	0.984	0.648	0.792	0.035	0.191	0.648	0.444	0.325
6/01-6/02	0.955	0.121	0.796	0.271	0.815	0.121	0.526	0.271	0.556	0.230
N-Wt Mean	0.976	0.014	0.966	0.028						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.27. Detection Histories for Yearling Chinook Salmon Smolts Released in the Upper BON Tailwater as Reference Releases for B2CC Specific Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
4/30-5/01	37	2	1	0	8	0	0	0	48
5/02-5/03	34	1	1	0	8	1	1	1	47
5/04-5/05	36	1	0	0	8	1	1	1	48
5/06-5/07	22	4	2	2	8	1	3	0	42
5/08-5/09	27	4	7	1	7	0	5	2	53
5/10-5/11	33	2	4	0	8	0	1	1	49
5/12-5/13	33	1	3	0	8	0	2	1	48
5/14-5/15	23	1	13	0	7	0	4	0	48
5/16-5/17	21	2	10	3	7	0	5	0	48
5/18-5/19	3	1	11	1	2	1	7	2	28
5/20-5/21	5	1	13	9	7	2	15	12	64
5/22-5/23	5	2	15	3	7	3	15	11	61
5/24-5/25	5	1	10	7	8	1	12	9	53
5/26-5/27	7	4	10	3	10	3	8	3	48
5/28-5/29	6	3	8	5	4	1	16	5	48
5/30-5/31	3	1	16	1	5	0	13	9	48
6/01-6/02	7	2	10	2	4	0	16	4	45
Pooled	307	33	134	37	116	14	124	61	826

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P < 0.0010).

Table C.28. Tag-Life-Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2CC Specific Survival[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
4/30-5/01	1.000	0.000	1.000	0.000	0.958	0.000	0.979	0.000	0.838	0.106
5/02-5/03	0.980	0.041	0.983	0.046	0.956	0.041	0.972	0.046	0.803	0.120
5/04-5/05	0.980	0.040	0.978	0.043	0.957	0.040	1.000	0.043	0.807	0.115
5/06-5/07	1.000	0.014	0.962	0.090	0.833	0.014	0.867	0.090	0.747	0.146
5/08-5/09	0.974	0.054	0.926	0.100	0.891	0.054	0.795	0.100	0.818	0.123
5/10-5/11	0.981	0.040	0.997	0.049	0.957	0.040	0.897	0.049	0.817	0.117
5/12-5/13	0.980	0.040	0.972	0.063	0.978	0.040	0.919	0.063	0.810	0.119
5/14-5/15	1.000	0.013	0.996	0.114	0.979	0.013	0.649	0.114	0.774	0.147
5/16-5/17	1.000	0.013	0.978	0.123	0.896	0.013	0.639	0.123	0.767	0.151
5/18-5/19	0.977	0.118	1.000	0.150	0.841	0.118	0.256	0.150	0.586	0.200
5/20-5/21	0.938	0.144	1.000	0.055	0.667	0.144	0.250	0.055	0.467	0.142
5/22-5/23	0.898	0.124	1.000	0.061	0.766	0.124	0.310	0.061	0.456	0.142
5/24-5/25	0.931	0.140	1.000	0.053	0.710	0.140	0.304	0.053	0.466	0.152
5/26-5/27	1.000	0.043	1.000	0.043	0.729	0.043	0.500	0.043	0.500	0.142
5/28-5/29	1.000	0.029	0.713	0.250	0.708	0.029	0.409	0.250	0.643	0.251
5/30-5/31	0.837	0.119	1.000	0.063	0.921	0.119	0.224	0.063	0.523	0.159
6/01-6/02	0.979	0.118	0.689	0.246	0.840	0.118	0.429	0.246	0.692	0.251
N-Wt Mean	0.966	0.021	0.954	0.045						

(a) Releases were in the upper Bonneville tailwater. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.29. Tag-Life-Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Reference Releases for B2CC-Specific Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
4/30-5/01	0.983	0.041
5/02-5/03	1.020	0.043
5/04-5/05	1.020	0.044
5/06-5/07	0.979	0.048
5/08-5/09	1.000	0.077
5/10-5/11	1.020	0.043
5/12-5/13	1.001	0.059
5/14-5/15	0.985	0.042
5/16-5/17	0.971	0.061
5/18-5/19	0.948	0.185
5/20-5/21	1.067	0.166
5/22-5/23	1.018	0.181
5/24-5/25	0.991	0.182
5/26-5/27	1.000	0.043
5/28-5/29	1.000	0.037
5/30-5/31	1.195	0.175
6/01-6/02	0.975	0.170
N-Wt Mean	1.011	0.027

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

C.3 Detection and Survival of Juvenile Steelhead in Spring

C.3.1 Bonneville Second Powerhouse Specific Survival

Table C.30. Detection Histories for Steelhead Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2 Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/06	73	5	1	0	41	1	1	3	125
5/07-5/08	58	6	5	0	17	1	2	2	91
5/09-5/10	58	4	21	2	21	4	8	2	120
5/11-5/12	76	3	14	1	38	1	5	1	139
5/13-5/14	58	4	8	0	41	3	1	1	116
5/15-5/16	23	1	12	0	13	0	4	1	54
5/17-5/18	17	2	10	2	8	1	14	4	58
5/19-5/20	10	1	7	1	5	1	16	6	47
5/21-5/22	4	4	5	1	8	0	8	2	32
5/23-5/24	3	2	1	1	5	0	8	2	22
5/25-5/26	3	0	7	0	9	2	14	1	36
5/27-5/28	8	1	8	1	5	0	17	8	48
5/29-6/04	7	0	4	1	6	1	13	3	35
Pooled	398	33	103	10	217	15	111	36	923

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.31. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Steelhead in Virtual Releases at B2 Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	1.000	0.019	1.000	0.000	0.951	0.019	0.983	0.000	0.648	0.085
5/07-5/08	0.990	0.034	1.000	0.001	0.920	0.034	0.920	0.001	0.781	0.087
5/09-5/10	1.000	0.008	1.000	0.000	0.909	0.008	0.733	0.000	0.716	0.082
5/11-5/12	0.998	0.015	1.000	0.000	0.962	0.015	0.853	0.000	0.680	0.078
5/13-5/14	0.995	0.017	1.000	0.000	0.937	0.017	0.920	0.000	0.608	0.089
5/15-5/16	0.984	0.036	1.000	0.000	0.979	0.036	0.697	0.000	0.678	0.126
5/17-5/18	0.966	0.077	0.821	0.173	0.875	0.077	0.613	0.173	0.683	0.174
5/19-5/20	0.920	0.117	0.679	0.218	0.880	0.117	0.579	0.218	0.647	0.227
5/21-5/22	1.000	0.050	0.875	0.304	0.781	0.050	0.571	0.304	0.500	0.245
5/23-5/24	1.000	0.053	0.636	0.292	0.773	0.053	0.714	0.292	0.500	0.310
5/25-5/26	1.000	0.028	1.000	0.061	0.917	0.028	0.389	0.061	0.278	0.147
5/27-5/28	0.867	0.121	0.673	0.241	0.913	0.121	0.500	0.241	0.643	0.251
5/29-6/04	0.958	0.118	0.716	0.295	0.895	0.118	0.583	0.295	0.500	0.262
N-Wt Mean	0.982	0.019	0.932	0.069						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

C.3.2 Bonneville Corner Collector Survival

Table C.32. Detection Histories for Steelhead Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2CC Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/06	44	4	1	0	32	1	1	2	85
5/07-5/10	91	10	22	2	27	3	7	2	164
5/11-5/14	109	5	10	0	63	4	5	2	198
5/15-5/18	35	2	17	1	18	1	13	2	89
5/19-5/22	13	3	10	2	10	1	17	5	61
5/23-5/26	3	2	4	0	11	2	17	3	42
5/27-5/30	10	1	10	1	8	0	16	8	54
Pooled	305	27	74	6	169	12	76	24	693

(a) 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 (BTW1, BTW2, and BTW3, respectively. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).
BTW = Bonneville tailwater

Table C.33. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Steelhead in Virtual Releases at B2CC Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/06	1.000	0.070	1.000	0.001	0.939	0.070	0.975	0.001	0.590	0.105
5/07-5/10	1.000	0.017	1.000	0.003	0.904	0.017	0.807	0.003	0.772	0.058
5/11-5/14	0.993	0.015	1.000	0.021	0.953	0.015	0.922	0.021	0.632	0.068
5/15-5/18	0.986	0.033	0.952	0.114	0.946	0.033	0.673	0.114	0.663	0.124
5/19-5/22	0.969	0.087	0.800	0.203	0.846	0.087	0.571	0.203	0.593	0.185
5/23-5/26	1.000	0.000	0.771	0.404	0.834	0.000	0.556	0.404	0.278	0.207
5/27-5/30	0.873	0.102	0.806	0.250	0.933	0.102	0.500	0.250	0.579	0.222
N-Wt Mean	0.984	0.027	0.947	0.068						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

C.3.3 Bonneville Second Powerhouse Turbine Survival

Table C.34. Detection Histories for Steelhead Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2 Turbines Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/16	43	2	12	1	21	1	3	2	85
5/17-6/04	5	0	5	2	5	1	22	6	46
Pooled	48	2	17	3	26	2	25	8	131

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.35. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Steelhead in Virtual Releases at B2 Turbines Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/16	0.991	0.036	1.000	0.000	0.949	0.036	0.805	0.000	0.698	0.099
5/17-6/04	0.965	0.163	0.595	0.341	0.833	0.163	0.417	0.341	0.455	0.294
N-Wt Mean	0.982	0.024	0.858	0.379						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

C.3.4 Bonneville Juvenile Bypass Survival

Table C.36. Detection Histories for Steelhead Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2 JBS Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
5/02-5/15	37	1	4	0	15	1	2	1	61
5/16-6/04	8	3	8	1	7	0	8	3	38
Pooled	45	4	12	1	22	1	10	4	99

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

Table C.37. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Steelhead in Virtual Releases at the B2 JBS Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
5/02-5/15	1.000	0.012	0.992	0.058	0.965	0.012	0.905	0.058	0.705	0.122
5/16-6/04	0.959	0.100	0.898	0.253	0.852	0.100	0.550	0.253	0.613	0.226
N-Wt Mean	0.984	0.039	0.956	0.090						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

C.4 Detection and Survival of Subyearling Chinook Salmon in Summer

C.4.1 Bonneville Dam Survival

Table C.38. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Lower Columbia Released Subyearling Chinook Salmon in Virtual Releases at the Bonneville Forebay Array Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	0.967	0.028	1.000	0.019	0.853	0.028	0.647	0.019	0.713	0.058
6/19-6/20	0.977	0.020	1.000	0.000	0.859	0.020	0.613	0.000	0.732	0.047
6/21-6/22	0.953	0.024	1.000	0.000	0.930	0.024	0.654	0.000	0.847	0.040
6/23-6/24	0.982	0.019	0.982	0.052	0.893	0.019	0.597	0.052	0.753	0.058
6/25-6/26	0.970	0.020	0.994	0.039	0.861	0.020	0.692	0.039	0.764	0.050
6/27-6/28	0.971	0.025	0.992	0.040	0.858	0.025	0.777	0.040	0.688	0.054
6/29-6/30	0.945	0.027	1.000	0.000	0.908	0.027	0.770	0.000	0.718	0.053
7/01-7/02	0.965	0.023	1.000	0.000	0.895	0.023	0.718	0.000	0.715	0.048
7/03-7/04	0.953	0.023	0.979	0.024	0.941	0.023	0.900	0.024	0.782	0.046
7/05-7/06	0.954	0.022	0.988	0.014	0.950	0.022	0.982	0.014	0.809	0.042
7/07-7/08	0.945	0.024	1.000	0.000	0.919	0.024	0.949	0.000	0.836	0.040
7/09-7/10	0.917	0.029	0.995	0.012	0.898	0.029	0.960	0.012	0.869	0.038
7/11-7/12	0.920	0.028	0.992	0.014	0.939	0.028	0.944	0.014	0.876	0.036
7/13-7/14	0.935	0.026	0.987	0.013	0.997	0.026	0.983	0.013	0.873	0.036
7/15-7/17	0.895	0.055	0.981	0.027	0.953	0.055	1.000	0.027	0.748	0.083
N-Wt Mean	0.953	0.011	0.993	0.004						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.39. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Lower Columbia Released Subyearling Chinook Salmon in Virtual Releases at the Bonneville Forebay Array Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	0.994	0.054	0.895	0.160	0.872	0.054	0.525	0.160	0.750	0.161
6/19-6/20	0.988	0.064	1.000	0.023	0.726	0.064	0.523	0.023	0.709	0.123
6/21-6/22	1.000	0.011	1.000	0.086	0.900	0.011	0.583	0.086	0.718	0.118
6/23-6/24	0.948	0.066	1.000	0.039	0.896	0.066	0.422	0.039	0.739	0.118
6/25-6/26	0.965	0.090	0.759	0.201	0.861	0.090	0.556	0.201	0.625	0.194
6/27-6/28	0.992	0.053	0.905	0.135	0.857	0.053	0.650	0.135	0.743	0.145
6/29-6/30	1.000	0.024	1.000	0.020	0.833	0.024	0.650	0.020	0.650	0.121
7/01-7/02	0.978	0.048	0.997	0.162	0.920	0.048	0.564	0.162	0.667	0.161
7/03-7/04	0.987	0.033	1.000	0.028	0.912	0.033	0.827	0.028	0.743	0.112
7/05-7/06	1.000	0.011	0.991	0.055	0.933	0.011	0.925	0.055	0.673	0.124
7/07-7/08	0.986	0.033	0.995	0.043	0.845	0.033	0.917	0.043	0.815	0.104
7/09-7/10	0.986	0.033	1.000	0.000	0.845	0.033	0.913	0.000	0.794	0.103
7/11-7/12	0.973	0.047	0.986	0.063	0.839	0.047	0.816	0.063	0.851	0.102
7/13-7/14	0.984	0.032	0.995	0.039	0.966	0.032	0.954	0.039	0.732	0.116
7/15-7/17	0.962	0.042	0.978	0.037	1.000	0.042	0.982	0.037	0.740	0.101
N-Wt Mean	0.982	0.008	0.967	0.033						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

C.4.2 Bonneville Second Powerhouse Specific Survival

Table C.40. Detection Histories for Subyearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in spring for Estimating B2 Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/18	28	2	14	2	16	5	4	5	76
6/19-6/20	49	6	35	6	30	2	12	3	143
6/21-6/22	54	7	23	1	13	1	4	6	109
6/23-6/24	62	11	36	3	18	2	16	5	153
6/25-6/26	70	7	39	6	16	2	5	3	148
6/27-6/28	54	12	14	2	22	5	12	4	125
6/29-6/30	52	4	20	4	23	1	6	6	116
7/01-7/02	71	10	23	2	20	2	7	2	137
7/03-7/04	71	4	10	2	21	3	8	8	127
7/05-7/06	85	2	3	0	29	2	0	2	123
7/07-7/08	99	8	3	1	20	3	0	7	141
7/09-7/10	100	15	4	0	11	3	1	12	146
7/11-7/12	96	7	4	2	11	0	3	7	130
7/13-7/14	106	0	2	0	15	0	2	9	134
7/15-7/17	36	2	0	0	10	0	1	4	53
Pooled	1033	97	230	31	275	31	81	83	1861

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.41. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Virtual Releases at B2 Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	0.948	0.058	1.000	0.018	0.860	0.058	0.708	0.018	0.638	0.113
6/19-6/20	1.000	0.001	1.000	0.017	0.881	0.001	0.609	0.017	0.672	0.077
6/21-6/22	0.950	0.043	1.000	0.000	0.909	0.043	0.725	0.000	0.824	0.075
6/23-6/24	0.982	0.030	0.950	0.072	0.879	0.030	0.652	0.072	0.790	0.084
6/25-6/26	0.988	0.024	1.000	0.000	0.891	0.024	0.651	0.000	0.840	0.061
6/27-6/28	0.995	0.036	0.936	0.074	0.826	0.036	0.805	0.074	0.710	0.092
6/29-6/30	0.955	0.041	1.000	0.018	0.912	0.041	0.722	0.018	0.725	0.085
7/01-7/02	0.994	0.022	0.993	0.053	0.891	0.022	0.764	0.053	0.790	0.080
7/03-7/04	0.945	0.043	0.959	0.055	0.919	0.043	0.862	0.055	0.758	0.084
7/05-7/06	0.985	0.022	1.000	0.000	0.967	0.022	0.975	0.000	0.746	0.078
7/07-7/08	0.951	0.036	1.000	0.000	0.910	0.036	0.970	0.000	0.829	0.064
7/09-7/10	0.919	0.045	0.995	0.017	0.865	0.045	0.966	0.017	0.893	0.054
7/11-7/12	0.948	0.039	0.980	0.030	0.925	0.039	0.945	0.030	0.906	0.054
7/13-7/14	0.933	0.042	0.986	0.022	1.000	0.042	0.982	0.022	0.876	0.059
7/15-7/17	0.927	0.071	0.979	0.041	0.958	0.071	1.000	0.041	0.794	0.115
N-Wt Mean	0.964	0.014	0.985	0.011						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.42. Detection Histories for Subyearling Chinook Salmon Smolts Released in the Upper Bonneville Tailwater as Reference Releases for B2 Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/18	18	3	16	3	7	0	11	2	60
6/19-6/20	14	6	17	5	8	3	4	3	60
6/21-6/22	22	3	15	3	10	0	7	0	60
6/23-6/24	16	1	22	3	6	1	7	4	60
6/25-6/26	14	1	8	4	9	0	18	5	59
6/27-6/28	23	3	12	2	7	2	9	2	60
6/29-6/30	17	6	15	1	14	2	4	1	60
7/01-7/02	21	1	17	0	8	3	8	2	60
7/03-7/04	33	3	7	1	12	1	2	1	60
7/05-7/06	34	3	3	0	17	1	2	0	60
7/07-7/08	37	7	4	0	8	2	1	1	60
7/09-7/10	34	8	5	0	11	1	0	1	60
7/11-7/12	34	6	8	1	5	2	2	2	60
7/13-7/14	41	0	1	1	14	1	1	1	60
7/15-7/17	54	0	1	0	19	0	2	3	79
Pooled	412	51	151	24	155	19	78	28	918

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tail water

Table C.43. Tag-Life-Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Reference Releases for B2 Survival. Releases were in the upper Bonneville tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	0.994	0.054	0.895	0.160	0.872	0.054	0.525	0.160	0.750	0.161
6/19-6/20	0.988	0.064	1.000	0.023	0.726	0.064	0.523	0.023	0.709	0.123
6/21-6/22	1.000	0.011	1.000	0.086	0.900	0.011	0.583	0.086	0.718	0.118
6/23-6/24	0.948	0.066	1.000	0.039	0.896	0.066	0.422	0.039	0.739	0.118
6/25-6/26	0.965	0.090	0.759	0.201	0.861	0.090	0.556	0.201	0.625	0.194
6/27-6/28	0.992	0.053	0.905	0.135	0.857	0.053	0.650	0.135	0.743	0.145
6/29-6/30	1.000	0.024	1.000	0.020	0.833	0.024	0.650	0.020	0.650	0.121
7/01-7/02	0.978	0.048	0.997	0.162	0.920	0.048	0.564	0.162	0.667	0.161
7/03-7/04	0.987	0.033	1.000	0.028	0.912	0.033	0.827	0.028	0.743	0.112
7/05-7/06	1.000	0.011	0.991	0.055	0.933	0.011	0.925	0.055	0.673	0.124
7/07-7/08	0.986	0.033	0.995	0.043	0.845	0.033	0.917	0.043	0.815	0.104
7/09-7/10	0.986	0.033	1.000	0.000	0.845	0.033	0.913	0.000	0.794	0.103
7/11-7/12	0.973	0.047	0.986	0.063	0.839	0.047	0.816	0.063	0.851	0.102
7/13-7/14	0.984	0.032	0.995	0.039	0.966	0.032	0.954	0.039	0.732	0.116
7/15-7/17	0.962	0.042	0.978	0.037	1.000	0.042	0.982	0.037	0.740	0.101
N-Wt Mean	0.982	0.008	0.967	0.033						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.44. Tag-Life-Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Reference Releases for B2 Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
6/17-6/18	0.954	0.078
6/19-6/20	1.013	0.066
6/21-6/22	0.950	0.044
6/23-6/24	1.036	0.079
6/25-6/26	1.024	0.099
6/27-6/28	1.003	0.065
6/29-6/30	0.955	0.047
7/01-7/02	1.016	0.055
7/03-7/04	0.957	0.054
7/05-7/06	0.985	0.025
7/07-7/08	0.964	0.049
7/09-7/10	0.932	0.055
7/11-7/12	0.975	0.062
7/13-7/14	0.948	0.053
7/15-7/17	0.964	0.085
N-Wt Mean	0.981	0.016

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

C.4.3 B2CC Survival

Table C.45. Detection Histories for Subyearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2CC Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/18	8	1	7	0	9	2	3	0	30
6/19-6/20	14	3	12	1	5	0	5	0	40
6/21-6/22	9	3	6	0	5	0	2	1	26
6/23-6/24	20	5	15	0	7	0	7	0	54
6/25-6/26	21	2	13	2	2	1	4	0	45
6/27-6/28	17	6	5	1	7	1	3	0	40
6/29-6/30	14	1	6	1	5	0	3	0	30
7/01-7/02	25	3	8	0	5	0	2	0	43
7/03-7/04	23	0	5	1	7	0	2	0	38
7/05-7/06	33	1	0	0	11	0	0	0	45
7/07-7/08	49	3	2	1	14	2	0	3	74
7/09-7/10	61	5	4	0	6	1	1	6	84
7/11-7/12	60	4	3	2	3	0	2	1	75
7/13-7/14	69	0	1	0	10	0	2	5	87
7/15-7/17	21	1	0	0	5	0	1	1	29
Pooled	444	38	87	9	101	7	37	17	740

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.46. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Virtual Releases at B2CC Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	1.000	0.016	1.000	0.027	0.900	0.016	0.667	0.027	0.533	0.179
6/19-6/20	1.000	0.014	0.971	0.154	0.900	0.014	0.567	0.154	0.773	0.175
6/21-6/22	0.974	0.077	1.000	0.084	0.869	0.077	0.672	0.084	0.715	0.182
6/23-6/24	1.000	0.012	0.948	0.122	0.907	0.012	0.625	0.122	0.788	0.144
6/25-6/26	1.000	0.013	0.955	0.103	0.889	0.013	0.605	0.103	0.890	0.123
6/27-6/28	1.000	0.000	0.978	0.103	0.800	0.000	0.793	0.103	0.742	0.154
6/29-6/30	1.000	0.016	0.978	0.149	0.933	0.016	0.682	0.149	0.752	0.190
7/01-7/02	1.000	0.013	0.987	0.075	0.930	0.013	0.778	0.075	0.851	0.123
7/03-7/04	1.000	0.000	0.995	0.092	0.974	0.000	0.793	0.092	0.767	0.152
7/05-7/06	1.000	0.013	1.000	0.013	0.978	0.013	1.000	0.013	0.758	0.126
7/07-7/08	0.961	0.045	1.000	0.011	0.915	0.045	0.957	0.011	0.775	0.098
7/09-7/10	0.930	0.055	0.992	0.028	0.922	0.055	0.943	0.028	0.905	0.068
7/11-7/12	0.989	0.026	0.974	0.041	0.917	0.026	0.928	0.041	0.958	0.050
7/13-7/14	0.943	0.049	0.977	0.034	1.000	0.049	0.986	0.034	0.873	0.073
7/15-7/17	0.970	0.067	0.963	0.071	0.963	0.067	1.000	0.071	0.814	0.146
N-Wt Mean	0.978	0.014	0.981	0.008						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.47. Detection Histories for Subyearling Chinook Salmon Smolts Released in the Upper Bonneville Tailwater as Reference Releases for B2CC Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/18	18	3	16	3	7	0	11	2	60
6/19-6/20	14	6	17	5	8	3	4	3	60
6/21-6/22	22	3	15	3	10	0	7	0	60
6/23-6/24	16	1	22	3	6	1	7	4	60
6/25-6/26	14	1	8	4	9	0	18	5	59
6/27-6/28	23	3	12	2	7	2	9	2	60
6/29-6/30	17	6	15	1	14	2	4	1	60
7/01-7/02	21	1	17	0	8	3	8	2	60
7/03-7/04	33	3	7	1	12	1	2	1	60
7/05-7/06	34	3	3	0	17	1	2	0	60
7/07-7/08	37	7	4	0	8	2	1	1	60
7/09-7/10	34	8	5	0	11	1	0	1	60
7/11-7/12	34	6	8	1	5	2	2	2	60
7/13-7/14	41	0	1	1	14	1	1	1	60
7/15-7/17	54	0	1	0	19	0	2	3	79
Pooled	412	51	151	24	155	19	78	28	918

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.48. Tag-Life-Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Reference Releases for B2CC Survival. Releases were in the upper Bonneville tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	0.994	0.054	0.895	0.160	0.872	0.054	0.525	0.160	0.750	0.161
6/19-6/20	0.988	0.064	1.000	0.023	0.726	0.064	0.523	0.023	0.709	0.123
6/21-6/22	1.000	0.011	1.000	0.086	0.900	0.011	0.583	0.086	0.718	0.118
6/23-6/24	0.948	0.066	1.000	0.039	0.896	0.066	0.422	0.039	0.739	0.118
6/25-6/26	0.965	0.090	0.759	0.201	0.861	0.090	0.556	0.201	0.625	0.194
6/27-6/28	0.992	0.053	0.905	0.135	0.857	0.053	0.650	0.135	0.743	0.145
6/29-6/30	1.000	0.024	1.000	0.020	0.833	0.024	0.650	0.020	0.650	0.121
7/01-7/02	0.978	0.048	0.997	0.162	0.920	0.048	0.564	0.162	0.667	0.161
7/03-7/04	0.987	0.033	1.000	0.028	0.912	0.033	0.827	0.028	0.743	0.112
7/05-7/06	1.000	0.011	0.991	0.055	0.933	0.011	0.925	0.055	0.673	0.124
7/07-7/08	0.986	0.033	0.995	0.043	0.845	0.033	0.917	0.043	0.815	0.104
7/09-7/10	0.986	0.033	1.000	0.000	0.845	0.033	0.913	0.000	0.794	0.103
7/11-7/12	0.973	0.047	0.986	0.063	0.839	0.047	0.816	0.063	0.851	0.102
7/13-7/14	0.984	0.032	0.995	0.039	0.966	0.032	0.954	0.039	0.732	0.116
7/15-7/17	0.962	0.042	0.978	0.037	1.000	0.042	0.982	0.037	0.740	0.101
N-Wt Mean	0.982	0.008	0.967	0.033						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.49. Tag-Life-Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Yearling Chinook Salmon in Virtual Releases for B2CC Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
6/17-6/18	1.007	0.057
6/19-6/20	1.013	0.067
6/21-6/22	0.974	0.078
6/23-6/24	1.055	0.074
6/25-6/26	1.037	0.098
6/27-6/28	1.008	0.054
6/29-6/30	1.000	0.029
7/01-7/02	1.022	0.052
7/03-7/04	1.013	0.034
7/05-7/06	1.000	0.017
7/07-7/08	0.974	0.056
7/09-7/10	0.943	0.064
7/11-7/12	1.017	0.056
7/13-7/14	0.958	0.059
7/15-7/17	1.008	0.083
N-Wt Mean	0.996	0.016

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

C.4.4 B2 Turbine Survival

Table C.50. Detection Histories for Subyearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2 Turbines Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/18	18	1	7	1	7	2	1	4	41
6/19-6/20	24	3	12	5	16	2	6	3	71
6/21-6/22	34	3	14	1	5	0	1	5	63
6/23-6/24	30	2	12	2	6	1	4	4	61
6/25-6/26	29	4	17	4	8	0	0	3	65
6/27-6/28	25	3	7	1	10	1	5	4	56
6/29-6/30	22	2	8	2	11	0	3	5	53
7/01-7/02	29	5	11	1	11	1	2	2	62
7/03-7/04	34	3	4	1	10	3	5	4	64
7/05-7/06	44	1	3	0	15	2	0	2	67
7/07-7/08	37	4	1	0	5	1	0	4	52
7/09-7/10	29	5	0	0	5	0	0	5	44
7/11-7/12	26	1	1	0	6	0	1	6	41
7/13-7/17	42	0	0	0	6	0	0	5	53
Pooled	423	37	97	18	121	13	28	56	793

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.51. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Virtual Releases at B2 Turbines Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	0.910	0.092	1.000	0.020	0.885	0.092	0.751	0.020	0.724	0.145
6/19-6/20	0.979	0.051	1.000	0.025	0.835	0.051	0.648	0.025	0.634	0.116
6/21-6/22	0.923	0.067	1.000	0.000	0.929	0.067	0.723	0.000	0.897	0.080
6/23-6/24	0.942	0.063	0.977	0.091	0.906	0.063	0.696	0.091	0.824	0.121
6/25-6/26	0.963	0.052	1.000	0.000	0.865	0.052	0.657	0.000	0.868	0.087
6/27-6/28	0.947	0.072	0.953	0.110	0.894	0.072	0.778	0.110	0.718	0.141
6/29-6/30	0.913	0.080	1.000	0.000	0.910	0.080	0.724	0.000	0.705	0.130
7/01-7/02	0.977	0.045	1.000	0.000	0.877	0.045	0.761	0.000	0.766	0.110
7/03-7/04	0.953	0.062	0.934	0.087	0.873	0.062	0.881	0.087	0.740	0.122
7/05-7/06	0.972	0.041	1.000	0.000	0.953	0.041	0.953	0.000	0.740	0.107
7/07-7/08	0.923	0.073	1.000	0.013	0.896	0.073	0.979	0.013	0.876	0.094
7/09-7/10	0.887	0.094	1.000	0.015	0.872	0.094	1.000	0.015	0.873	0.105
7/11-7/12	0.855	0.108	0.978	0.059	0.971	0.108	0.964	0.059	0.820	0.132
7/13-7/17	0.906	0.079	1.000	0.000	1.000	0.079	1.000	0.000	0.877	0.094
N-Wt Mean	0.937	0.018	0.988	0.011						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.52. Detection Histories for Subyearling Chinook Salmon Smolts Released in the Upper Bonneville Tailwater as Reference Releases for B2 Turbine Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/18	18	3	16	3	7	0	11	2	60
6/19-6/20	14	6	17	5	8	3	4	3	60
6/21-6/22	22	3	15	3	10	0	7	0	60
6/23-6/24	16	1	22	3	6	1	7	4	60
6/25-6/26	14	1	8	4	9	0	18	5	59
6/27-6/28	23	3	12	2	7	2	9	2	60
6/29-6/30	17	6	15	1	14	2	4	1	60
7/01-7/02	21	1	17	0	8	3	8	2	60
7/03-7/04	33	3	7	1	12	1	2	1	60
7/05-7/06	34	3	3	0	17	1	2	0	60
7/07-7/08	37	7	4	0	8	2	1	1	60
7/09-7/10	34	8	5	0	11	1	0	1	60
7/11-7/12	34	6	8	1	5	2	2	2	60
7/13-7/17	95	0	2	1	33	1	3	4	139
Pooled	412	51	151	24	155	19	78	28	918

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant ($P < 0.0010$).

BTW = Bonneville tailwater

Table C.53. Tag-Life-Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Reference Releases for B2 Turbines Survival. Releases were in the upper Bonneville tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/18	0.994	0.054	0.895	0.160	0.872	0.054	0.525	0.160	0.750	0.161
6/19-6/20	0.988	0.064	1.000	0.023	0.726	0.064	0.523	0.023	0.709	0.123
6/21-6/22	1.000	0.011	1.000	0.086	0.900	0.011	0.583	0.086	0.718	0.118
6/23-6/24	0.948	0.066	1.000	0.039	0.896	0.066	0.422	0.039	0.739	0.118
6/25-6/26	0.965	0.090	0.759	0.201	0.861	0.090	0.556	0.201	0.625	0.194
6/27-6/28	0.992	0.053	0.905	0.135	0.857	0.053	0.650	0.135	0.743	0.145
6/29-6/30	1.000	0.024	1.000	0.020	0.833	0.024	0.650	0.020	0.650	0.121
7/01-7/02	0.978	0.048	0.997	0.162	0.920	0.048	0.564	0.162	0.667	0.161
7/03-7/04	0.987	0.033	1.000	0.028	0.912	0.033	0.827	0.028	0.743	0.112
7/05-7/06	1.000	0.011	0.991	0.055	0.933	0.011	0.925	0.055	0.673	0.124
7/07-7/08	0.986	0.033	0.995	0.043	0.845	0.033	0.917	0.043	0.815	0.104
7/09-7/10	0.986	0.033	1.000	0.000	0.845	0.033	0.913	0.000	0.794	0.103
7/11-7/12	0.973	0.047	0.986	0.063	0.839	0.047	0.816	0.063	0.851	0.102
7/13-7/14	0.984	0.032	0.995	0.039	0.966	0.032	0.954	0.039	0.732	0.116
7/15-7/17	0.962	0.042	0.978	0.037	1.000	0.042	0.982	0.037	0.740	0.101
N-Wt Mean	0.982	0.008	0.967	0.033						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.54. Tag-Life-Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Reference Releases for B2 Turbine Survival[a]

Paired Release	S to Tailrace	1/2 95% CI
6/17-6/18	0.916	0.105
6/19-6/20	0.991	0.082
6/21-6/22	0.923	0.068
6/23-6/24	0.994	0.096
6/25-6/26	0.998	0.108
6/27-6/28	0.954	0.088
6/29-6/30	0.913	0.083
7/01-7/02	0.998	0.067
7/03-7/04	0.965	0.071
7/05-7/06	0.972	0.042
7/07-7/08	0.936	0.080
7/09-7/10	0.899	0.100
7/11-7/12	0.879	0.119
N-Wt Mean	0.954	0.02

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

C.4.5 Bonneville JBS Survival

Table C.55. Detection Histories for Subyearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2 JBS Survival[a]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/19	8	0	8	1	4	1	1	1	24
6/20-6/22	16	1	6	0	8	1	1	0	33
6/23-6/25	25	5	15	1	9	2	6	1	64
6/26-6/28	19	3	5	0	7	3	4	0	41
6/29-7/01	25	2	8	1	9	2	2	1	50
7/02-7/04	22	2	3	1	6	0	2	4	40
7/05-7/07	19	0	0	0	4	0	0	0	23
7/08-7/10	12	6	0	0	0	2	0	1	21
7/11-7/13	12	2	1	0	2	0	0	1	18
7/14-7/17	8	1	0	0	4	0	0	1	14
Pooled	166	22	46	4	53	11	16	10	328

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).
BTW = Bonneville tailwater

Table C.56. Tag-Life-Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Virtual Releases at B2 JBS Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/19	0.970	0.083	1.000	0.025	0.903	0.083	0.559	0.025	0.732	0.184
6/20-6/22	1.000	0.000	1.000	0.000	0.939	0.000	0.788	0.000	0.697	0.157
6/23-6/25	1.000	0.054	0.983	0.120	0.860	0.054	0.652	0.120	0.736	0.136
6/26-6/28	1.000	0.014	0.959	0.114	0.854	0.014	0.815	0.114	0.691	0.161
6/29-7/01	0.987	0.040	1.000	0.000	0.892	0.040	0.771	0.000	0.733	0.126
7/02-7/04	0.907	0.094	0.967	0.091	0.912	0.094	0.857	0.091	0.801	0.143
7/05-7/07	1.000	0.018	1.000	0.018	1.000	0.018	1.000	0.018	0.827	0.155
7/08-7/10	0.952	0.091	1.000	0.025	0.600	0.091	1.000	0.025	0.902	0.132
7/11-7/13	0.945	0.106	1.000	0.023	0.882	0.106	0.940	0.023	0.882	0.154
7/14-7/17	0.929	0.135	1.000	0.025	0.923	0.135	1.000	0.025	0.698	0.253
N-Wt Mean	0.975	0.021	0.987	0.010						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.57. Detection Histories for Subyearling Chinook Salmon Smolts Released in the Upper BON Tailwater as Reference Releases for B2 JBS Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/17-6/19	25	6	23	5	13	2	13	3	90
6/20-6/22	29	6	25	6	12	1	9	2	90
6/23-6/25	21	1	26	6	10	1	19	5	89
6/26-6/28	32	4	16	3	12	2	15	6	90
6/29-7/01	29	6	25	1	17	4	6	2	90
7/02-7/04	42	4	14	1	17	2	8	2	90
7/05-7/07	53	5	5	0	23	2	2	0	90
7/08-7/10	52	13	7	0	13	2	1	2	90
7/11-7/13	50	6	9	2	14	3	3	2	89
7/14-7/17	79	0	1	0	24	0	2	4	110
Pooled	412	51	151	24	155	19	78	28	918

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.58. Tag-Life-Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for subyearling Chinook Salmon in Reference Releases for B2 JBS Survival. Releases were in the upper Bonneville tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/17-6/19	0.997	0.045	0.975	0.145	0.824	0.045	0.525	0.145	0.674	0.135
6/20-6/22	1.000	0.000	1.000	0.061	0.833	0.000	0.533	0.061	0.734	0.092
6/23-6/25	0.974	0.055	0.935	0.186	0.877	0.055	0.407	0.186	0.667	0.161
6/26-6/28	0.958	0.057	0.886	0.118	0.870	0.057	0.655	0.118	0.720	0.124
6/29-7/01	1.000	0.000	1.000	0.018	0.856	0.000	0.622	0.018	0.678	0.096
7/02-7/04	0.986	0.032	0.971	0.085	0.913	0.032	0.754	0.085	0.708	0.111
7/05-7/07	1.000	0.009	1.000	0.033	0.922	0.009	0.922	0.033	0.700	0.095
7/08-7/10	0.981	0.031	1.000	0.000	0.827	0.031	0.906	0.000	0.816	0.082
7/11-7/13	0.983	0.032	0.999	0.054	0.869	0.032	0.836	0.054	0.767	0.097
7/14-7/17	0.964	0.035	0.984	0.027	1.000	0.035	0.988	0.027	0.767	0.082
N-Wt Mean	0.984	0.010	0.975	0.023						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.59. Tag-Life-Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for subyearling Chinook Salmon in Reference Releases for B2 JBS Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
6/17-6/19	0.972	0.094
6/20-6/22	1.000	0.000
6/23-6/25	1.027	0.081
6/26-6/28	1.044	0.064
6/29-7/01	0.987	0.040
7/02-7/04	0.919	0.100
7/05-7/07	1.000	0.020
7/08-7/10	0.971	0.098
7/11-7/13	0.962	0.112
7/14-7/17	0.964	0.144
N-Wt Mean	0.991	0.024

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

C.4.6 B2CC-Specific Release Survival

Table C.60. Detection Histories for Subyearling Chinook Salmon Smolts Detected and Regrouped to Form Virtual Releases in Spring for Estimating B2CC-Specific Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/15-6/16	22	2	12	1	6	3	5	1	52
6/17-6/18	12	3	19	6	7	3	7	3	60
6/19-6/20	22	5	13	2	7	1	9	1	60
6/21-6/22	17	4	16	1	7	1	11	3	60
6/23-6/24	13	2	16	4	7	1	14	3	60
6/25-6/26	14	3	16	4	11	4	6	2	60
6/27-6/28	16	4	12	7	7	4	10	1	61
6/29-6/30	30	6	12	0	4	3	5	0	60
7/01-7/02	19	2	15	2	13	3	6	0	60
7/03-7/04	22	5	9	0	16	1	7	0	60
7/05-7/06	34	5	2	1	15	1	1	0	59
7/07-7/08	33	4	9	2	10	1	2	0	61
7/09-7/10	35	9	5	2	5	1	2	1	60
7/11-7/12	38	4	2	1	10	2	2	1	60
7/13-7/14	41	2	3	0	10	1	1	2	60
7/15-7/16	38	1	0	0	12	0	0	2	53
7/17-7/19	53	0	0	0	18	0	1	2	74
Pooled	459	61	161	33	165	30	89	22	1020

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.61. Tag-Life Corrected, Single-Release Estimates of Dam (Concrete) Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Virtual Releases at B2CC-Specific Survival Based on Three Downstream Arrays[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/15-6/16	0.997	0.042	0.983	0.132	0.870	0.042	0.649	0.132	0.727	0.152
6/17-6/18	0.998	0.068	1.000	0.029	0.752	0.068	0.418	0.029	0.669	0.128
6/19-6/20	1.000	0.019	0.907	0.122	0.850	0.019	0.643	0.122	0.771	0.139
6/21-6/22	0.978	0.063	0.895	0.162	0.870	0.063	0.553	0.162	0.724	0.163
6/23-6/24	0.995	0.072	0.899	0.226	0.837	0.072	0.429	0.226	0.652	0.195
6/25-6/26	1.000	0.028	1.000	0.022	0.783	0.028	0.533	0.022	0.617	0.123
6/27-6/28	1.000	0.014	0.991	0.182	0.738	0.014	0.513	0.182	0.645	0.168
6/29-6/30	1.000	0.011	0.956	0.082	0.850	0.011	0.750	0.082	0.837	0.110
7/01-7/02	1.000	0.011	1.000	0.021	0.883	0.011	0.617	0.021	0.633	0.122
7/03-7/04	1.000	0.011	0.978	0.121	0.900	0.011	0.750	0.121	0.614	0.144
7/05-7/06	1.000	0.011	1.000	0.028	0.881	0.011	0.932	0.028	0.712	0.116
7/07-7/08	1.000	0.011	1.000	0.021	0.885	0.011	0.787	0.021	0.787	0.103
7/09-7/10	0.992	0.035	0.974	0.061	0.790	0.035	0.863	0.061	0.880	0.090
7/11-7/12	0.988	0.033	0.976	0.056	0.877	0.033	0.933	0.056	0.778	0.111
7/13-7/14	0.968	0.045	0.995	0.040	0.947	0.045	0.935	0.040	0.796	0.107
7/15-7/16	0.962	0.051	1.000	0.012	0.980	0.051	1.000	0.012	0.765	0.116
7/17-7/19	0.973	0.037	0.986	0.027	1.000	0.037	1.000	0.027	0.747	0.101
N-Wt Mean	0.991	0.006	0.973	0.018						

(a) 'Lambda' is the product of survival and detection probabilities for the third array, and CI = confidence interval. The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.62. Detection Histories for Subyearling Chinook Salmon Smolts Released in the Upper Bonneville Tailwater as Reference Releases for B2CC-Specific Survival[(a)]

Date	P_111	P_011	P_101	P_001	P_110	P_010	P_100	P_000	Total
6/15-6/16	21	2	12	2	8	2	4	1	52
6/17-6/18	18	3	16	3	7	0	11	2	60
6/19-6/20	14	6	17	5	8	3	4	3	60
6/21-6/22	22	3	15	3	10	0	7	0	60
6/23-6/24	16	1	22	3	6	1	7	4	60
6/25-6/26	14	1	8	4	9	0	18	5	59
6/27-6/28	23	3	12	2	7	2	9	2	60
6/29-6/30	17	6	15	1	14	2	4	1	60
7/01-7/02	21	1	17	0	8	3	8	2	60
7/03-7/04	33	3	7	1	12	1	2	1	60
7/05-7/06	34	3	3	0	17	1	2	0	60
7/07-7/08	37	7	4	0	8	2	1	1	60
7/09-7/10	34	8	5	0	11	1	0	1	60
7/11-7/12	34	6	8	1	5	2	2	2	60
7/13-7/14	41	0	1	1	14	1	1	1	60
7/15-7/16	37	0	1	0	12	0	1	3	54
7/17-7/19	53	0	4	0	15	0	1	2	75
Pooled	469	53	167	26	171	21	82	31	1020

(a) 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 (BTW1, BTW2, and BTW3, respectively). A chi-square test for homogeneity, excluding pooled estimates, columns with < 5 pooled detections, and totals, was significant (P <0.0010).

BTW = Bonneville tailwater

Table C.63. Tag-Life Corrected, Single-Release Estimates of Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Reference Releases for B2CC-Specific Survival. Releases were in the upper Bonneville tailwater[(a)]

Virtual Release Dates	S to 1st Array	1/2 95% CI	S from 1st to 2nd Array	1/2 95% CI	Detect. Prob. To 1st Array	1/2 95% CI	Detect. Prob. from 1st to 2nd Array	1/2 95% CI	Lambda	1/2 95% CI
6/15-6/16	0.994	0.040	1.000	0.035	0.871	0.040	0.639	0.035	0.718	0.126
6/17-6/18	0.994	0.054	0.895	0.160	0.872	0.054	0.525	0.160	0.750	0.161
6/19-6/20	0.988	0.064	1.000	0.023	0.726	0.064	0.523	0.023	0.709	0.123
6/21-6/22	1.000	0.011	1.000	0.086	0.900	0.011	0.583	0.086	0.718	0.118
6/23-6/24	0.948	0.066	1.000	0.039	0.896	0.066	0.422	0.039	0.739	0.118
6/25-6/26	0.965	0.090	0.759	0.201	0.861	0.090	0.556	0.201	0.625	0.194
6/27-6/28	0.992	0.053	0.905	0.135	0.857	0.053	0.650	0.135	0.743	0.145
6/29-6/30	1.000	0.024	1.000	0.020	0.833	0.024	0.650	0.020	0.650	0.121
7/01-7/02	0.978	0.048	0.997	0.162	0.920	0.048	0.564	0.162	0.667	0.161
7/03-7/04	0.987	0.033	1.000	0.028	0.912	0.033	0.827	0.028	0.743	0.112
7/05-7/06	1.000	0.011	0.991	0.055	0.933	0.011	0.925	0.055	0.673	0.124
7/07-7/08	0.986	0.033	0.995	0.043	0.845	0.033	0.917	0.043	0.815	0.104
7/09-7/10	0.986	0.033	1.000	0.000	0.845	0.033	0.913	0.000	0.794	0.103
7/11-7/12	0.973	0.047	0.986	0.063	0.839	0.047	0.816	0.063	0.851	0.102
7/13-7/14	0.984	0.032	0.995	0.039	0.966	0.032	0.954	0.039	0.732	0.116
7/15-7/16	0.944	0.061	0.987	0.040	1.000	0.061	0.974	0.040	0.755	0.120
7/17-7/19	0.973	0.036	1.000	0.000	1.000	0.036	0.932	0.000	0.781	0.095
N-Wt Mean	0.982	0.008	0.971	0.030						

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates.

Table C.64. Tag-life Corrected, Paired-Release Estimates of Survival (S) and Detection Probabilities for Subyearling Chinook Salmon in Reference Releases for B2CC-Specific Release Survival[(a)]

Paired Release	S to Tailrace	1/2 95% CI
6/15-6/16	1.003	0.058
6/17-6/18	1.004	0.088
6/19-6/20	1.013	0.068
6/21-6/22	0.978	0.064
6/23-6/24	1.050	0.105
6/25-6/26	1.037	0.101
6/27-6/28	1.008	0.056
6/29-6/30	1.000	0.027
7/01-7/02	1.022	0.052
7/03-7/04	1.013	0.036
7/05-7/06	1.000	0.016
7/07-7/08	1.014	0.036
7/09-7/10	1.006	0.049
7/11-7/12	1.015	0.060
7/13-7/14	0.983	0.056
7/15-7/16	1.019	0.086
7/17-7/19	1.000	0.053
N-Wt Mean	1.009	0.010

(a) The N-Wt Mean (weighted by numbers of fish in virtual releases) is preferred over the pooled estimate when capture histories are not homogeneous and some variance estimates approach zero, which would overly weight high survival estimates. A chi-square test for homogeneity, excluding pooled estimates, columns with <5 pooled detections, and totals, was significant ($P < 0.0010$).

Appendix D

Burnham Tests

Appendix D

Burnham Tests

Table D.1. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release Recapture Data for Yearling Chinook Salmon Smolts Passing Through B2[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test*	
	Test 2.2	Test 3.1
5/02-5/06	0.1407	0.5793
5/07-5/08	0.3637	1.0000
5/09-5/10	0.2903	0.5631
5/11-5/12	0.2606	0.3007
5/13-5/14	0.2727	0.5486
5/15-5/16	1.0000	1.0000
5/17-5/18	1.0000	0.6386
5/19-5/20	0.6424	1.0000
5/21-5/22	0.0425	1.0000
5/23-5/24	0.3667	1.0000
5/25-5/26	0.4306	1.0000
5/27-5/28	0.6724	1.0000
5/29-6/04	0.2256	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.2. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Yearling Chinook Salmon Smolts Passing Through the Bonneville Tailwater[a]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/06	0.2241	0.3705
5/07-5/08	0.2368	1.0000
5/09-5/10	1.0000	1.0000
5/11-5/12	1.0000	1.0000
5/13-5/14	1.0000	1.0000
5/15-5/16	1.0000	1.0000
5/17-5/18	0.0877	1.0000
5/19-5/20	1.0000	0.5804
5/21-5/22	1.0000	0.2448
5/23-5/24	1.0000	1.0000
5/25-5/26	0.4951	0.3378
5/27-5/28	1.0000	0.2445
5/29-6/04	1.0000	0.3295

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.3. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Yearling Chinook Salmon Smolts Passing Through B2 Turbines[a]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/07	0.2529	1.0000
5/08-5/12	0.0842	1.0000
5/13-5/17	1.0000	0.5694
5/18-5/22	0.0256	NC
5/23-5/27	1.0000	1.0000
5/28-6/04	0.5804	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.4. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Yearling Chinook Salmon Smolts Passing Through the B2 JBS[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/16	0.2664	1.0000
5/17-6/04	0.6560	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.5. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Yearling Chinook Salmon Smolts Detected Passing through the B2CC[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/08	1.0000	1.0000
5/09-5/12	0.4668	0.4549
5/13-5/16	0.3301	1.0000
5/17-5/20	1.0000	0.3437
5/21-5/24	1.0000	1.0000
5/25-6/04	0.4719	0.6722

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture.

Table D.6. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Yearling Chinook Salmon Smolts Released into the B2CC[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
4/30-5/01	1.0000	1.0000
5/02-5/03	NC	1.0000
5/04-5/05	1.0000	1.0000
5/06-5/07	1.0000	1.0000
5/08-5/09	1.0000	1.0000
5/10-5/11	0.125	NC
5/12-5/13	1.0000	1.0000
5/14-5/15	0.0399	NC
5/16-5/17	1.0000	0.0857
5/18-5/19	0.3408	1.0000
5/20-5/21	0.2877	1.0000
5/22-5/23	0.6965	0.6108
5/24-5/25	0.6350	0.4286
5/26-5/27	1.0000	0.3213
5/28-5/29	0.657	1.0000
5/30-5/31	1.0000	0.1667
6/01-6/02	0.6361	0.5882

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.7. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Steelhead Smolts Passing Through B2[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/06	1.0000	0.6638
5/07-5/08	1.0000	0.5184
5/09-5/10	1.0000	0.2193
5/11-5/12	0.4556	1.0000
5/13-5/14	1.0000	1.0000
5/15-5/16	1.0000	1.0000
5/17-5/18	0.6266	1.0000
5/19-5/20	1.0000	1.0000
5/21-5/22	1.0000	0.0769
5/23-5/24	0.4545	0.4444
5/25-5/26	0.5333	1.0000
5/27-5/28	1.0000	1.0000
5/29-6/04	0.4678	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture.

Table D.8. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Steelhead Smolts Passing B2 Turbines[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/16	0.5154	1.0000
5/17-6/04	0.5282	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture.

Table D.9. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Steelhead Smolts Passing the B2 JBS[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/15	1.0000	0.5087
5/16-6/04	1.0000	0.2451

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture.

Table D.10. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Steelhead Smolts Passing Detected Passing Through the B2CC[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
5/02-5/06	1.0000	0.6436
5/07-5/10	1.0000	1.0000
5/11-5/14	1.0000	0.7278
5/15-5/18	1.0000	1.0000
5/19-5/22	1.0000	0.6239
5/23-5/26	0.5538	0.6239
5/27-5/30	1.0000	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture.

Table D.11. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Subyearling Chinook Salmon Smolts Passing Through B2[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/17-6/18	1.0000	0.1091
6/19-6/20	0.3743	0.7047
6/21-6/22	0.4481	1.0000
6/23-6/24	0.3923	0.7271
6/25-6/26	0.5615	0.6777
6/27-6/28	0.7331	1.0000
6/29-6/30	0.2063	1.0000
7/01-7/02	1.0000	1.0000
7/03-7/04	0.2509	0.3554
7/05-7/06	1.0000	0.2817
7/07-7/08	0.3160	0.4098
7/09-7/10	1.0000	0.4136
7/11-7/12	0.0643	1.0000
7/13-7/14	NC	1.0000
7/15-7/17	NC	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.12 Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Subyearling Chinook Salmon Smolts Passing the Bonneville Tailwater[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/17-6/18	0.6739	0.5513
6/19-6/20	0.7552	1.0000
6/21-6/22	0.3965	0.5416
6/23-6/24	1.0000	0.5072
6/25-6/26	0.0336	1.0000
6/27-6/28	1.0000	0.5855
6/29-6/30	0.2576	0.4318
7/01-7/02	0.2855	0.0968
7/03-7/04	0.5446	1.0000
7/05-7/06	1.0000	1.0000
7/07-7/08	1.0000	0.6667
7/09-7/10	1.0000	0.6652
7/11-7/12	1.0000	0.5850
7/13-7/14	0.0684	0.2679
7/15-7/17	NC	NC

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.13. Burnham et al. (1987). Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Subyearling Chinook Salmon Smolts Passing B2 Turbines[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/17-6/18	1.0000	0.2344
6/19-6/20	0.1199	1.0000
6/21-6/22	1.0000	1.0000
6/23-6/24	0.5987	0.4573
6/25-6/26	0.4259	0.5690
6/27-6/28	1.0000	1.0000
6/29-6/30	0.2093	1.0000
7/01-7/02	1.0000	1.0000
7/03-7/04	0.5078	0.1729
7/05-7/06	1.0000	0.1798
7/07-7/08	1.0000	0.5115
7/09-7/10	NC	1.0000
7/11-7/12	1.0000	1.0000
7/13-7/17	NC	NC

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays.

Table D.14. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Subyearling Chinook Salmon Smolts Passing Through the B2 JBS[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/17-6/19	1.0000	0.3846
6/20-6/22	1.0000	1.0000
6/23-6/25	0.4195	1.0000
6/26-6/28	0.5669	0.3461
6/29-7/01	1.0000	0.5641
7/02-7/04	0.3215	1.0000
7/05-7/07	NC	NC
7/08-7/10	NC	0.1474
7/11-7/13	1.0000	1.0000
7/14-7/17	NC	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays.

Table D.15. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Subyearling Chinook Salmon Smolts Detected Passing into the B2CC[a]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/17-6/18	0.5453	1.0000
6/19-6/20	1.0000	1.0000
6/21-6/22	0.5392	0.5147
6/23-6/24	0.1617	0.5603
6/25-6/26	1.0000	0.3188
6/27-6/28	1.0000	0.6417
6/29-6/30	0.4587	1.0000
7/01-7/02	1.0000	1.0000
7/03-7/04	0.1667	NC
7/05-7/06	NC	1.0000
7/07-7/08	0.2358	0.5845
7/09-7/10	1.0000	0.4663
7/11-7/12	0.0522	1.0000
7/13-7/14	NC	NC
7/15-7/17	1.0000	1.0000

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays. Shaded cells had P-values <0.10, indicating a violation of model assumptions.

Table D.16. Burnham et al. (1987) Test 2 and Test 3 P-Values for Goodness-of-Fit to the Single Release-Recapture Data for Subyearling Chinook Salmon Smolts Released into the B2CC and Passing Through John Day Top Spill Weir Bays (15 and 16) in 2008[(a)]

Virtual Release Date	P-Values from Fisher's Exact Test	
	Test 2.2	Test 3.1
6/15-6/16	0.6592	0.111
6/17-6/18	1.0000	0.6532
6/19-6/20	1.0000	1.0000
6/21-6/22	0.3899	1.0000
6/23-6/24	0.6867	1.0000
6/25-6/26	1.0000	0.6783
6/27-6/28	0.5279	0.4055
6/29-6/30	0.1809	0.1466
7/01-7/02	1.0000	0.6339
7/03-7/04	0.5743	0.3801
7/05-7/06	0.3251	0.6595
7/07-7/08	0.6043	1.0000
7/09-7/10	0.6303	1.0000
7/11-7/12	0.3301	0.6048
7/13-7/14	1.0000	0.5025
7/15-7/16	NC	1.0000
7/17-7/19	NC	NC

(a) Test 2 examines whether upstream detections affect downstream survival or detection, and Test 3 examines whether upstream capture histories affect downstream survival or capture. Cells containing NC could not be calculated because of high detection rates on the primary and secondary arrays.

Appendix E

Fish Guidance Efficiency

Appendix E

Fish Guidance Efficiency

Table E.1. Nighttime Passage Numbers and Associated FGE and FPE Values for Yearling Chinook Salmon Released from Lower Granite Dam and Migrating Downstream Through B2 Routes. Dates associated with nighttime values are the beginning date for a continual night.

Date	B2CC	Turbine	JBS	FGE	FPE
5/2/2008	4	4	0	0.00	0.50
5/3/2008	1	5	0	0.00	0.17
5/6/2008	0	2	0	0.00	0.00
5/7/2008	0	1	0	0.00	0.00
5/12/2008	1	0	0	0.00	1.00
5/13/2008	0	4	0	0.00	0.00
5/14/2008	2	2	1	0.33	0.60
5/15/2008	4	9	1	0.10	0.36
5/16/2008	4	3	3	0.50	0.70
5/17/2008	3	2	1	0.33	0.67
5/18/2008	2	6	1	0.14	0.33
5/19/2008	3	16	1	0.06	0.20
5/20/2008	1	14	1	0.07	0.13
5/21/2008	4	15	1	0.06	0.25
5/22/2008	4	13	1	0.07	0.28
5/23/2008	1	7	1	0.13	0.22
5/24/2008	5	5	0	0.00	0.50
5/25/2008	9	21	2	0.09	0.34
5/26/2008	15	23	2	0.08	0.43
5/27/2008	9	25	2	0.07	0.31
5/28/2008	10	7	0	0.00	0.59
5/29/2008	2	1	0	0.00	0.67
5/30/2008	2	4	1	0.20	0.43
5/31/2008	4	2	0	0.00	0.67
6/1/2008	0	2	1	0.33	0.33
6/3/2008	0	1	0	0.00	0.00
6/4/2008	0	1	0	0.00	0.00
Total	90	195	20	0.09	0.36

Table E.2. Daytime Passage Numbers and Associated FGE and FPE Values for Lower Yearling Chinook Salmon Released from Lower Granite Dam and Migrating Downstream Through B2 Routes

Date	B2CC	Turbine	JBS	FGE	FPE
5/8/2008	0	1	0	0.00	0.00
5/11/2008	2	1	1	0.50	0.75
5/12/2008	1	3	0	0.00	0.25
5/13/2008	5	3	1	0.25	0.67
5/14/2008	9	6	3	0.33	0.67
5/15/2008	9	6	8	0.57	0.74
5/16/2008	15	8	12	0.60	0.77
5/17/2008	13	2	1	0.33	0.88
5/18/2008	10	3	6	0.67	0.84
5/19/2008	17	0	7	1.00	1.00
5/20/2008	3	4	0	0.00	0.43
5/21/2008	7	0	1	1.00	1.00
5/22/2008	5	2	1	0.33	0.75
5/23/2008	4	0	0	0.00	1.00
5/24/2008	14	4	2	0.33	0.80
5/25/2008	24	5	2	0.29	0.84
5/26/2008	17	5	2	0.29	0.79
5/27/2008	22	10	1	0.09	0.70
5/28/2008	6	2	0	0.00	0.75
5/29/2008	1	1	0	0.00	0.50
5/30/2008	8	1	1	0.50	0.90
5/31/2008	4	1	0	0.00	0.80
6/1/2008	0	1	0	0.00	0.00
6/2/2008	1	0	0	0.00	1.00
Total	197	69	49	0.42	0.78

Table E.3 Nighttime Passage Numbers and Associated FGE and FPE Values for Yearling Chinook Salmon Released in the Lower Columbia River and Migrating Downstream Through B2 Routes. Dates associated with nighttime values are the beginning date for a continual night.

Date	B2CC	Turbine	JBS	FGE	FPE
5/2/2008	1	1	0	0.00	0.50
5/5/2008	3	1	2	0.67	0.83
5/6/2008	12	11	3	0.21	0.58
5/7/2008	9	4	1	0.20	0.71
5/8/2008	4	8	4	0.33	0.50
5/9/2008	3	11	2	0.15	0.31
5/10/2008	8	9	3	0.25	0.55
5/11/2008	9	9	2	0.18	0.55
5/12/2008	6	7	1	0.13	0.50
5/13/2008	8	11	2	0.15	0.48
5/14/2008	9	4	3	0.43	0.75
5/15/2008	12	2	2	0.50	0.88
5/16/2008	5	12	2	0.14	0.37
5/17/2008	3	3	1	0.25	0.57
5/18/2008	5	5	0	0.00	0.50
5/19/2008	5	6	1	0.14	0.50
5/20/2008	2	8	1	0.11	0.27
5/21/2008	2	4	1	0.20	0.43
5/22/2008	3	7	3	0.30	0.46
5/23/2008	3	5	1	0.17	0.44
5/24/2008	5	3	0	0.00	0.63
5/25/2008	5	6	1	0.14	0.50
5/26/2008	6	9	2	0.18	0.47
5/27/2008	4	7	2	0.22	0.46
5/28/2008	7	11	4	0.27	0.50
5/29/2008	3	3	2	0.40	0.63
5/30/2008	4	9	0	0.00	0.31
5/31/2008	2	1	0	0.00	0.67
Total	148	177	46	0.21	0.52

Table E.4. Daytime Passage Numbers and Associated FGE and FPE Values for Yearling Chinook Salmon Released in the Lower Columbia River and Migrating Downstream Through B2 Routes

Date	B2CC	Turbine	JBS	FGE	FPE
5/4/2008	1	0	0	0.00	1.00
5/5/2008	4	6	4	0.40	0.57
5/6/2008	12	3	7	0.70	0.86
5/7/2008	21	5	8	0.62	0.85
5/8/2008	9	8	4	0.33	0.62
5/9/2008	24	7	15	0.68	0.85
5/10/2008	9	3	7	0.70	0.84
5/11/2008	17	6	10	0.63	0.82
5/12/2008	17	5	7	0.58	0.83
5/13/2008	20	7	5	0.42	0.78
5/14/2008	18	5	8	0.62	0.84
5/15/2008	12	13	14	0.52	0.67
5/16/2008	16	7	5	0.42	0.75
5/17/2008	23	12	6	0.33	0.71
5/18/2008	15	7	7	0.50	0.76
5/19/2008	8	1	6	0.86	0.93
5/20/2008	5	0	1	1.00	1.00
5/21/2008	5	0	1	1.00	1.00
5/22/2008	5	0	0	0.00	1.00
5/23/2008	1	0	0	0.00	1.00
5/24/2008	7	3	3	0.50	0.77
5/25/2008	7	0	0	0.00	1.00
5/26/2008	3	2	1	0.33	0.67
5/27/2008	4	2	4	0.67	0.80
5/28/2008	7	2	1	0.33	0.80
5/29/2008	6	3	2	0.40	0.73
5/30/2008	7	1	0	0.00	0.88
5/31/2008	1	0	0	0.00	1.00
Total	284	108	126	0.54	0.79

Table E.5. Nighttime Passage Numbers and Associated FGE and FPE Values for Tagged Juvenile Steelhead Migrating Downstream Through B2 Routes. Dates associated with nighttime values are the beginning date for a continual night.

Date	B2CC	Turbine	JBS	FGE	FPE
5/4/2008		2	2	0.50	0.50
5/5/2008	13	2	3	0.60	0.89
5/6/2008	29	6	5	0.45	0.85
5/7/2008	10	2	7	0.78	0.89
5/8/2008	6	4	1	0.20	0.64
5/9/2008	6	2	1	0.33	0.78
5/10/2008	10	4		0.00	0.71
5/11/2008	18	5	8	0.62	0.84
5/12/2008	4	5	4	0.44	0.62
5/13/2008	4	4	1	0.20	0.56
5/14/2008	12	2	1	0.33	0.87
5/15/2008	4	3		0.00	0.57
5/16/2008	2				1.00
5/17/2008	8	4	2	0.33	0.71
5/18/2008	3	2		0.00	0.60
5/19/2008	2	2	1	0.33	0.60
5/20/2008	2				1.00
5/21/2008	3	1	2	0.67	0.83
5/22/2008	3	1		0.00	0.75
5/23/2008	1	2	1	0.33	0.50
5/24/2008	3	1	2	0.67	0.83
5/25/2008		1		0.00	0.00
5/26/2008	1	2	2	0.50	0.60
5/27/2008	2	2		0.00	0.50
5/28/2008	1	1		0.00	0.50
5/29/2008	1	3		0.00	0.25
5/30/2008	1	2	1	0.33	0.50
Total	149	65	44	0.40	0.75

Table E.6 Daytime Passage Numbers and Associated FGE and FPE Values for Tagged Juvenile Steelhead Migrating Downstream Through B2 Routes

Date	B2CC	Turbine	JBS	FGE	FPE
5/4/2008	1				1.00
5/5/2008	12	3	4	0.57	0.84
5/6/2008	30	7	4	0.36	0.83
5/7/2008	32	5		0.00	0.86
5/8/2008	18	6	3	0.33	0.78
5/9/2008	39	7	4	0.36	0.86
5/10/2008	44	1	3	0.75	0.98
5/11/2008	57	5	4	0.44	0.92
5/12/2008	24	2	2	0.50	0.93
5/13/2008	39	6	2	0.25	0.87
5/14/2008	38	3	2	0.40	0.93
5/15/2008	21				1.00
5/16/2008	24		3	1.00	1.00
5/17/2008	9	2	4	0.67	0.87
5/18/2008	20	1	3	0.75	0.96
5/19/2008	20	1		0.00	0.95
5/20/2008	14	3	2	0.40	0.84
5/21/2008	10		2	1.00	1.00
5/22/2008	7	1	1	0.50	0.89
5/23/2008	6				1.00
5/24/2008	4	2	1	0.33	0.71
5/25/2008	15		1	1.00	1.00
5/26/2008	12	1	1	0.50	0.93
5/27/2008	18	4	2	0.33	0.83
5/28/2008	12	2	4	0.67	0.89
5/29/2008	13	2	2	0.50	0.88
5/30/2008	6	3	1	0.25	0.70
Total	545	67	55	0.45	0.90

Table E.7. Nighttime Passage Numbers and Associated FGE and FPE Values for Tagged Subyearling Chinook Migrating Downstream Through B2 Routes. Dates associated with nighttime values are the beginning date for a continual night.

Date	B2CC	Turbine	JBS	FGE	FPE
6/17/2008	5	1	0	0.00	0.83
6/18/2008	2	19	1	0.05	0.14
6/19/2008	2	27	6	0.18	0.23
6/20/2008	10	20	3	0.13	0.39
6/21/2008	3	17	4	0.19	0.29
6/22/2008	5	23	3	0.12	0.26
6/23/2008	4	17	3	0.15	0.29
6/24/2008	12	18	7	0.28	0.51
6/25/2008	8	28	6	0.18	0.33
6/26/2008	8	22	6	0.21	0.39
6/27/2008	1	19	6	0.24	0.27
6/28/2008	4	18	6	0.25	0.36
6/29/2008	4	15	5	0.25	0.38
6/30/2008	4	7	5	0.42	0.56
7/1/2008	5	23	5	0.18	0.30
7/2/2008	8	17	5	0.23	0.43
7/3/2008	2	22	5	0.19	0.24
7/4/2008	6	18	5	0.22	0.38
7/5/2008	8	27	3	0.10	0.29
7/6/2008	4	11	3	0.21	0.39
7/7/2008	10	13	6	0.32	0.55
7/8/2008	12	10	0	0.00	0.55
7/9/2008	9	14	4	0.22	0.48
7/10/2008	11	4	1	0.20	0.75
7/11/2008	6	7	1	0.13	0.50
7/12/2008	5	12	3	0.20	0.40
7/13/2008	13	3	0	0.00	0.81
7/14/2008	11	7	2	0.22	0.65
7/15/2008	9	2	1	0.33	0.83
7/16/2008	0	5	1	0.17	0.17
7/17/2008	2	0	0	0.00	1.00
Total	193	446	106	0.19	0.40

Table E.8. Daytime Passage Numbers and Associated FGE and FPE Values for Tagged Subyearling Chinook Migrating Downstream Through B2 Routes

Date	B2CC	Turbine	JBS	FGE	FPE
6/17/2008	2	2	1	0.33	0.60
6/18/2008	19	14	3	0.18	0.61
6/19/2008	16	10	13	0.57	0.74
6/20/2008	12	18	10	0.36	0.55
6/21/2008	15	4	7	0.64	0.85
6/22/2008	4	16	6	0.27	0.38
6/23/2008	11	12	11	0.48	0.65
6/24/2008	26	11	16	0.59	0.79
6/25/2008	11	12	16	0.57	0.69
6/26/2008	20	6	11	0.65	0.84
6/27/2008	13	11	9	0.45	0.67
6/28/2008	22	9	6	0.40	0.76
6/29/2008	8	10	17	0.63	0.71
6/30/2008	14	18	7	0.28	0.54
7/1/2008	17	13	12	0.48	0.69
7/2/2008	13	9	9	0.50	0.71
7/3/2008	13	15	9	0.38	0.59
7/4/2008	17	8	8	0.50	0.76
7/5/2008	11	11	1	0.08	0.52
7/6/2008	22	23	4	0.15	0.53
7/7/2008	31	17	6	0.26	0.69
7/8/2008	21	11	2	0.15	0.68
7/9/2008	29	13	9	0.41	0.75
7/10/2008	34	14	5	0.26	0.74
7/11/2008	32	12	5	0.29	0.76
7/12/2008	33	12	5	0.29	0.76
7/13/2008	38	15	4	0.21	0.74
7/14/2008	23	12	4	0.25	0.69
7/15/2008	17	6	5	0.45	0.79
7/16/2008	2	1	0	0.00	0.67
7/17/2008	1	2	1	0.33	0.50
Total	547	347	222	0.39	0.69

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