PNNL-24260

US Army Corps of Engineers

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

Systematic Review of JSATS Passage and Survival Data at Bonneville and The Dalles Dams During Alternative Turbine and Spillbay Operations from 2008–2012

Draft Final Report

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April 2015

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Preface

This analysis was conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers (USACE), Portland District (CENWP), using data acquired during Biological Opinion (BiOp) compliance and preliminary studies conducted from 2008 through 2012. The purpose of these studies was to obtain estimates of the dam passage survival of downstream-migrating juvenile salmonids and other metrics. The data collected to meet the needs of the compliance studies include dam operations, environmental conditions, and the behavior and survival rates of yearling Chinook salmon, juvenile steelhead trout (referred to herein as “steelhead”), and fall Chinook salmon (referred to herein as “subyearling Chinook salmon”). These large data sets can be analyzed to answer questions beyond those asked by the compliance studies. Of particular interest are details about how specific dam structural configurations and operations may affect or benefit juvenile salmonids. This report evaluates:

- turbine operations proposed to maximize the survival of juvenile salmonids that pass through the first and second powerhouses at Bonneville Dam (BON),
- the differential effects of spillbay structural configuration and possible spillbay damage to the survival of juvenile salmonids passing at BON, and
- the impact on survival of juvenile salmonids that pass in spill at The Dalles Dam through spillbays outside (southeast) of a new spill wall in the spillway tailrace.

The CENWP technical leads for the study were Mr. Jon Rerecich and Mr. Brad Eppard.

This report should be cited as follows:

Weiland, MA, CM Woodley, TJ Carlson, B Rayamajhi, and J Kim. 2015. *Systematic Review of JSATS Passage and Survival Data at Bonneville and The Dalles Dams during Alternative Turbine and Spillbay Operations from 2008–2012*. PNNL-24260. Report submitted to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, by the Pacific Northwest National Laboratory, Richland, Washington.

Executive Summary

From 2008 through 2012, the Pacific Northwest National Laboratory (PNNL) conducted 38 studies at the four main-stem dams on the lower Columbia River (LCR) to estimate the dam passage survival rates of yearling Chinook (CH1), subyearling Chinook (CH0), and juvenile steelhead (STH). All studies were conducted using the Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic micro-transmitters (AMTs) and receivers developed by PNNL for the U.S. Army Corps of Engineers (USACE). These studies were conducted to determine if structural configurations and operations at main-stem dams provide sufficiently safe dam passage to meet criteria detailed in the Biological Opinion (BiOp) for dam passage survival of juvenile salmonids. During this period over 75,000 juvenile salmonids were tagged with AMTs, released, and their detections recorded at downstream receiving arrays. The resulting multi-year, multi-out-migration season, and multi-species-run data set was used to answer questions about the operation of turbines and the operation and condition of spillways.

Bonneville Dam (BON)

The USACE through the Turbine Survival Program (TSP) have a goal of identifying the best operations for turbines at the Bonneville first (B1) and second (B2) powerhouses to maximize the juvenile salmonid passage survival rates. Data related to CH1, STH, and CH0 passage through turbines in B1 and B2 were analyzed for patterns in turbine passage survival, by turbine discharge, the presence of turbine intake fish diversion screens (herein referred to as “submerged traveling screens” [STS]), tailwater elevation, and tailrace egress time. The overarching goal is to help identify the operations for B1 and B2 turbines that will optimize migrant juvenile salmonid turbine passage survival. For B1 turbines, the operating ranges assessed include the following: lower quarter of 1% efficiency range (Q1), lower middle quarter of 1% efficiency range (Q2), upper middle quarter of 1% efficiency range (Q3), upper quarter of 1% of peak efficiency range (Q4), best operating range (BOR), and above best operating point to generator limit (ABOP). For B2 turbines, the operating ranges assessed include the following: lower quarter of 1% efficiency range (Q1), lower middle quarter of 1% efficiency range (Q2), upper middle quarter of 1% efficiency range (Q3), and upper quarter of 1% of peak efficiency range (Q4).

Large sample size variation that occurred when the data were parsed into quartiles within the 1% of peak efficiency range, reduced confidence in the utility of detected statistically significant differences in estimates of turbine passage survival rates. High uniformity of turbine passage survival estimates for all juvenile salmonid runs for combined operating ranges (including high discharges above the best operating point for CH1 and STH and larger samples sizes for all combined operating ranges) suggests that the survival rates for juvenile salmonids passing through B1 turbines are probably independent of turbine operations.

More specifically, at B1, the turbine passage data for all three juvenile salmonid runs showed that the largest number of fish passed during turbine operation within the Q4 operating range. This was consistent with how the turbines were operated during the study period. The turbine passage survival rate for CH1 was significantly lower in the Q4 operating range than it was in Q1 and Q2 operating ranges. There were no other significant differences in survival rates at operations within quartiles of the 1% of peak efficiency range or various combinations of turbine operations, including no significant difference in survival rates from the upper end of 1% of peak operating efficiency up to discharge at the operating limit of the turbine generator. The patterns in differences with turbine operations for STH and CH0 were similar to those observed for CH1. In the case of STH, fish that passed at operations in Q1 had significantly higher survival rate than those that passed in Q3 and Q4.

No significant differences were detected for survival estimates at other combinations of turbine operations, though survival of STH passing in Q2 and Q3 was lower than STH passing in Q4 and in BOR and ABOP. No significant differences in survival were detected for CH0 at any turbine operation condition, though survival of CH0 in Q1 and Q2 was lower than survival estimates at Q3 and Q4. For all juvenile salmonids there was a trend in lower tailrace egress time with increasing turbine discharge and higher tailwater elevations. Because B1 has its own tailrace channel, the increases in discharge through the B1 generally resulted in higher tailwater elevations and higher flow rates through the tailrace, with some influence by ocean tidal effects.

The B2 turbine passage survival rates for all juvenile salmonid runs, CH1, STH, and CH0, were quite uniform over all flow conditions, Q1, Q2, Q3, Q4, Q1+Q2, and Q3+Q4. Differences in the samples sizes for survival estimates were less pronounced than was the case for juvenile salmonid B1 turbine passage survival estimates. Contrary to B1 turbine passage patterns, for the spring migration period the largest proportion of CH1 and STH passed through turbines when discharges were in the lower half of the 1% of peak efficiency operating range (Q1 and Q2). The opposite was true for the summer migration period when most CH0 passed through flows in the Q4. Tailrace egress times for all juvenile salmonid groups showed a decrease in egress time with increased powerhouse discharge. The results of this analysis, particularly considering juvenile salmonid survival rates in grouped discharge ranges (Q1+Q2 and Q3+Q4), indicate that there is little evidence to support selection of any particular turbine operating range to optimize the rate of turbine passage survival at B2 for any juvenile salmonid run.

Survival rates for juvenile salmonids passing in spill over the last several years have been lower than those through other passage routes at BON. Potential causes for the lower spill passage survival rates include 1) erosion of the stilling basin and the ogees in several spillbays and/or 2) accumulated rocks in stilling basins and the immediate tailrace region. Data for passage of CH1, STH, and CH0 through the BON spillway acquired from 2008 through 2012 were used to investigate the effect of spill passage on downstream migration of juvenile salmonids and to assess whether fish passing through damaged spillbays had an increased likelihood of mortality.

CH1 and STH passed through the spillbays at either end of the BON spillway more often than through spillbays toward the center of the spillway. CH0 passing through the spillway during the summer did not favor any part of the spillway. No significant difference in survival rates through individual spillbays was detected for any juvenile salmonid run. Likewise, when the BON spillbays were consolidated into five groups based on deflector elevation, spillway damage, and other factors, no significant difference in the rate of spill passage survival was observed for any juvenile salmonid run passing through damaged spillbays compared to other spillbay groups. Both CH1 and STH exhibited a subtle but general increase in survival rate up to a point and then a significant decrease in survival rate at the highest spill discharge (≥290 kcfs); whereas the CH0 survival rate noticeably increased with increasing spill. When grouped into 20 kcfs bins, both CH1 and STH had the highest survival rate at 240 kcfs, followed by a decline in survival rate at higher discharge. There were no significant differences between estimated survival rates relative to tailwater elevation for CH1 or STH. Given the relationship between higher discharge and high tailwater elevation for the BON spillway, and powerhouse tailraces, CH0 showed steadily increasing survival rates with increases in tailwater elevation. Declining tailrace egress times were observed for CH1, STH, and CH0 with increasing spillway discharge.

The Dalles Dam (TDA)

In response to high river discharge at The Dalles Dam (TDA) in 2011 and 2012, it was necessary to spill using spillbays outside (southeast) of the new tailrace spill wall, which was designed to contain and direct discharge from spillbays inside (northwest) toward the river thalweg, bypassing shallow areas on the south side of the river with high piscivorous predator density. Concerns were raised about potential reduction in spillway survival rates for juvenile salmonids passing outside of the spill wall under high spill conditions in flow directed toward the south side of the river because of potential increased predation. Passage route-specific data acquired in 2010, 2011, and 2012 for CH1, STH, and CH0 at TDA spillway were used to investigate whether juvenile salmonids passing through the southeast spillbays (9–23) outside of the spill wall had lower survival rates that those passing through the northwest spillbays (1–8) inside of the spill wall.

The majority of juvenile salmonids, CH1 (92.5%), STH (90.8%), and CH0 (97.3%), passed through spillbays inside the spill wall, leaving a small percentage of juvenile salmonids passing through spillbays outside of the spill wall exposed to potentially higher predation. The distribution of juvenile salmonids passing through bays within the spill wall was skewed toward the bays nearer the spill wall. The survival rate between 2010 and 2012 for CH1 passing through spillbay 2 was significantly lower than that of spillbay 3, and had the lowest or second lowest survival in all 3 years of studies. STH through spillbay 2 had the second lowest survival rates in 2011 and 2012, but had the second highest survival rate of the eight spillbays in 2010, and spillbay 3 had the lowest survival rate, none of which were significantly different. All other differences in spillway passage survival rates through spillbays 1–8 were not significant for CH1, STH, and CH0. No significant difference in spillway passage survival rates was detected for CH1, STH, or CH0 that passed at spillbays inside and outside of the spill wall. A discernable increase in spill passage survival rate with increasing discharge was noted for CH0 passing through spillbays inside the spill wall, where survival estimates for those passing in spill discharge levels ≤70 kcfs were significantly lower than for those passing at discharge levels ≥90 kcfs. A similar, less distinct, trend in survival rate with increasing discharge was observed for CH1 and STH. The survival rate of CH1 that passed in spill discharge ≤72 kcfs (survival = 0.9405) was significantly lower than for CH1 that passed in spill discharge ≥168 kcfs (survival = 0.9645). The egress times for all juvenile salmonid groups showed large proportional decreases with increasing discharge.

Our analysis obtained answers to the questions that motivated the analysis. It appears that turbine passage survival rate for CH1, STH, and CH0 is not a function of turbine discharge. The survival rates for juvenile salmonids that passed through spillbays at BON that are damaged or that may have rock in the stilling basin and tailrace are not different from those for juvenile salmonids that passed through bays without these structural issues. Finally, the survival rate of juvenile salmonids that passed in spill at TDA outside of the spill wall was not different from that of juvenile salmonids that passed through spillbays within the spill wall.

Acknowledgments

Many people from Pacific Northwest National Laboratory (PNNL), Pacific States Marine Fisheries Commission (PSMFC), the U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration-Fisheries (NOAA), Cascade Aquatics, and the University of Washington (UW) made valuable contributions to this study and deserve acknowledgment. We have done our best to capture everyone, and give our apologies to anyone we might have overlooked.

- Cascade Aquatics: E Anderson, C Green, E Green, J Herdman, B James, P James, K Martin, K Prather, and H Watson.
- NOAA: S Brewer, J Everett, L McComas, J Moser, and G Wolf.
- PNNL: T Abel, C Anderson, C Arimescu, G Batten III, B Bellgraph, J Boyd, C Brandt, R Brown, A Bryson, T Carlson, S Carpenter, J Carter, K Carter, M Chalk, E Choi, A Cushing, D Dauble, Z Deng, K Deters, G Dirkes, J Duncan, R Durham, S Ennor, D Faber, E Fischer, A Flory, T Fu, G Gaulke, M Gay, D Geist, G Gill, B Goodman, M Greiner, K Hall,, K Ham, K Hand, R Harnish, M Hennen, R Herrington, J Horner, JL Hughes, JS Hughes, M Hughes, M Ingraham, G Johnson, R Karls, R Kaufman, F Khan, K Knox, B LaMarche, K Larson, K Lavender, X Li, J Martinez, S Matzner, G McMichael, B Miller, A Miracle, T Monter, K Neiderhiser, B Noland, E Oldenburg, A Phillips, N Phillips, G Ploskey, H Ren, G Roesijadi, I Royer, D Saunders, S Schlata, T Seim, J Smith, A Solcz, S Southard, G Squeochs, N Tavan, A Thronas, S Titzler, N Trimble, D Trott, J Vavrinec III, C Vernon, K Wagner, M Wilberding, Y Yaun, and S Zimmerman.
- PSMFC: R Martinson, G Kolvachuk, and D Ballenger, along with the helpful staff at John Day Dam and Bonneville Dam Smolt Monitoring Facilities. In addition, A Ajmani, B Babcock, M Bahnick, A Barnes, C Beyer, R Blanchard, A Collins, A Cook, J Cox, L Cushing, L Daniel, R Davis, C Dittbrenner, T Elder, D Etherington, G George, S Goss, D Grugett, A Halston, B Harkleroad, C Holzer, M Jenkins, P Kahut, K Kenny, T Levandowsky, D Lock, D Marvin, S Marvin, J Mathieus, L McPhetridge, M Meyer, T Mitchell, M Neumann, G Ottoway, K Paine, R Plante, D Quaempts, J Robertson, T Royal, K Schaedel, G Schilperoort, G Seybert, D Spiteri, N Tancreto, P Tramel, M Walker, R Wall, and L Wood.
- USACE: B Cordie, B Eppard, B Hausmann, T Hurd, P Keller, M Langeslay, J Rerecich, D Schwartz, A Traylor, K Welch, and M Zyndol.
- UW: R Buchanan, C Helfrich, J Lady, A Seaburg, J Skalski, R Townsend, and P Westhagen.

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

- Advanced Telemetry Systems, Inc. (Isanti, MN) manufactured the JSATS AMT (2008–2012).
- Sonic Concepts (Bothell, WA) produced the autonomous and dam-mounted hydrophones (2008–2012).
- Precision Acoustic Systems (Seattle, WA) made the quad channel receivers and conducted node acceptance tests (2008–2010).
- The Dalles Ironworks (The Dalles, OR) provided the anchors for autonomous nodes and various components required for successful completion of this project (2011 and 2012).

- Cascade Aquatics, Inc. (Ellensburg, WA) activated and delivered acoustic tags (2008–2010).
- Schlosser Machine Shop (Hood River, OR) fabricating anchors for autonomous nodes and frames for star clusters (2008–2010).

Acronyms and Abbreviations

°C	degree(s) Celsius or Centigrade
ABOP	above best operating point to generator limit
AFEP	Anadromous Fish Evaluation Program
AMT	acoustic micro-transmitter
ATS	Advanced Telemetry Systems, Inc.
B1	Bonneville Powerhouse 1
B2	Bonneville Powerhouse 2
BiOp	Biological Opinion
BON	Bonneville Dam
BOP	best operating point
BOR	best operating range
cfs	cubic feet per second
CH0	subyearling Chinook salmon
CH1	yearling Chinook salmon
CRFM	Columbia River Fish Mitigation Program
ERDC	Engineer Research and Development Center
FCRPS	Federal Columbia River Power System
FPP	Fish Passage Plan
ft	feet
h	hour(s)
HDC	Hydroelectric Design Center
JDA	John Day Dam
JSATS	Juvenile Salmon Acoustic Telemetry System
kcfs	thousands of cubic feet per second
kHz	kilohertz
LCR	lower Columbia River
LL	lower limit of 1% of peak efficiency operating range
max	maximum
MCN	McNary Dam
MGR	minimum gap runner
min	minimum
min	minute
mm	millimeter(s)
MN	Minnesota
MSL	mean sea level
N	sample size

NOAA	National Oceanic and Atmospheric Administration
NWP	Portland District
NWW	Walla Walla District
OR	Oregon
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
Q1	lower quarter of 1% of peak efficiency operating range
Q2	lower middle quarter of 1% of peak efficiency operating range
Q3	upper middle quarter of 1% of peak efficiency operating range
Q4	upper quarter of 1% of peak efficiency operating range
rkm	river kilometer(s)
s	second(s)
SE	standard error
SRWG	Study Review Work Group
STH	juvenile steelhead
STS	submersible traveling screen
TDA	The Dalles Dam
TSP	Turbine Survival Program
UL	upper limit of 1% of peak efficiency operating range
USACE	U.S. Army Corps of Engineers
WA	Washington
yr	year(s)

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1.0 Introduction

The U.S. Army Corps of Engineers (USACE) Turbine Survival Program (TSP) is an element of the Columbia River Fish Mitigation Program (CRFM) and consists of a team of biologists and engineers from the Portland (NWP) and Walla Walla (NWW) Districts, the Hydroelectric Design Center (HDC), the Engineer Research and Development Center (ERDC), and the National Oceanic and Atmospheric Administration-Fisheries (NOAA). The primary objectives of the TSP are to 1) improve the understanding of the turbine passage environment and the impact of that environment on juvenile salmonids, 2) optimize turbine operations for safer fish passage, and 3) improve turbine designs for safer fish passage. The TSP uses physical and numerical hydraulic models and other information to estimate the best operating point (BOP) for turbine units at hydroelectric projects to optimize the survival of juvenile salmonids passing through turbines.

At Bonneville Dam (BON), the TSP developed a set of recommendations that included moving the lower limit of the 1% of peak efficiency operating range (LL) of BON Powerhouse 1 (B1) turbine units from the current LL at 7.3 kcfs to a new LL of 7.5 kcfs, and moving the upper operating limit of the 1% of peak efficiency operating range (UL) from 9.8 kcfs to a new UL at 11.5 kcfs, under the model head condition tested. The new operating range was recommended to improve hydraulic conditions (quality of flow) within the B1 minimum gap runner (MGR) units, provide the largest opening between turbine runner blades, and deliver a high water velocity through the runner; thus, providing safer turbine passage conditions for migrating juvenile salmonids.

Due to increased injury and mortality of juvenile salmonids in the gatewell environment of BON Powerhouse 2 (B2), B2 turbines have been operated within the lower half of the range within 1% of peak efficiency. This operation reduces turbine intake water velocity, which is better for guided fish; although, it may create conditions in the turbine environment that decrease the rate of turbine passage survival. In addition, modeling studies have indicated that operation of turbine units at an open geometry configuration (i.e., higher discharge where runner blades are at greater angles and wicket gates and stay vanes are aligned) improves hydraulic conditions in the turbine environment that may improve passage survival for fish.

The research, monitoring, and evaluation studies managed under the Anadromous Fish Evaluation Program (AFEP) are coordinated through the Study Review Work Group (SRWG), whose participants include federal, state, and tribal fish agencies, as well as other interested stakeholders throughout the region. The SRWG objectives are often linked to recommendations for Federal Columbia River Power System (FCRPS) improvements in order to answer biological questions in a timely manner. At BON, the SRWG is concerned that erosion of the stilling basin and ogees (spillway chutes) in several spillbays and the accumulation of rock in stilling basins could affect spillway survival rates. In addition, at The Dalles Dam (TDA), high river flows in recent years have forced operators to open spillbays outside of a new tailrace spill wall to pass water in excess of that safely passed through the spillbays within the spill wall. The SRWG is concerned that this spill operation may lead to a reduction in the survival rate for fish passing outside of the spill wall under high flow and high spill conditions, due to passage of juvenile salmonids near predatory fish habitat located adjacent to a group of islands downstream of the south side of the spillway.

From 2008 through 2012, the Pacific Northwest National Laboratory (PNNL) conducted 38 survival studies using the Juvenile Salmon Acoustic Telemetry System (JSATS) at the four lower Columbia River (LCR) main-stem dams—BON, TDA, John Day Dam (JDA), and McNary Dam (MCN)—to determine if fish passage and survival rates were in accordance with requirements of the 2008 Biological Opinion (BiOp) on operation of the FCRPS (NMFS 2008). The 2008 BiOp mandates that dam passage survival rates of 96% and 93% be achieved for spring (CH1 and STH) and summer (CH0) downstream-migrating juvenile salmonids, respectively. Since 2008, over 75,000 juvenile salmonids have been surgically implanted with JSATS acoustic micro-transmitters (AMTs) and passive integrated transponders (PITs), and released into the river as part of various BiOp studies. The data acquired in these studies, until now, have been mainly used to evaluate whether the structural configuration and operations at main-stem dams meet BiOp fish passage criteria and other juvenile salmonid dam passage criteria. Although the primary purpose of BiOp studies was to estimate the juvenile salmonid survival rates and passage behavior, additional processing and analysis of these large datasets can be used to answer other relevant fish management questions.

1.1 Study Objectives

The study included objectives to evaluate the survival rates of juvenile salmonids relative to operation levels at BON powerhouses and spillway and the TDA spillway.

1.1.1 Bonneville Dam Powerhouses 1 and 2

Using multi-year datasets, the survival of juvenile salmonids passing through turbines at B1 and B2 were analyzed across the operating ranges fish experienced during passage to identify operating conditions that provide the safest and most efficient passage conditions for juvenile salmonids.

Turbine operations included in the analysis for B1 were the lower quarter of 1% of the peak efficiency operating range (Q1), lower middle quarter of the 1% of peak efficiency operating range (Q2), upper middle quarter of the 1% of peak efficiency operating range (Q3), upper quarter of the 1% of peak efficiency operating range (Q4), best operating range (BOR, from upper end of peak 1% of peak efficiency to BOP), and above BOP to the generator limit (ABOP). Operations included in analysis of B2 were Q1, Q2, Q3, and Q4. The effects of tailrace elevation and egress time on juvenile salmonid survival rates for the turbine operations listed above for B1 and B2 were also evaluated.

1.1.2 Bonneville Dam Spillway

BON juvenile salmonid spill passage survival data, factored by individual spillbays, groups of spillbays, tailrace elevations, and discharges, were analyzed to determine whether lower passage survival rates could be attributed to regions of the spillway that may have been damaged by erosion or other mechanisms. The effect of spillway discharge on tailrace egress time was also investigated.

1.1.3 The Dalles Dam Spillway

Juvenile salmonid spillway passage survival rates were estimated for passage through spillbays within the new spill wall at TDA (spillbays 1–8) and compared to survival rates for fish that passed in spill outside of the spill wall (spillbays 9–23) to determine whether high river flows and the resultant use of spillbays outside of the new tailrace spill wall affected survival rates. Survival rates were also estimated for juvenile salmonids passing through spillbays 9–12 compared to other estimated spill passage survival rates to determine if fish that passed near the spill wall survived at a rate different from those passing further from the edge of the spill wall (edge effect). Spillway discharge and tailrace elevation were investigated for their effects on the survival rates for juvenile salmonids passing through spillbays.

1.2 Study Area Description

BON is located on the Columbia River at river kilometer (rkm) 234 and is the last dam before the Pacific Ocean. BON consists of two powerhouses (B1 and B2), a spillway (18 spillbays), and a navigation lock (Figure 1.1). B1 has 10 turbine units with a sluiceway running along the top of the turbine intakes; normally only three of the sluice gates are open due to channel volume limitations. B2 has 8 turbine units with a surface flow outlet, a modified ice and trash sluiceway, located near the south end of the powerhouse (corner collector). The spillway has 18 spillbays with lift-type gates. At B1, B2, and the spillway, cabled hydrophones were deployed through large-diameter pipes attached to spillway pier noses (see Ploskey et al. 2009 for detailed descriptions).

Juvenile salmonids tagged with AMTs and released at various sites between rkm 503 (Port Kelley, WA) and rkm 275 (Hood River, OR) from 2008 through 2012 were pooled to form the dataset used for the BON data analyses (see Section 2.4). All fish detected by JSATS detection arrays at BON were regrouped as a virtual release, and several arrays of autonomous nodes located downstream of BON were used as survival and detection arrays for survival analysis. The locations of downstream arrays varied between years due to differences in study designs, with the most downstream array deployed at rkm 86 (Oak Point, WA). Table 1.1,

Table 1.2, Table 1.3, Table 1.4,

Table 1.5, and Table 1.6 show the locations at which fish were released and the locations of the detection arrays used for these analyses. The first two survival array locations below BON (i.e., primary, secondary arrays) varied by year, while the location of the tertiary survival array was always at rkm 86. The primary survival detection array was located 31 rkm downstream of BON in 2008, and 42, 81, 73, and 78 rkm downstream of BON in 2009, 2010, 2011, and 2012, respectively. The secondary array was located at rkm 192 (near Lady Island) in 2008, and at rkm 113 (Kalama, WA) from 2009 through 2012. The tertiary array was not present in 2011, or during spring 2012.

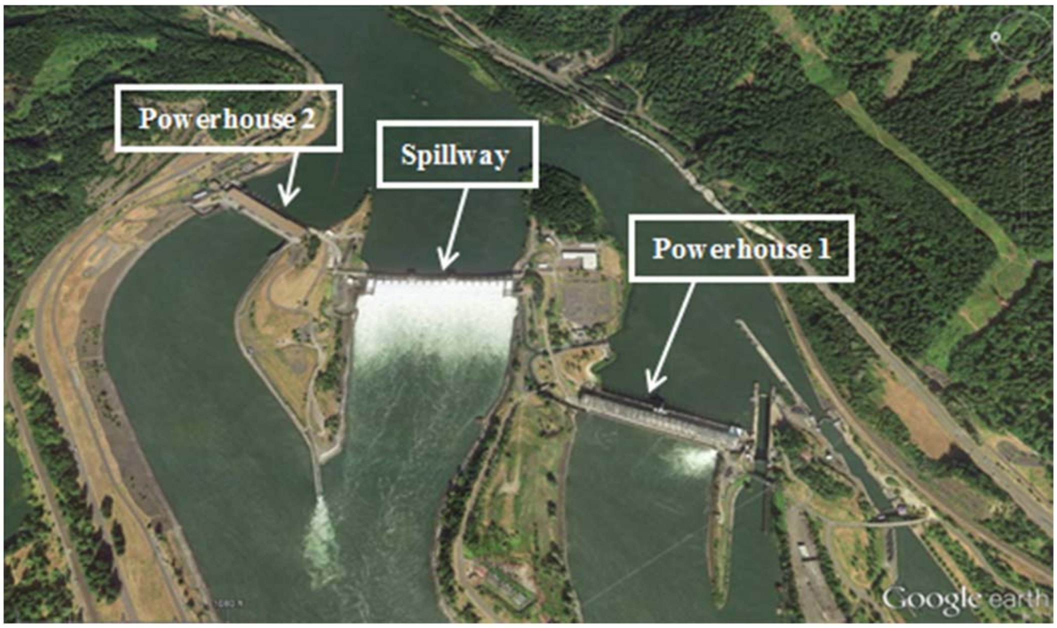

Figure 1.1. BON Study Area Photo Showing the Two Powerhouses and Spillway. The BON B1 is to the right. A modified image (45°38'34.64"N, 121°56'43.61"W) from Google Earth™ (V7.1.2.2041), Google Inc. (Accessed October 14, 2013).

Table 1.1. Release and Survival Detection Array Locations and Descriptions for BON, 2008

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Arlington, OR
346	Release 2	JDA tailrace
306	Release 3	TDA tailrace
234	**Virtual Release 1**	**BON**[(a)]
203	Primary survival array	Reed Island, WA
192	Secondary survival array	Lady Island, WA
86	Tertiary survival array	Oak Point, WA[(b)]

(a) Spillway and B2 only
(b) Summer only

Table 1.2. Release and Survival Detection Array Locations and Descriptions for BON, 2009

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
234	**Virtual Release 1**	**BON**[(a)]
192	Primary survival array	Lady Island, WA
113	Secondary survival array	Kalama, WA
86	Tertiary survival array	Oak Point, WA[(b)]

(a) B2 only
(b) Summer only

Table 1.3. Release and Survival Detection Array Locations and Descriptions for BON, 2010

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
307	Release 2	TDA tailrace
275	Release 3	Hood River, OR
234	**Virtual Release 1**	**BON**[(a)]
153	Primary survival array	Knapp, WA
113	Secondary survival array	Kalama, WA
86	Tertiary survival array	Oak Point, WA[(b)]

(a) B1, spillway, and B2
(b) Summer only

Table 1.4. Release and Survival Detection Array Locations and Descriptions for BON, 2011

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
346	Release 2	JDA tailrace
325	Release 3	Celilo, OR
307	Release 4	TDA tailrace
275	Release 5	Hood River, OR
234	**Virtual Release 1**	**BON**[(a)]
161	Primary survival array	Reeder Point, WA
113	Secondary survival array	Kalama, WA

(a) B1, spillway, and B2

Table 1.5. Release and Survival Detection Array Locations and Descriptions for BON, Spring 2012

Columbia River Kilometer (rkm)	Release and Array Description	Location
503	Release 1	Port Kelley, WA
468	Release 2	MCN tailrace
422	Release 3	Crow Butte State Park, WA
346	Release 4	JDA tailrace
325	Release 5	Celilo, OR
234	**Virtual Release 1**	**BON**[(a)]
156	Primary survival array	Knapp, WA
113	Secondary survival array	Kalama, WA

(a) B1, spillway, and B2

Table 1.6. Release and Survival Detection Array Locations and Descriptions for BON, Summer 2012

Columbia River Kilometer (rkm)	Release and Array Description	Location
503	Release 1	Port Kelley, WA
468	Release 2	MCN tailrace
422	Release 3	Crow Butte State Park, WA
346	Release 4	JDA tailrace
325	Release 5	Celilo, OR
307	Release 6	TDA tailrace
275	Release 7	Hood River, OR
234	**Virtual Release 1**	**BON**[(a)]
156	Primary survival array	Knapp, WA
113	Secondary survival array	Kalama, WA
86	Tertiary survival array	Oak Point, WA

(b) B1, spillway, and B2

TDA is located on the Columbia River at rkm 309 and is the second dam upstream from the Pacific Ocean. TDA powerhouse has 22 turbine units, 2 fish units, and a sluiceway. TDA spillway has 23 spillbays (Figure 1.2). Only fish detected passing at the spillway from 2010 through 2012 were used in the metadata analysis to evaluate the survival rates and egress times of juvenile salmonids passing within the spill wall (spillbays 1–8) and outside the spill wall (spillbays 9–23). The newly installed spill wall was designed to improve egress conditions for and survival of out-migrating salmonids. Fish used in this data analysis were released between rkm 325 and 503 (Celilo, OR). The primary, secondary, and tertiary survival detection arrays for TDA were located at rkm 234 (BON cabled array), rkm 156 or 161 (Knapp or Reeder Point, WA), and rkm 113 (Kalama, WA), respectively. Table 1.7, Table 1.8, and Table 1.9 show the locations of tagged fish releases, detection arrays for virtual releases, and the locations of survival arrays used in the data analyses.

Figure 1.2. TDA Study Area Photo Showing TDA Spillbays and Spill Walls. A modified image (45°36'49.19"N, 121°8'0.61"W) from Google Earth™ (V7.1.2.2041), Google Inc. (Accessed October 14, 2013).

Table 1.7. Release and Survival Detection Array Locations and Descriptions for TDA, 2010

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
309	**Virtual Release 1**	**TDA Spillway**
234	Primary survival array	BON
153	Secondary survival array	Knapp, WA
113	Tertiary survival array	Kalama, WA

Table 1.8. Release and Survival Detection Array Locations and Descriptions for TDA, 2011

Columbia River Kilometer (rkm)	Release and Array Description	Location
390	Release 1	Roosevelt, WA
346	Release 2	JDA tailrace
325	Release 3	Celilo, OR
309	**Virtual Release 1**	**TDA Spillway**
234	Primary survival array	BON
161	Secondary survival array	Reeder Point, WA
113	Tertiary survival array	Kalama, WA

Table 1.9. Release and Survival Detection Array Locations and Descriptions for TDA, 2012

Columbia River Kilometer (rkm)	Release and Array Description	Location
503	Release 1	Port Kelley, WA
468	Release 2	MCN tailrace
422	Release 3	Crow Butte State Park, WA
346	Release 4	JDA tailrace
325	Release 5	Celilo, OR
309	**Virtual Release 1**	**TDA Spillway**
234	Primary survival array	BON
156	Secondary survival array	Knapp, WA
113	Tertiary survival array	Kalama, WA

1.3 Report Contents and Organization

The ensuing sections of this report present the study methods (Section 2.0) relative to each particular dam and passage route used by the three species/life stages studied. The associated results for each dam passage route are then presented in Sections 3.0 through 6.0 by species/life stage. Sections 7.0 and 8.0 contain discussion and the concluding recommendations, respectively.

2.0 Methods

Data for the analysis described in this report were compiled from survival studies conducted from 2008 through 2012 at BON and from 2010 through 2012 at TDA. Significant differences between survival rate estimates were detected by comparing the 95% confidence intervals of survival estimates.

2.1 Species

Two species of juvenile salmonids that out-migrate in three runs were included in our study. They are yearling Chinook salmon (CH1) and juvenile steelhead (STH), which both out-migrate in the spring, and subyearling Chinook salmon (CH0), which out-migrate in summer. For brevity in figure or table titles, the term "each species-run" refers to the two runs of Chinook salmon and juvenile steelhead.

2.2 Array Locations and Study Functions

Two types of JSATS arrays, cabled (see Weiland et al. 2011a) and autonomous (see Titzler et al. 2010), were deployed to detect out-migrating salmonids double-tagged with JSATS AMTs and PITs as they passed through study reaches (Table 1.1 through Table 1.9).

Detailed descriptions of the design of each BiOp compliance study, details such as AMT tag-life, and the results of the studies can be found in the technical/compliance reports listed below.

2008

- *Survival Rates of Juvenile Salmonids Passing Through the Bonneville Dam and Spillway in 2008* (Ploskey et al. 2009)
- *Evaluation of a Behavioral Guidance Structure at Bonneville Dam Second Powerhouse including Passage Survival of Juvenile Salmon and Steelhead using Acoustic Telemetry, 2008* (Faber et al. 2010)
- *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival at John Day Dam with Emphasis on the Prototype Surface Flow Outlet, 2008* (Weiland et al. 2009).

2009

- *Evaluation of a Behavioral Guidance Structure on Juvenile Salmonid Passage and Survival at Bonneville Dam, 2009* (Faber et al. 2011)
- *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival Proportions at John Day Dam, 2009* (Weiland et al. 2011b).

2010

- *Survival and Passage of Juvenile Chinook Salmon and Steelhead Passing Through Bonneville Dam, 2010* (Ploskey et al. 2011a)
- *Survival and Passage of Yearling and Subyearling Chinook Salmon and Steelhead at The Dalles Dam, 2010* (Johnson et al. 2011)

- *Monitoring of Subyearling Chinook Salmon Survival and Passage at Bonneville Dam, Summer 2010* (Ploskey et al. 2011b)
- *Compliance Monitoring of Juvenile Subyearling Chinook Salmon Survival and Passage at The Dalles Dam, Summer 2010* (Skalski et al. 2010a)
- *Monitoring of Juvenile Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at Bonneville Dam, Spring 2010* (Ploskey et al. 2011c)
- *Compliance Monitoring of Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at The Dalles Dam, Spring 2010* (Skalski et al. 2010b).

2011

- *Compliance Monitoring of Yearling Chinook Salmon and Juvenile Steelhead Survival and Passage at Bonneville Dam, Spring 2011* (Skalski et al. 2012a)
- *Compliance Monitoring of Juvenile Yearling Chinook Salmon and Steelhead Survival and Passage at The Dalles Dam, Spring 2011* (Skalski et al. 2012b)
- *Route-Specific Passage Proportions and Survival Rates for Fish Passing through John Day Dam, The Dalles Dam, and Bonneville Dam in 2010 and 2011* (Ploskey et al. 2012)
- *Survival and Passage of Juvenile Chinook Salmon and Steelhead Passing through Bonneville Dam, 2011* (Ploskey et al. 2013)
- *Survival and Passage of Yearling Chinook Salmon and Steelhead at The Dalles Dam, Spring 2011* (Johnson et al. 2012).

2012

- *Compliance Monitoring of Subyearling Chinook Salmon Survival and Passage at Bonneville Dam, Summer 2012* (Skalski et al. 2013a)
- *Compliance Monitoring of Subyearling Chinook Salmon Survival and Passage at The Dalles Dam, Summer 2012* (Skalski et al. 2013b).

2.3 Division of Operation Levels

The turbine operating ranges used in the analysis of turbine passage survival data for BON were obtained from the B1 and B2 turbine output and discharge tables in annual USACE Fish Passage Plans (FPPs) (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/).

The operating range of B1 and B2 turbines within the lower and upper bounds of the 1% of peak efficiency operating range were divided into quartiles for analysis of fish turbine passage survival rates. The bounds for the quartiles in terms of turbine discharge were determined using head and discharge values from the turbine output and discharge tables in the 2013 FPP (USACE 2013), which included data identifying the BOP for B1 turbines.

The times when tagged fish were detected passing turbines were merged with 5 min dam operation data. Fish were then assigned to an operation range bin that coincided with the operating condition of a turbine unit at the time they passed the turbine.

2.3.1 Bonneville Dam Powerhouse 1

Turbine discharge curves for B1 were developed for operations without submersible traveling screens (STSs) in the turbine intakes. The discharge curves for B1 turbines were divided into quartiles within the limits of the 1% of peak efficiency operating range.

Four treatments (herein referred to as "operation treatments"—Q1, Q2, Q3, and Q4) were used to segment the turbine operating range for analysis of the survival rates of fish passing through B1 turbines as follows:

- Q1 – the lower limit of 1% of the peak efficiency operating range to the first quartile
- Q2 – lower quartile or 25th percentile up to the median
- Q3 – median or 50th percentile to the 75th percentile
- Q4 – 75th percentile to the upper limit of 1% of peak efficiency operating range.

Two additional ranges above the upper 1% of peak efficiency operating limit were also defined:

- BOR – turbine operations from the upper 1% boundary of the peak efficiency operating limit to the BOP
- ABOP – turbine operations from BOP to the generator limit.

The turbine operation values used to construct the data ranges for the analysis are shown in Figure 2.1 and are provided in Appendix A (Table A.1).

In addition to the turbine operating ranges identified above, two operating range groups (herein referred to as "grouped operation treatments") were defined for the analysis:

- LL through UL – lower limit through the upper limit of the 1% of peak efficiency operating range, which includes Q1, Q2, Q3, and Q4
- LL to BOP – lower limit of 1% of peak efficiency operating range to the best operating point, which includes ranges Q1, Q2, Q3, Q4, and BOR.

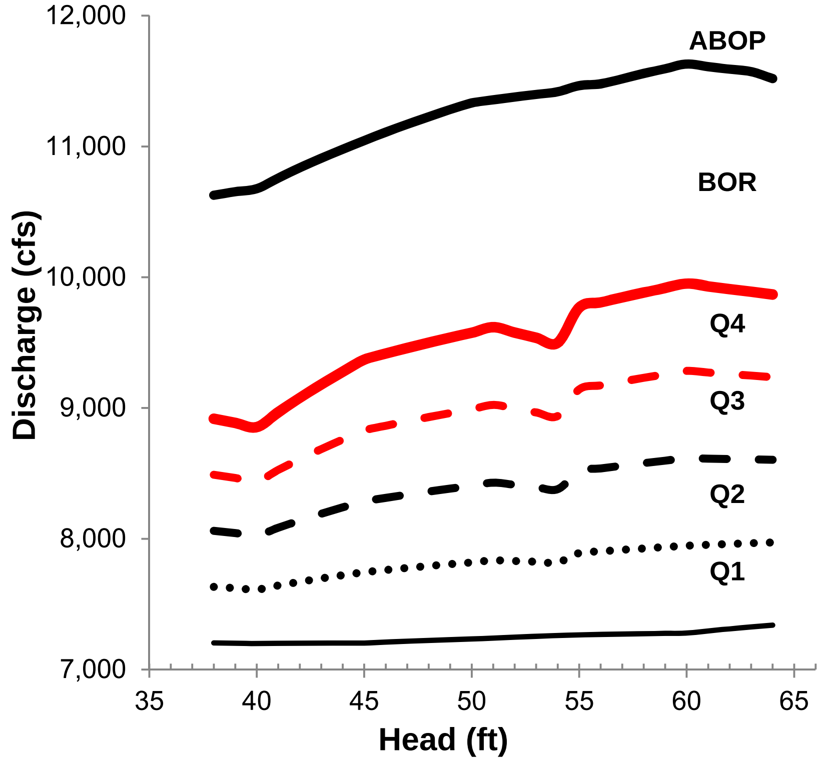

Figure 2.1. Turbine Operating Treatment Boundaries for B1 without Submersible Traveling Screens by Turbine Head and Discharge

2.3.2 Bonneville Dam Powerhouse 2

Discharge curves for B2 turbines were divided into four quartiles within the limits of the 1% of peak efficiency operating range (Q1, Q2, Q3, and Q4) for operation with and without STSs in turbine intakes (Figure 2.2 and Figure 2.3, respectively). The values used to construct the data ranges shown in the figures are provided in Appendix A, Table A.2 and Table A.3, respectively.

Four treatments (herein referred to as “operation treatments” Q1, Q2, Q3, and Q4) were used to segment the turbine operating range for analysis of the survival rates of fish passing through B2 turbines as follows:

- Q1 – the lower limit of 1% of the peak efficiency operating range to the first quartile
- Q2 – lower quartile or 25th percentile up to the median
- Q3 – median or 50th percentile to the 75th percentile
- Q4 – 75th percentile to the upper limit of 1% of peak efficiency operating range.

Grouped operation treatments BOR and ABOP were not included in analysis of the survival rates of fish passing through B2 turbines because turbine operation is physically limited at the upper limit of the 1% of peak operating efficiency range.

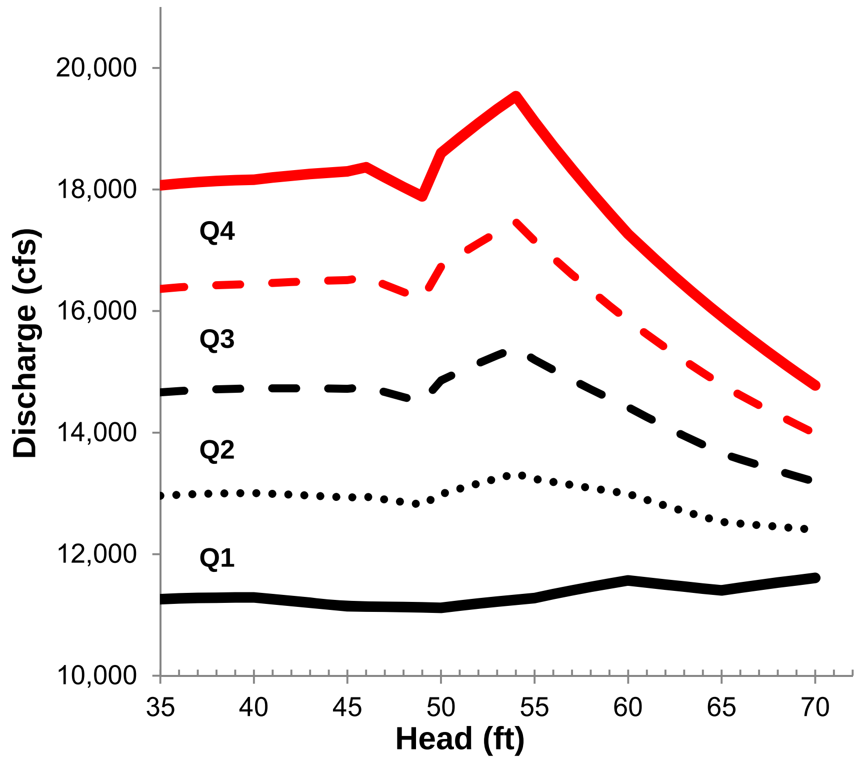

Figure 2.2. B2 Turbine Operating Treatments by Discharge as a Function of Operating Head for Turbines with Submersible Traveling Screens

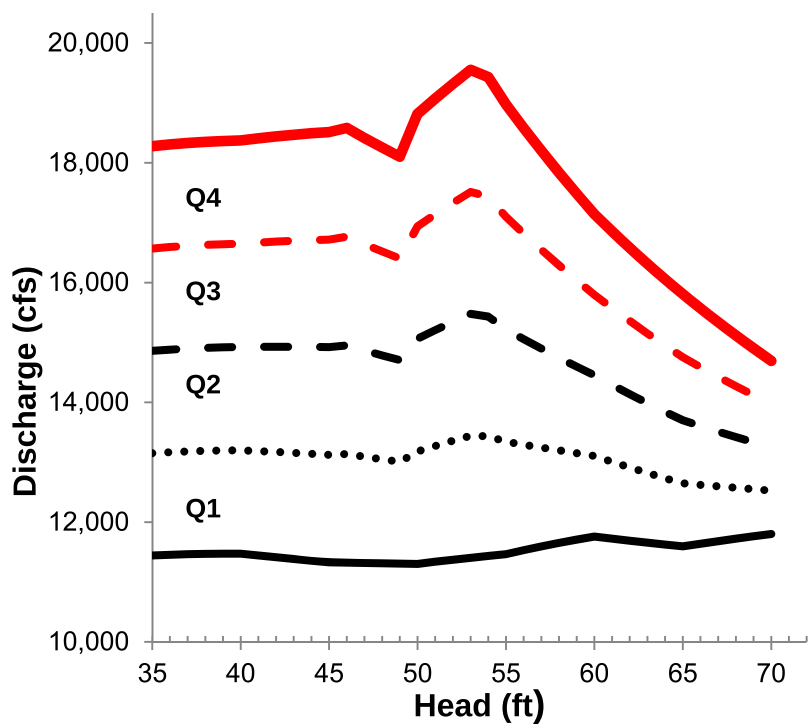

Figure 2.3. B2 Turbine Operating Treatments by Discharge as a Function of Operating Head for Turbines without Submersible Traveling Screens

2.3.3 Bonneville Dam Spillway

At the BON spillway, survival rates for juvenile salmonids passing in spill were analyzed to determine if there were differences in rate of fish passage survival resulting from structural or operational differences between spillbays and groups of spillbays. The survival performance of fish that passed through individual spillbays were analyzed for differences in survival rates between individual spillbays, the proportion of fish passing through individual spillbays, the effects of discharge and tailwater elevation on survival rates, the effects of potential spillbay erosion or presence of rocks, and egress time of fish through the spillway tailrace. Spillbays were grouped by flow deflector type (shallow or deep) and by potential spillbay erosion or the presence of rocks in the stilling basin. The survival rates for fish that passed through spillways with deep-flow (spillbays 1–3 and 16–18) and shallow-flow (spillbays 4–15) deflectors were compared. Spillbays with shallow-flow deflectors were divided into three groups (spillbays 4–7, spillbays 8–12, and spillbays 13–15). Spillbays 8–12 are suspected of having structural damage and rock present in their stilling basins, and spillbays 4–7 and spillbays 13–15 bracket the spillbays having possible damage.

2.3.4 The Dalles Dam Spillway

The survival rates and fish distribution were examined for fish passing through individual spillbays 1–8 (spillbays northeast of the new spill wall) at TDA. In addition, the differences in survival rates for fish passing spillbay groups 1–8 and 9–23 (spillbays southwest of the new spill wall) were compared, as were those of spillbays 9–12 and 13–23. The spillway discharges were analyzed for the effects on fish survival and tailrace egress time.

2.4 Analytical Methods

A single-release-recapture model (Cormack-Jolly-Seber Model) was used to estimate turbine and spillbay passage survival probabilities, using at least two downstream detection arrays (Figure 2.4 and Figure 2.5) (see Burnham et al. 1987). Typically, the analyses used three survival arrays with the exception of BON in 2011 and spring 2012, when two survival arrays were used for the analyses (Table 1.1 through Table 1.9). Detection histories of survival estimates were based on detection at downstream detection arrays. When there were only two downstream detection arrays, the model has $2^2 = 4$ possible detection histories as follows:

- 11 – detected on both the primary and secondary arrays
- 10 – detected on the primary but not on the secondary array
- 01 – not detected on the primary but detected on the secondary array
- 00 – never detected.

When there are three detection arrays, the model has $2^3 = 8$ possible detection histories as follows:

- 111 – detected on all three arrays
- 110 – detected on the primary and secondary arrays, but not on the tertiary array
- 101 – detected on the primary and tertiary arrays, but not on the secondary array
- 100 – detected on the primary array, but not on the secondary or tertiary arrays
- 011 – not detected on the primary array, but detected on the secondary and tertiary arrays

- 010 – detected on the secondary array, but not on the primary or tertiary arrays
- 001 – not detected on the primary or secondary arrays, but detected on the tertiary array
- 000 – never detected.

2.4.1 Release-Recapture Design and Sample Size

The release-recapture designs and sample sizes for BON and TDA BiOp compliance studies are described in the following sections.

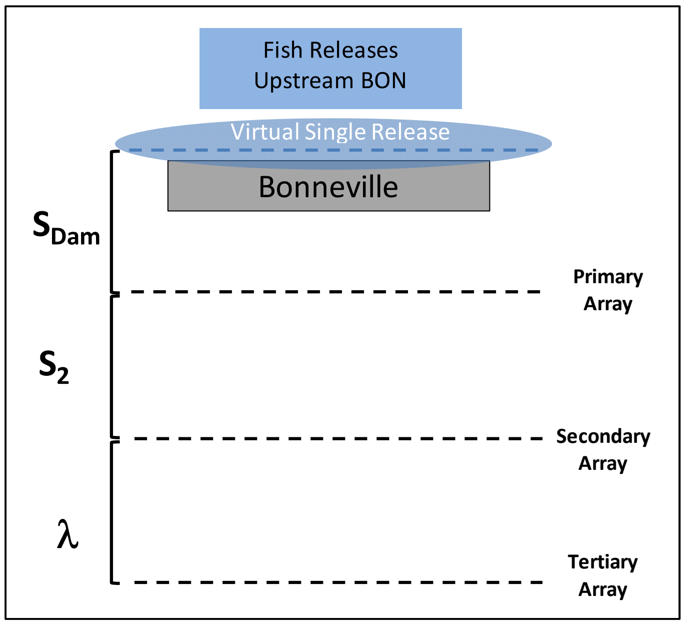

Figure 2.4. Schematic of the Single-Release-Recapture Model for Passage Survival Estimates at BON. The virtual release was composed of fish released upstream of the dam that were detected on the dam-face cabled array (Table 1.1 through Table 1.6).

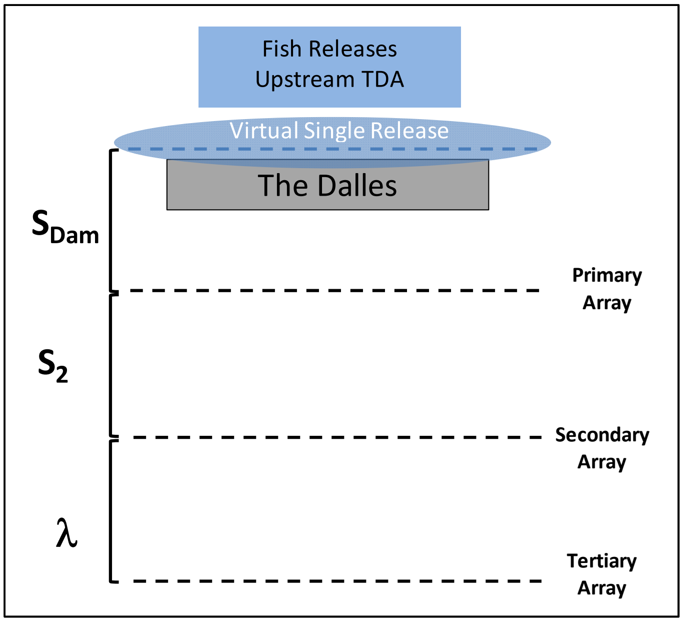

Figure 2.5. Schematic of the Single-Release-Recapture Model for Passage Survival Estimates at TDA. The virtual release was composed of fish released upstream of the dam that were detected on the dam-face cabled array (Table 1.7, Table 1.8, and Table 1.9).

2.4.1.1 Bonneville Dam

All tagged fish released above BON detected on the BON dam-face cabled array were regrouped to form a virtual release. These fish were used to estimate dam passage survival probability using the single-release-recapture model. A total of 13,360 CH1, 12,118 STH, and 13,094 CH0 (Table 2.1) were detected on the BON dam-face cabled array used in the analysis. Tag-life corrections were not applied to the model.

Table 2.1. The Numbers (N) of Fish Detected and Regrouped as a Virtual Release Fish at BON by Year, Species, and Dam Passage Route

	CH1			STH			CH0		
Year	B1	B2	Spillway	B1	B2	Spillway	B1	B2	Spillway
2008		274	1,514		130	1,473		759	2,279
2009		368			268			215	
2010	124	533	1,767	110	574	1,363	561	437	1,787
2011	1,162	446	3,170	1,298	162	3,111			
2012	1,164	613	2,225	1,301	202	2,126	1,229	1,295	4,532
Total	2,450	2,234	8,676	2,709	1,336	8,073	1,790	2,706	8,598

2.4.1.2 The Dalles Dam

At TDA, only tagged fish passing the spillway that were detected on the dam-face cabled array were used to estimate spillbay passage survival rates. Fish released upstream of TDA (rkm 309) and detected at the spillway were regrouped to form a virtual release. A total of 8,223 CH1, 9,056 STH, and 6,901 CH0 were used in the survival analyses (Table 2.2). Tag-life corrections were not applied to the model.

Table 2.2. The Numbers of Fish Detected Passing through Groups of Spillbays at TDA by Species and Year that were Regrouped as a Virtual Release

Year	CH1		STH		CH0	
	Spillbays 1–8	Spillbays 9–23	Spillbays 1–8	Spillbays 9–23	Spillbays 1–8	Spillbays 9–23
2010	1,715		1,796		1,720	
2011	2,401	391	2,700	544		
2012	3,620	96	3,894	122	5,040	141
Total	7,736	487	8,390	666	6,760	141

2.4.2 BON Tailwater Elevation Evaluation

The effect of tailwater elevation on the survival of juvenile salmonids after passage at BON was estimated over the observed range of tailwater elevations. Tailwater elevations obtained from USACE operations data (5 min intervals) were placed into 1 m depth bins relative to mean sea level (MSL). These elevation groups were identified as 5 m for tailrace elevations <5.5 m; 6 m for tailrace elevations 5.5 m to <6.5 m; 7 m for tailrace elevations 6.5 m to <7.5 m; 8 m for tailrace elevations 7.5 m to <8.5 m; and 9 m for tailrace elevations ≥8.5 m. Each juvenile salmonid was assigned to an elevation bin associated with the time of passage at the dam.

2.4.3 BON Spillway Discharge Evaluation

To evaluate the survival rates of juvenile salmonids passing the spillway relative to discharge levels, spillway discharge was incremented into 10 and 20 kcfs discharge bins. Spillway discharges volumes were calculated from USACE dam operations data (5 min intervals) and juvenile salmonids were assigned to a discharge bin associated with their spillway passage time. The 10 kcfs discharge bins include the 5 kcfs discharge range on either side of the 10 kcfs point (i.e., 100 kcfs = 95–104 kcfs; 110 kcfs = 105–114 kcfs). For the ≤90 kcfs discharge range, discharge encompassed all spillway discharge volumes ≤94 kcfs. In spring ≥290 kcfs was the largest discharge bin and included discharge levels ≥285 kcfs. In summer the largest discharge bin was ≥230 and included discharge levels ≥225 kcfs.

Using the same operations data, the 20 kcfs discharge bins included the 10 kcfs discharge range on either side of the 20 kcfs point (i.e., 100 kcfs = 90–109 kcfs; 120 kcfs =110–129 kcfs). The ≤80 kcfs bin included spillway discharge ≤89 kcfs. In spring, the upper end of the discharge bin was ≥280 kcfs and included all fish passing the spillway in discharge volumes ≥270 kcfs. In summer the upper end discharge bin was ≥ 20 and included all fish passing the spillway in discharge volumes ≥210 kcfs.

2.4.4 TDA Spillway Discharge Evaluation

To investigate the survival rates of juvenile salmonids passing TDA spillway relative to discharge levels, spillway discharge was incremented into 10 and 24 kcfs discharge bins. Spillway discharge was calculated from USACE dam operations data (5 min intervals) and juvenile salmonids were assigned to a discharge bin associated with when it passed at the spillway. The 10 kcfs discharge bins include the 5 kcfs discharge range on either side of the 10 kcfs point (i.e., 80 kcfs = 75–84 kcfs; 90 kcfs=85–94 kcfs). For the ≤70 kcfs discharge range discharge encompassed all spillway discharge volumes ≤74 kcfs. The upper end of the discharge range included all discharge ≥155 kcfs in the ≥160 kcfs bin.

Using the same operations data, the 24 kcfs discharge bins included the 12 kcfs discharge range on either side of the 24 kcfs point (i.e., 96 kcfs = 85–108 kcfs; 120 kcfs = 109–132 kcfs). The ≤72 kcfs bin included spillway discharge ≤84 kcfs. The upper end of the discharge range included all fish passing the spillway in discharge volume ≥157 kcfs in the ≥168 kcfs discharge range bin.

2.5 Tag Specifications and Tag Life

The JSATS AMTs used in these studies were manufactured by Advanced Telemetry Systems Inc. (ATS). Two models of JSATS AMTs manufactured by ATS were used in the 2008 through 2012 studies (Table 2.3). Over time the AMTs were reduced in size and weight. Both designs transmitted the same binary phase-shift keying coded signal type at a frequency of 416.7 kHz (Weiland et al. 2011a).

Table 2.3. Tag Sizes, Pulse Repetition Interval, and Expected Tag Life in Days by Year

Year	Manufacturer	Model Number	Mass In Air (g)	Dimensions (mm)	Pulse Repetition Interval (s)	Median Tag Life (d)
2008 spring	ATS		0.485	12.46 x 2.30 x 3.70	3	31
2008 summer	ATS	SS130	0.425	12.04 x 5.27 x 3.74	3	31
2009	ATS	SS130	0.439	12.02 x 5.21 x 3.72	3	35
2010	ATS	SS130	0.440	11.99 x 5.20 x 3.78	3	34
2011	ATS	SS130	0.438	11.88 x 5.08 x 3.74	3	30
2012[a]	ATS	SS130	0.438	11.88 x 5.08 x 3.74	3	32
2012[b]	ATS	SS300	0.303	10.69 x 5.20 x 3.02	3	24

(a) AMT implanted in STH during spring 2012.
(b) AMT implanted in CH1 and CH0 in 2012.

2.6 Environmental Conditions

Environmental conditions included in the analyses were project water discharge (kcfs), spillway discharge (kcfs), and water temperature (°C). All data were obtained from the Columbia River DART (Data Access in Real Time) website (http://www.cbr.washington.edu/dart).

2.6.1 Bonneville Dam

Fourteen years of BON environmental data, from 1999 through 2012, which includes 9 years prior to 2008 and the passage survival study years 2008 through 2012, were averaged to provide a baseline for environmental conditions for this evaluation. BON project discharge in the spring was generally greater than the 14 yr average during 2011 and 2012, and lower than the 14 yr average in spring 2010 (Figure

2.6). Flows were greater than the 14 yr average during the summers of 2008, 2010, 2011, and 2012 (Figure 2.6 and Figure 2.7).

In general, water temperatures in 2008, 2010, 2011, and 2012 were cooler than the 14 yr average in both spring and summer (Figure 2.8). Water temperatures were above the 14 yr average only once during summer 2009.

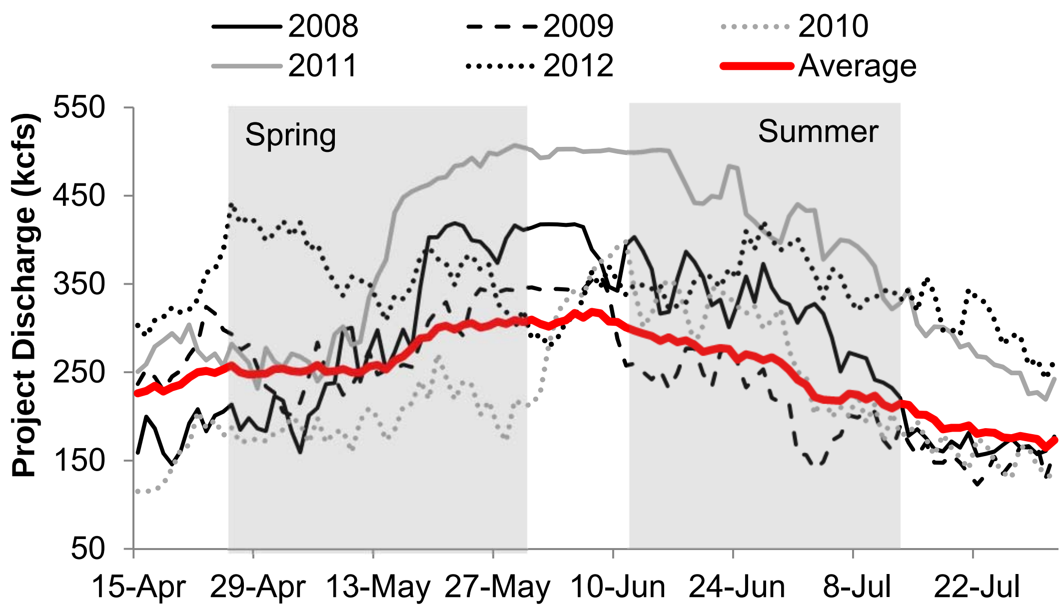

Figure 2.6. BON Project Discharge by Study Year (2008–2012) and 14-Year Average (1999–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

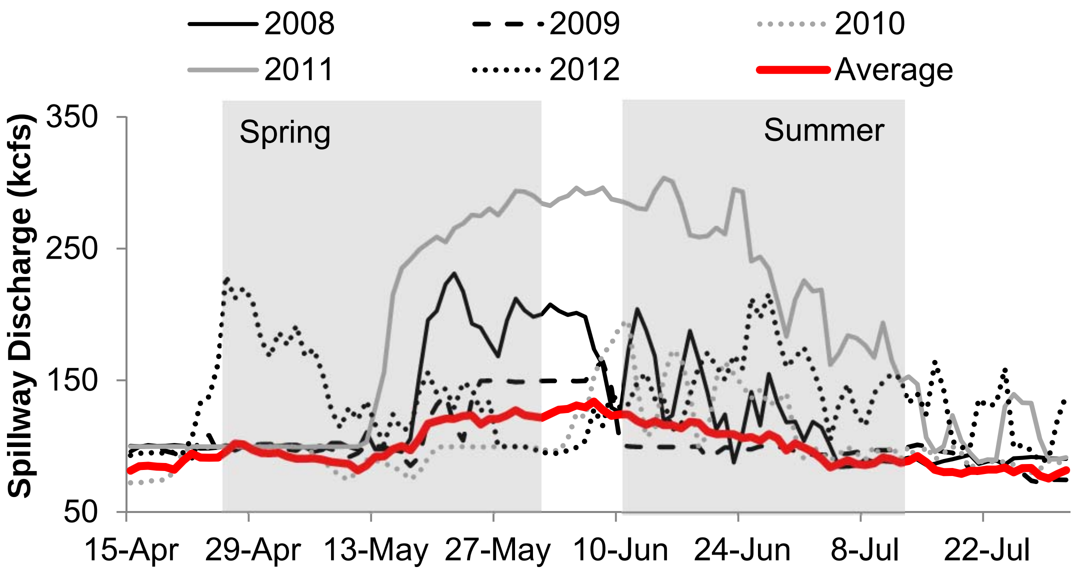

Figure 2.7. BON Spillway Discharge by Study Year (2008–2012) and 14-Year Average (1999–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

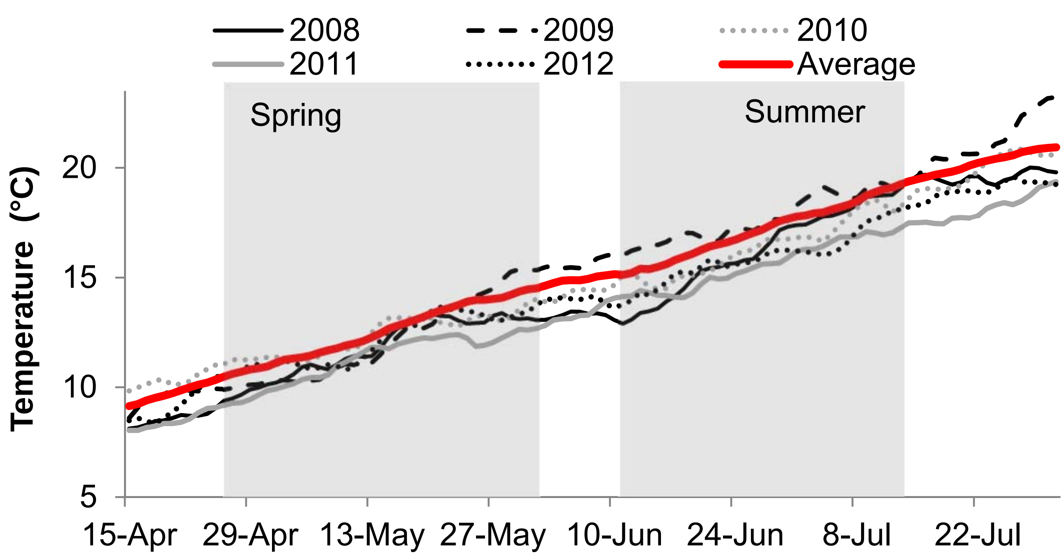

Figure 2.8. BON Forebay Water Temperature by Study Year (2008–2012) and 14-Year Average (1999–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

2.6.2 The Dalles Dam

Twelve years of TDA environmental data, 2001–2012, were averaged to provide a baseline of environmental conditions for comparison with those experienced during the study years included in this analysis, 2010−2012. In 2010, TDA project discharge was lower than the 12 yr average in spring, greater in early summer, and lower in late summer (Figure 2.9 and Figure 2.10). From the late spring through summer in 2011 the project discharge was nearly double the 12 yr average project discharge. The very high discharge in 2011 resulted in the cancelation of a planned summer study. In 2012, TDA total discharge was also higher than the 12 yr average during both the spring and summer studies. Generally, temperatures for the years 2010–2012 were below the 12 yr average (Figure 2.11).

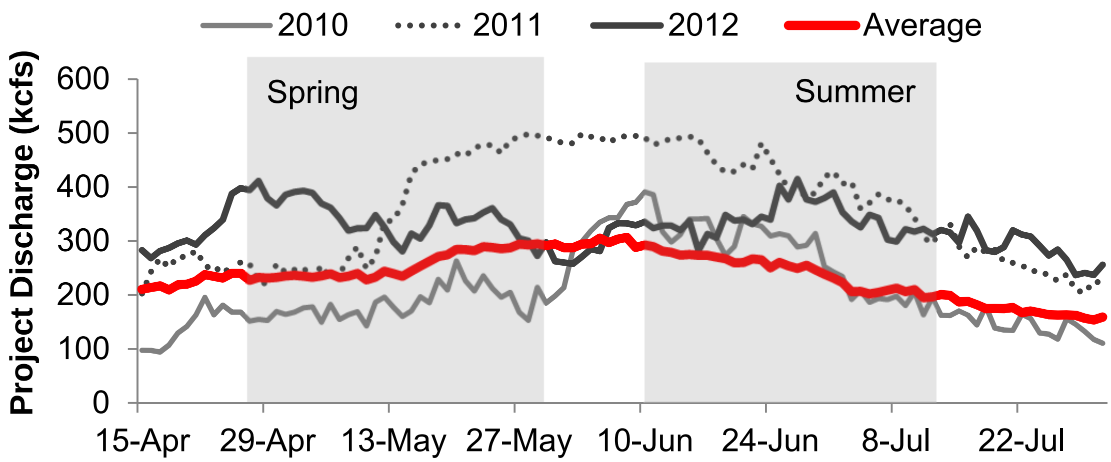

Figure 2.9. TDA Project Discharge by Study Year (2010–2012) and 12-Year Average (2001–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

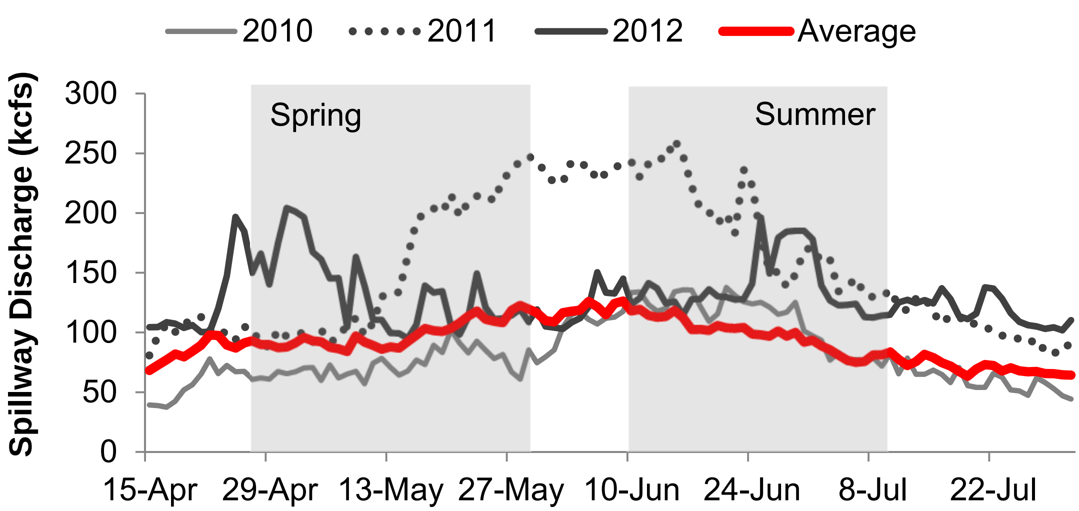

Figure 2.10. TDA Spillway Discharge by Study Year (2010–2012) and 12-Year Average (2001–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

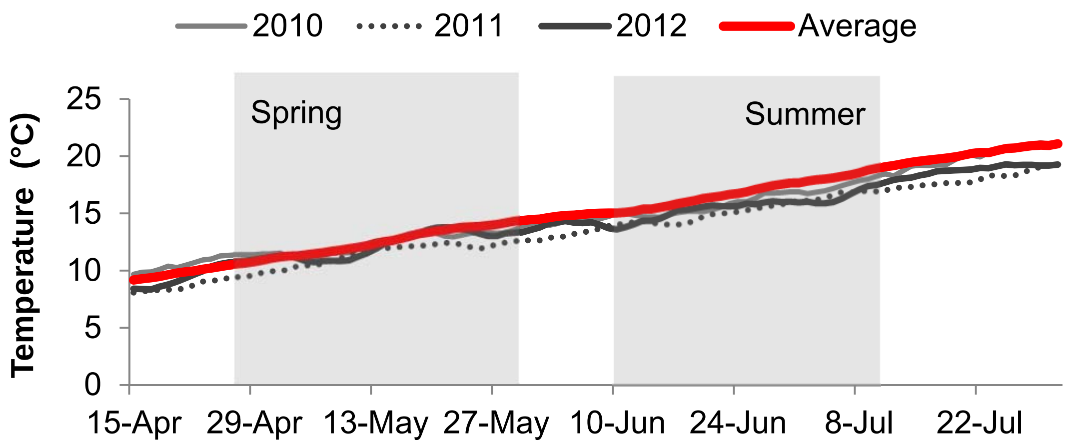

Figure 2.11. TDA Forebay Water Temperature by Study Year (2010–2012) and 12-Year Average (2001–2012). The gray boxes identify the duration of the spring and summer portions of dam passage studies.

2.6.3 River Discharge and Forebay/Tailrace Elevation

Dam discharge data (dam operations) by spillbay and turbine unit and forebay and tailrace elevations used in these analyses were in 5 min increments using automated data-acquisition systems at BON (2008–2012) and TDA (2010–2012).

2.6.4 Spillway Conditions

Scheduled spillway discharges for BON and TDA are included in the FPP for each year (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/).

2.6.4.1 Bonneville Dam

The planned spillway discharge at BON in spring was 100 kcfs day/night for all study years. There were two treatment spillway discharges at BON in summer, 85 kcfs/121 kcfs (day/night) and 95 kcfs/95 kcfs (day/night) in 2010 and 2012. Spill discharges planned for BON 2008 through 2012 are presented in Table 2.4.

BON spillway discharge was greater than the 14 yr average, and discharge was greater than the spill pattern set in the FPP for much of the spring fish passage season in 2008, 2011, and 2012. Spill during the summer out-migration season was above the 14 yr average for the first half of the season in 2008 and 2010, and the entire summer season in 2011 and 2012 (Figure 2.7). The planned spill pattern was achieved after July 4 and July 1, during 2008 and 2010 study years, respectively, but not achieved during the 2012 study. The 2011 summer study was canceled due to high river discharge.

Table 2.4. BON Spillway Discharge (2008–2012) as Specified in the FPP and Special Operations for Spill Treatment Tests

Year	Spring Day/Night (kcfs)	Summer Day/Night (kcfs)	Spill Pattern Met
2008	100/100	85/gas cap[(a)]	Before May 18 and after July 3
2009	100/100	85/gas cap[(a)]	No study at spillway
2010	100/100	85/121 or 95/95	Before June 5 and after July 1
2011	100/100	85/121 or 95/95	Before May 13 but not after
2012	100/100	85/121 or 95/95	Not met during study

(a) Approximately 120 kcfs at night.

2.6.4.2 The Dalles Dam

During early spring 2011, TDA spillway discharge was maintained near 40% of total project discharge during day and night at spillbays 1–8. Beginning in late spring 2011, river flows were significantly higher than observed for normal water years. As a result, some spillbays outside of the spill wall were opened; spillbays 10, 11, 13, 16, 18, 19, and 23 were not opened (due to structural or wire rope issues). Figure 2.12, Figure 2.13, and Figure 2.14 show total spillway discharge as a percent of total project discharge, percent of total spill discharge for spillbays 1–8, and percent of total spill for spillbays 9–23 for spring 2011, spring 2012, and summer 2012, respectively. Spill discharge percentages were calculated from hourly spill discharge divided by hourly project discharge (kcfs). Project operating plans recommended not using spillbays 14–22, because discharge from this portion of the spillway is believed to create poor tailrace egress conditions for spillway-passed fish.

Operators attempted to maintain TDA spillway discharge as near 40% of total project discharge as specified in the FPP, even when the total discharge was greater than the 12 yr average discharge during 2011 and 2012 (Figure 2.10). The spillway discharge in 2010 was lower in the spring than the 12 yr average.

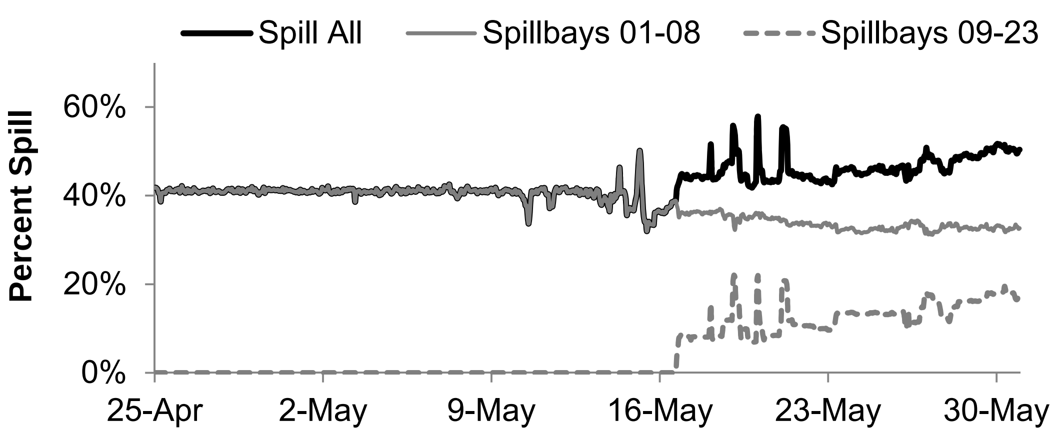

Figure 2.12. TDA 2011 Spring Percent Spill of Total Project Discharge for All Spillbays, Spillbays 1–8, and Spillbays 9–23

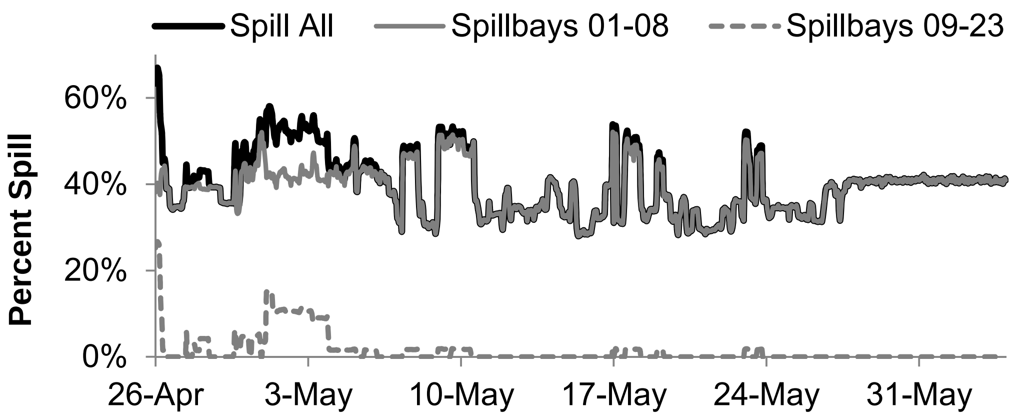

Figure 2.13. TDA 2012 Spring Percent Spill of Total Project Discharge for All Spillbays, Spillbays 1–8, and Spillbays 9–23

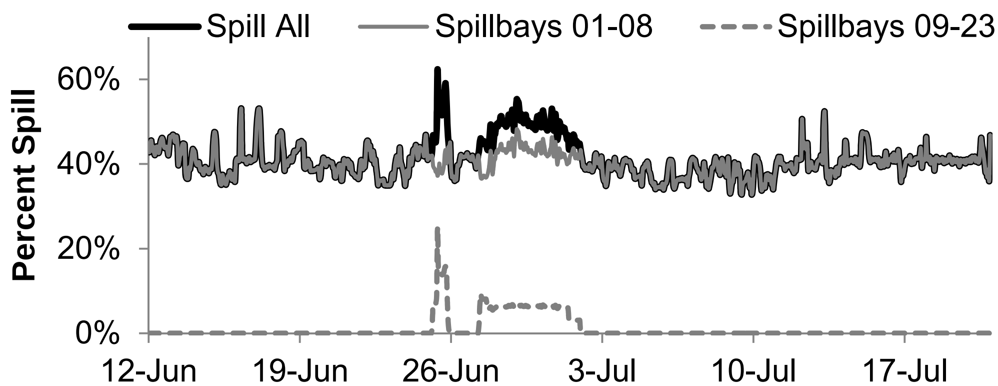

Figure 2.14. TDA 2012 Summer Percent Spill of Total Project Discharge for All Spillbays, Spillbays 1–8, and Spillbays 9–23

In late spring 2011, spillbays 9, 12, 14, 15, 17, 20, and 21 were opened in response to high river flow. Among those spillbays, spillbay 12 was open the longest (40% of the study season, 342 of 864 total hours), followed by spillbays 9, 14, and 15 (**Error! Reference source not found.**). Average discharge for each spillbay inside the spill wall was 15.64 kcfs and for operating spillbays within the range of bays 9–23 average discharge was 16.38 kcfs per spillbay (Table 2.6).

In 2012, spillbays 12, 14, 15, 17, 20, 21, and 22 were open a total of 806 and 565 h during spring and summer study periods, respectively. Spillbay 12 was open longer than other spillbays outside of the spill wall, 29% of total spill time in spring and 14% in summer (269 and 133 h, respectively). In general, spillbays outside of the spill wall close to the spill wall were open more hours than spillbays outside of the spill wall and further away from the spill wall. For details on the hours individual spillbays were open and average spillbay and total spillway discharge, refer to Table 2.5 and Table 2.6.

Table 2.5. TDA Operation Hours for Open Spillbays 9–23 for 2011 and 2012. Percentage of hours individual spillbays were open relative to the total spillway operating hours during the study period are shown in parentheses.

Year	Season	Open Spillbays (h)								Total Hours in Study
		9	12	14	15	17	20	21	22	
2011	Spring	341 (39%)	342 (40%)	297 (34%)	191 (22%)	56 (6%)	12 (1%)	4 (0.5%)	–	864
2012	Spring	–	269 (29%)	123 (13%)	114 (12%)	86 (9%)	79 (8%)	74 (8%)	61 (7%)	936
2012	Summer	–	133 (14%)	131 (14%)	119 (13%)	118 (13%)	26 (3%)	22 (2%)	16 (2%)	936

Table 2.6. TDA Operating Hours for Open Spillbays and Average Discharge for 2011 and 2012 for Spillbays Inside the Spill Wall (Spillbays 1–8) vs. Outside the Spill Wall (Spillbays 9–23)

Year	Season	Spillbays 1–8		Spillbays 9–23	
		Open (h)	Discharge (kcfs)	Open (h)	Discharge (kcfs)
2011	Spring	6,912	15.64	1,243	16.38
2012	Spring	7,488	15.89	806	6.33
2012	Summer	7,488	16.44	565	6.16

3.0 Results – Bonneville Dam Powerhouse 1

The turbine operating ranges (Q1, Q2, Q3, Q4, BOR, and ABOP) for Bonneville Dam Powerhouse 1 (B1), as described under Methods (Section 2.0), are further detailed in Appendix A (Table A.1). CH1, STH, and CH0 detection and survival rates for B1 in the specified operating ranges are described in the following sections. In addition, fish passage survival estimates for the operating ranges are provided in Appendix B (Table B.1, Table B.2, Table B.3).

3.1 Yearling Chinook Salmon (CH1) at B1

3.1.1 CH1 Passage Survival Rates at B1 by Operating Condition

The distribution of CH1 detected passing through B1 turbines by turbine operating conditions during the survival studies conducted in 2010, 2011, and 2012 are shown in Figure 3.1. The detected CH1 were clustered within certain operating ranges (head-discharge combinations) because of fish behavior, river flow, spillway discharge, and resulting turbine operations (Figure 3.1).

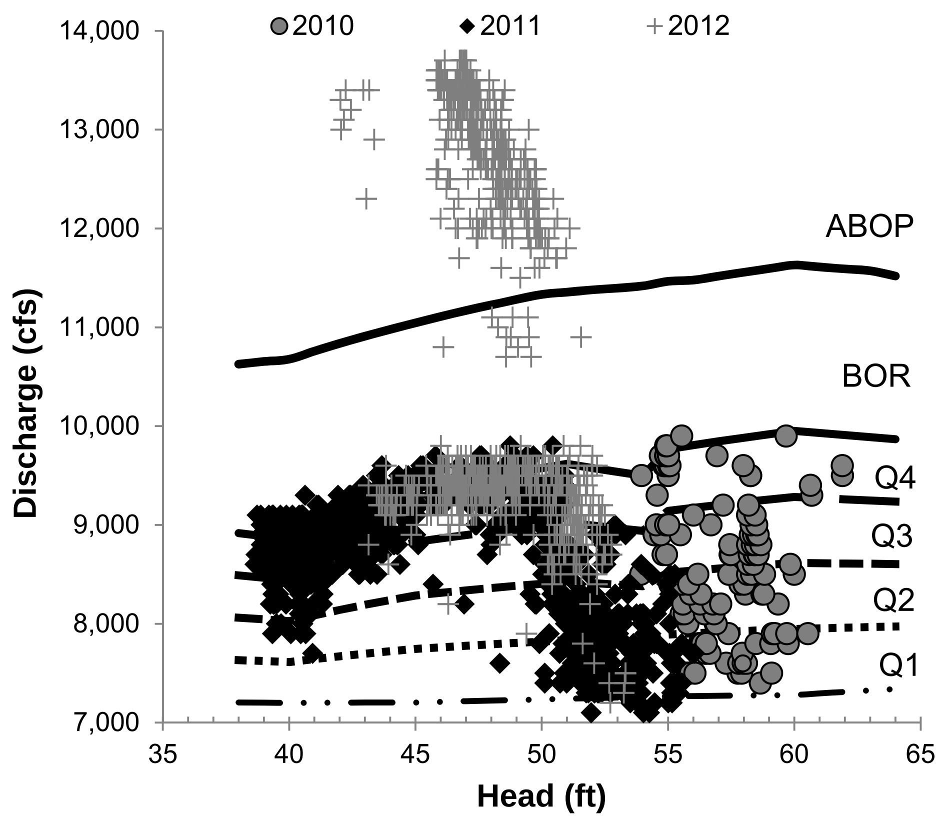

Figure 3.1. Turbine Operating Conditions for CH1 Detected Passing at B1 by Study Year. Each point represents the operating condition when an individual CH1 was detected passing through a turbine.

Estimated survival rates for CH1 passing through B1 and the number of detected fish used in the survival estimates for turbine operation ranges Q1 through ABOP are shown in Figure 3.2 and Table 3.1 (Appendix B, Table B.1). Among the six treatment operations, approximately 42% of the fish passed when operations were within Q4, the upper quartile of the 1% of peak operating efficiency range. Survival estimates were not significantly different for CH1 passage at Q1, Q2, Q3, BOR, or ABOP based on comparing 95% confidence intervals for survival estimates. However, there was a significant difference in survival estimates between Q4 and Q1 and Q2. When survival estimates were grouped into treatments LL to UL, LL to BOP, BOR, and ABOP, there was not a significant difference in survival rates between any of the groups (Figure 3.3; Appendix B, Table B.3.).

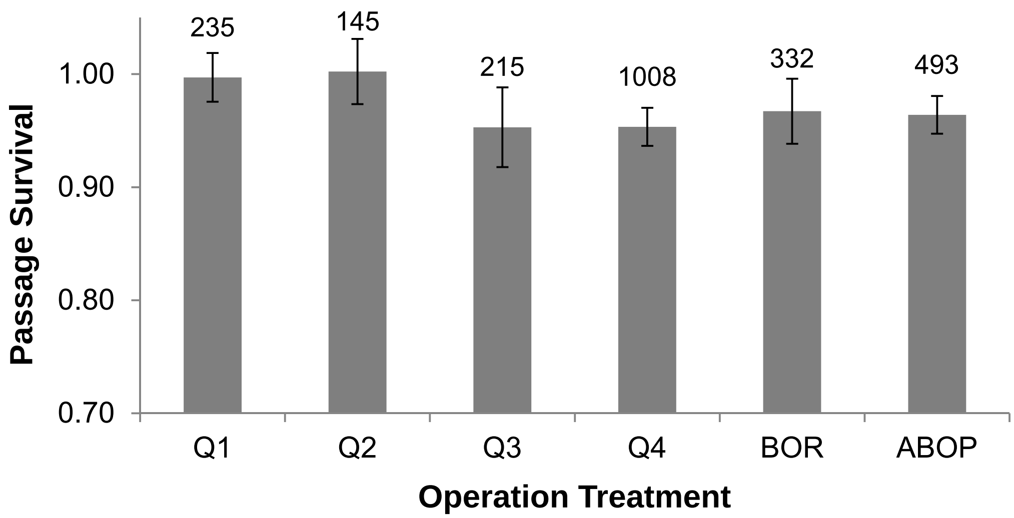

Figure 3.2. CH1 Survival Estimates with 95% Confidence Interval through B1 Turbines by Operation Treatment. Sample sizes are shown above the treatments.

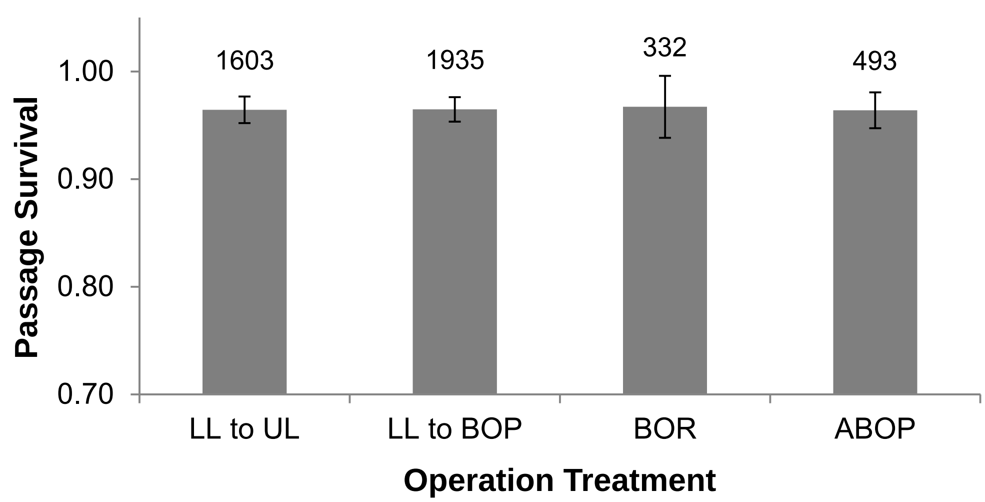

Figure 3.3. CH1 Survival Estimates with 95% Confidence Interval through B1 Turbines by Grouped Operation Treatment. Sample sizes are shown above the corresponding grouped survival estimate.

Table 3.1. CH1 Survival Estimates and Passage Proportions at B1 by Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9971	9.7
Q2	1.0023	6.0
Q3	0.9530	8.9
Q4	0.9534	41.5
BOR	0.9672	13.7
ABOP	0.9640	20.3
LL–UL	0.9644	–
LL–BOP	0.9648	–

3.1.2 CH1 Passage Survival Rates at B1 by Tailrace Elevation

Each CH1 detected passing a turbine at B1 was placed into a 1 m tailrace elevation bin that corresponded to the tailrace elevation (MSL) when the fish passed into a turbine (Appendix D, Table D.1). The proportion of CH1 passing through B1 turbines was highest when the tailrace elevation was within the 8 m tailwater elevation bin (35.2%), followed by the 9 m (28.9%), 7 m (25.4%), 6 m (6.7%), and 5 m (3.8%) tailwater elevation bins. The mean survival estimates for 5 m (0.9868, SE 0.0260) and 6 m bins (1.0052, SE 0.0152) were higher than those of the 7 m, 8 m and 9 m bins (Figure 3.4; Appendix D, Table D.2); however, none of the survival estimates were significantly different. The 6 m tailwater elevation bin had the highest passage survival rate, although not it was significantly different from those of the other tailwater elevation bins, and it had the lowest operating hours percentage compared to the other tailrace elevation bins, except for 5 m bin (Figure 3.4; Appendix D, Table D.1, Table D.2). At B1, the tailwater level is a function of powerhouse discharge so that passage proportion and tailwater level are directly influenced by powerhouse operation.

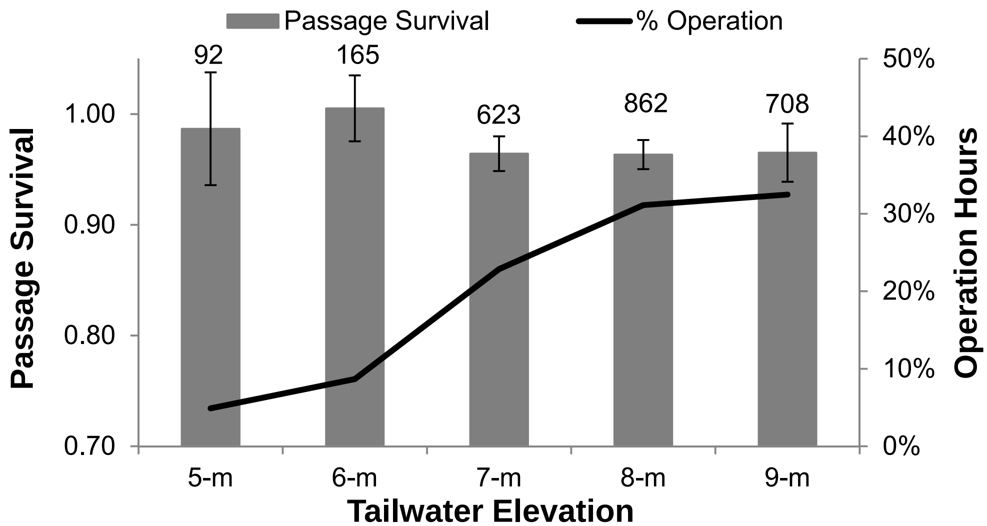

Figure 3.4. CH1 Survival Estimates Passing Turbines at B1 with 95% Confidence Interval and Percent Hours of Operation (Black Line) by Tailrace Elevation Bins. Sample sizes are shown above the estimates.

3.1.3 CH1 Tailrace Egress Time at B1

The median tailrace egress time for CH1 decreased with increasing turbine discharge (Table 3.2). The mean tailrace egress time and the range of egress times varied greatly within and between turbine operating conditions.

Table 3.2. CH1 Egress Times for CH1 at B1 by Turbine Operating Treatment

Operation Treatment	Median (h)	Mean (h)	Min (h)	Max (h)	SE	N
Q1	0.46	6.40	0.27	280.27	2.10	234
Q2	0.44	3.36	0.28	102.24	1.15	136
Q3	0.38	2.43	0.23	110.46	0.82	189
Q4	0.37	3.55	0.24	273.35	0.57	860
BOR	0.37	5.90	0.24	281.36	1.67	286
ABOP	0.30	4.23	0.21	200.41	0.70	485

3.2 Juvenile Steelhead (STH) at B1

3.2.1 STH Passage Survival Rates at B1 by Operating Condition

The distributions of STH detected passing through B1 turbines by turbine operating conditions during the survival studies conducted in 2010, 2011, and 2012 are shown in Figure 3.5. The detected STH were clustered within certain operating ranges (head-discharge combinations) because of fish behavior, river flow, spillway discharge, and resulting turbine operations (Figure 3.5).

B1 STH survival estimates for turbine operating ranges Q1 through ABOP and the number of detected fish in samples used to compute survival estimates are shown in Table 3.3. Among the six turbine operation treatments, the highest survival estimate was for operating range Q1, the lower quartile of the 1% of peak efficiency operating range. STH survival rate was lowest for the Q3 operating range, followed by that for passage with discharges within in the Q2 operating range. STH survival estimates for operating ranges Q3 and Q4 were significantly lower than that for Q1, and also lower, but not significantly so, than those for BOR and ABOP. STH survival rates ranged from 0.9328 to 0.9477 for the three operating conditions above the upper limit of 1% of peak efficiency (Figure 3.6; Appendix B, Table B.1). More than 44% of STH passed through turbines operating in the upper quartile of the 1% of peak efficiency operating range (Q4, N = 1199). STH survival rate was slightly higher, but not significantly so, at BOR than ABOP and the grouped ranges LL to UL and BOR (Figure 3.7; Appendix B, Table B.3.).

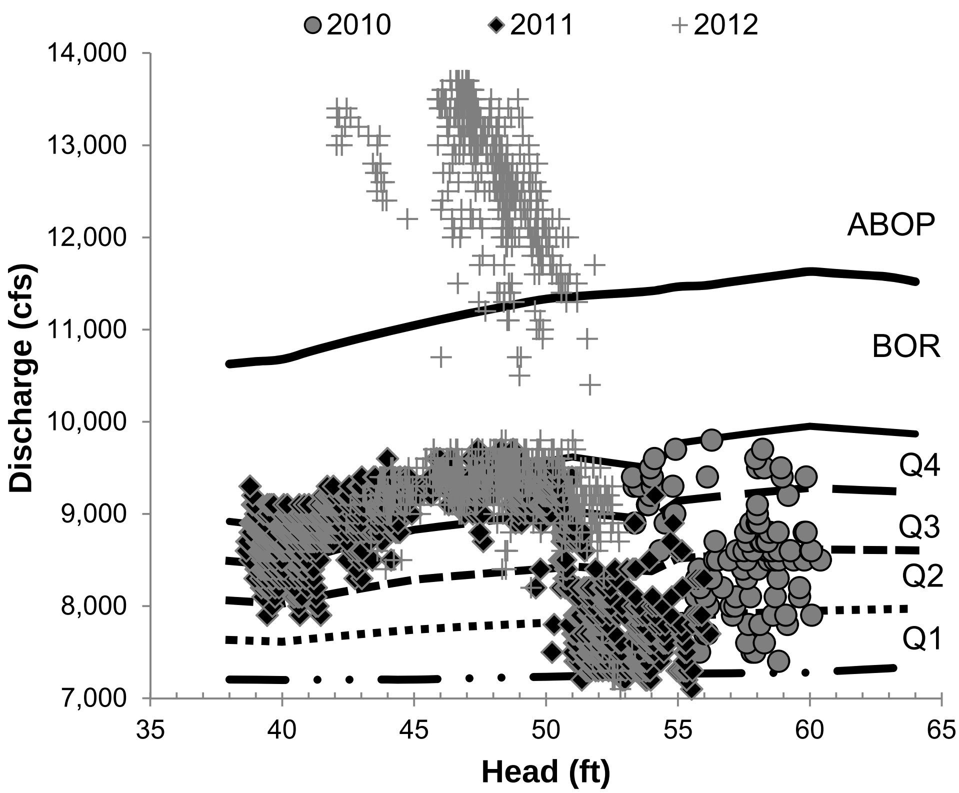

Figure 3.5. Turbine Operating Conditions for STH Detected Passing at B1 by Study Year. Each point represents the operating condition when an individual STH passed through a turbine.

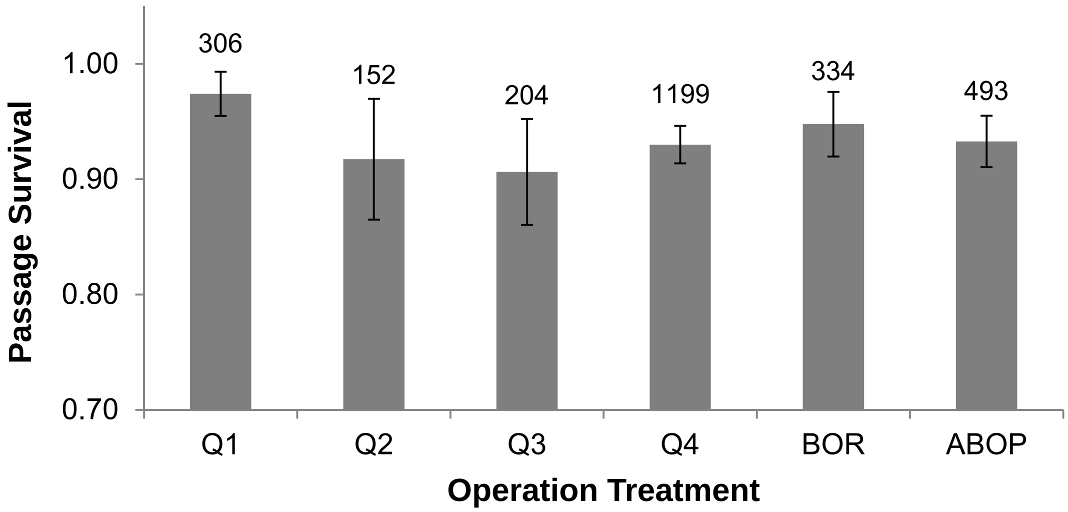

Figure 3.6. Survival Estimates with 95% Confidence Interval for STH through B1 Turbines by Operation Treatment. Sample sizes are shown above the corresponding treatment.

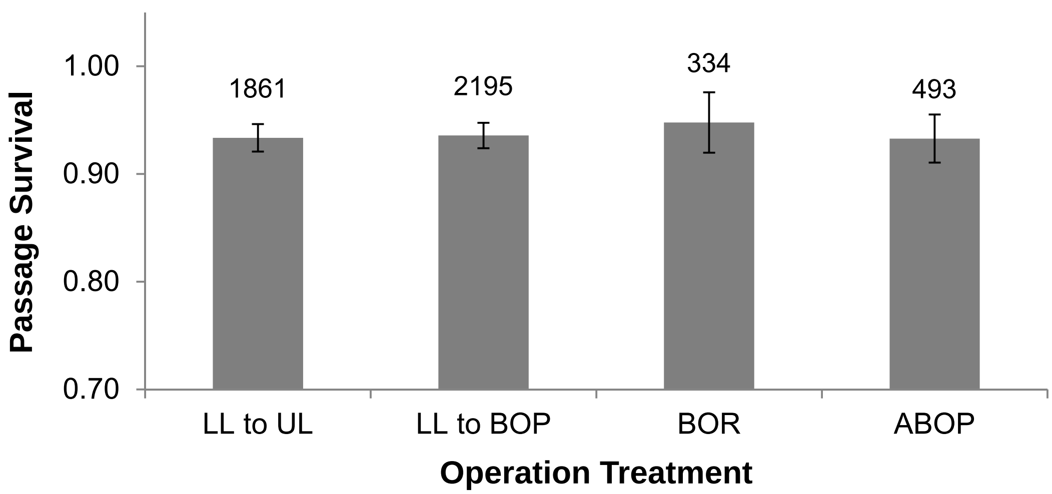

Figure 3.7. Survival Estimates with 95% Confidence Interval for STH Passing through B1 Turbines by Grouped Operation Treatment. Sample sizes are shown above the corresponding grouped survival estimate.

Table 3.3. Survival Estimates and Passage Proportions for STH at B1 by Operating Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9740	11.4
Q2	0.9173	5.7
Q3	0.9064	7.6
Q4	0.9300	44.6
BOR	0.9477	12.4
ABOP	0.9328	18.3
LL_UL	0.9335	–
LL_BOP	0.9357	–

3.2.2 STH Passage Survival Rates at B1 by Tailwater Elevation

STH detected passing turbines at B1 were assigned to 1 m tailrace elevation bins that contained the tailrace elevation relative to MSL at the time they passed into a turbine (Appendix D, Table D.1). The survival estimate for STL in the 5 m bin was lower (0.8605, SE 0.0446) than that for fish in any of the other tailwater elevation bins (6 m, 7 m, 8 m, and 9 m), though none of the survival estimates was significantly different (Figure 3.8, Appendix D, Table D.2). The limited powerhouse operating time when tailrace elevations were low affected the number of STH detected passing into turbines for tailrace elevations in the 5 m bin. STH passage proportion through B1 turbines was highest for the 8 m tailwater elevation bin (33.8%), followed by the 9 m (28.7%), 7 m (25.8%), 6 m (8.6%), and 5 m (3.1%) tailwater elevation bins.

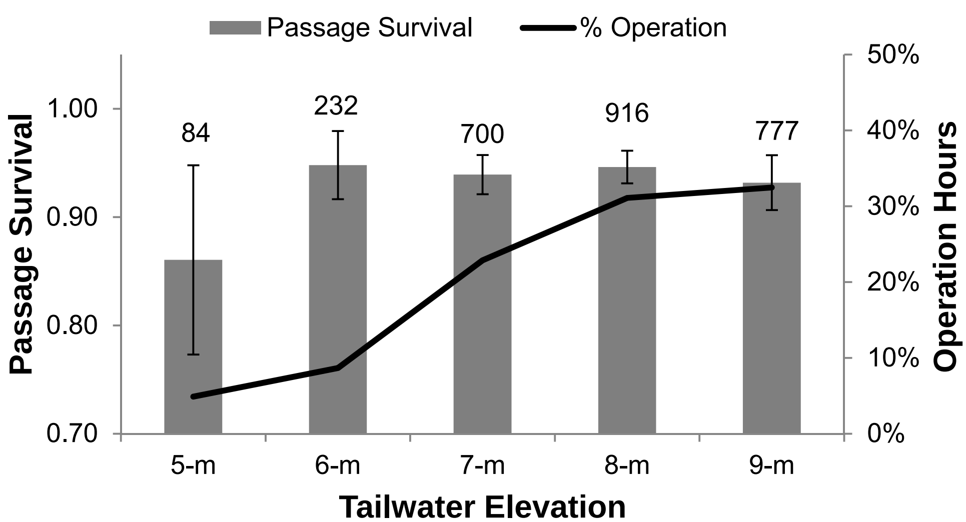

Figure 3.8. Survival Estimates for STH Passing Turbines at B1 with 95% Confidence Interval with Percent Hours of Turbine Operation (Black Line) by Tailrace Elevation. Sample sizes are shown above the estimates.

3.2.3 STH Tailrace Egress Time at B1

The median tailrace egress time for STH showed a slight trend in shorter egress times with increasing turbine discharge (Table 3.4). The mean tailrace egress time and range of egress times varied greatly between turbine operating conditions.

Table 3.4. Egress Times for STH at B1 by Turbine Operating Treatment

Operation Treatment	Median (h)	Mean (h)	Min (h)	Max (h)	SE	N
Q1	0.60	8.51	0.25	254.90	1.69	301
Q2	0.57	9.84	0.25	589.93	4.57	146
Q3	0.63	7.75	0.26	225.21	2.10	146
Q4	0.52	17.14	0.24	419.08	1.39	1013
BOR	0.58	23.96	0.25	404.61	3.49	282
ABOP	0.42	15.11	0.20	415.51	2.21	476

3.3 Subyearling Chinook Salmon (CH0) at B1

3.3.1 CH0 Passage Survival Rates at B1 by Operating Condition

During the survival studies conducted in 2010 and 2012 at B1, detected CH0 were distributed across the entire 1% of peak efficiency turbine operating range. However, CH0 were clustered at certain operation levels because of river discharge and the turbine operations needed to respond to meet power production needs (Figure 3.9). Turbines were seldom operated outside of the upper limit of the 1% of peak efficiency operating range in summer and, when they were, the limit was only exceeded by several hundred cubic feet per second.

Survival estimates for B1 CH0 for operation ranges Q1 through BOR, and the sample size for the estimates, are shown in Figure 3.10 and Table 3.5. Turbines at B1 were not operated up to BOP in either the 2010 or 2012 summer seasons because river flows were not high enough to require turbine operation outside of the 1% of peak efficiency operating range. CH0 survival estimates were highest for operating range Q3, followed by Q4 and BOR. Lowest survival estimates were found when turbines were operating at Q1 and Q2, the lower half of the 1% of peak efficiency operating range. None of the CH0 survival estimates were significantly different. More than 60% of the CH0 detected passed when turbines were operating in the Q4 operating range and only about 5% of fish were detected when turbines were running in the Q1 and Q2 operating ranges (Figure 3.10, Appendix B, Table B.1). The differences in the survival estimates for grouped treatments (LL to UL, LL to BOP, BOR, and ABOP), were less than 0.002, which was not significant based on 95% confidence intervals (Figure 3.11; Appendix B, Table B.3.).

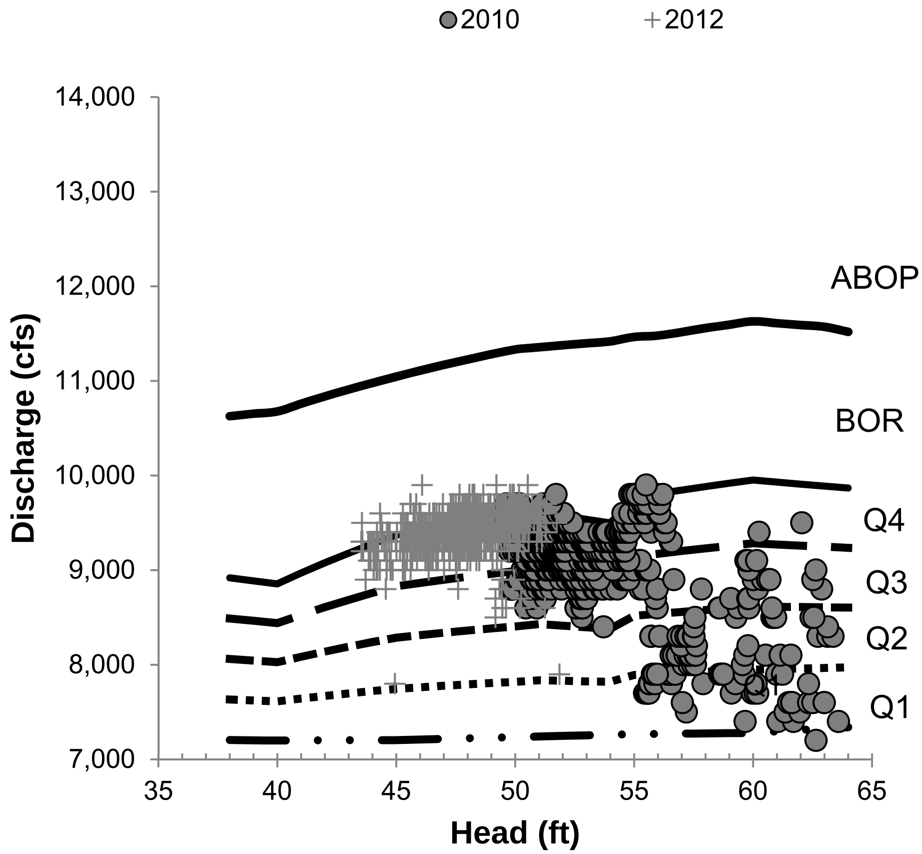

Figure 3.9. Turbine Operating Conditions for CH0 Detected Passing at B1 by Study Year. Each point represents the operating condition when an individual CH0 passed through a turbine.

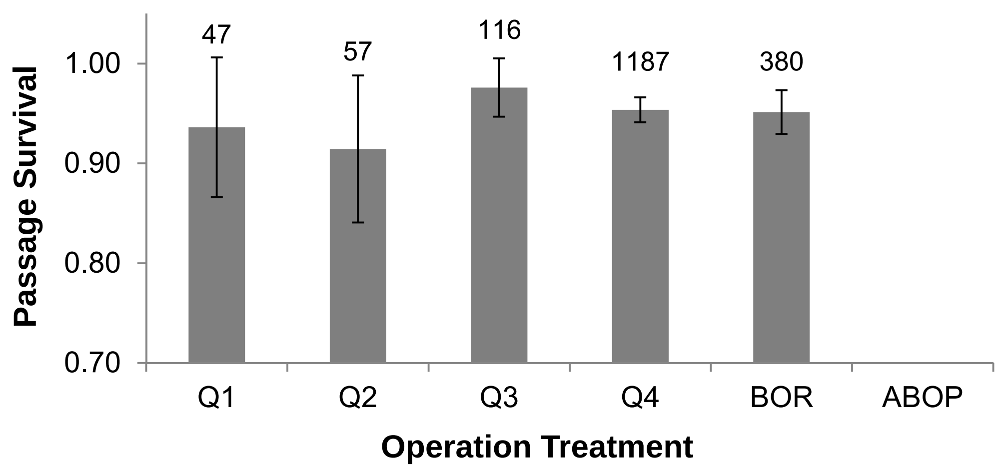

Figure 3.10. Survival Estimates with 95% Confidence Interval for CH0 Passing through B1 Turbines by Operation Treatment. Sample sizes are shown above the corresponding treatment.

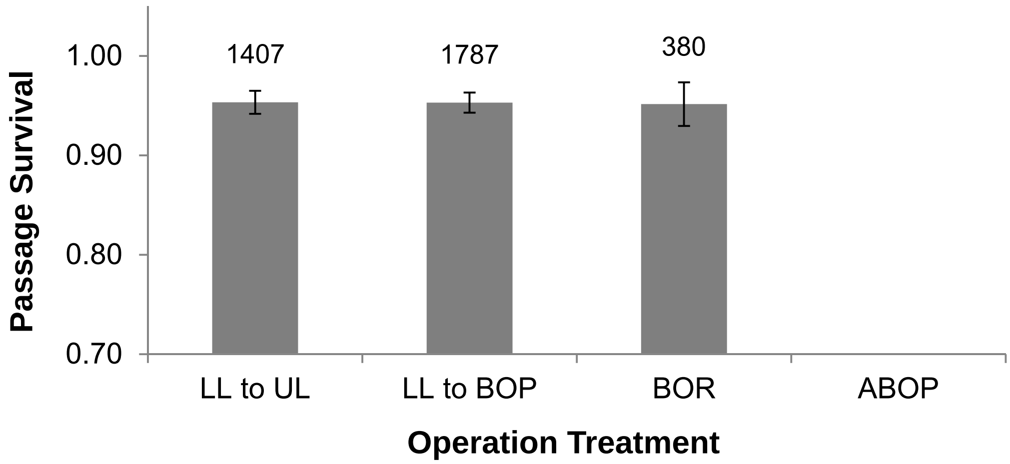

Figure 3.11. Survival Estimates with 95% Confidence Interval for CH0 Passing through B1 Turbines by Grouped Operation Treatment. Sample sizes are shown above the corresponding grouped survival estimate.

Table 3.5. Survival Estimates and Passage Proportions for CH0 at B1 by Operation Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9362	2.6
Q2	0.9145	3.2
Q3	0.9760	6.5
Q4	0.9537	66.4
BOR	0.9515	21.3
LL-UL	0.9534	–
LL-BOP	0.9530	–

3.3.2 CH0 Passage Survival Rates at B1 by Tailwater Elevation

CH0 detected passing turbines at B1 were assigned to 1 m tailrace elevation bins, depending upon the tailrace elevation relative to MSL at the time they passed (Appendix D, Table D.1). More CH0 passed through B1 turbines when the tailrace elevations were within the 7 m (31.7%) and 8 m (45.5%) bins than during tailwater elevations contained within 9 m (9.6%), 6 m (7.4%), and 5 m (5.8%) bins. Turbine operating times were lowest when tailwater elevations were in the ranges of the 6 m and 9 m tailwater elevation bins (~5%) (Figure 3.12; Appendix D, Table D.1). The survival estimate (0.8939, SE 0.0305) for CH0 that passed when the tailwater was low (5 m bin) was lower than those for fish that passed when tailwater elevations were higher. CH0 survival rate was highest for passage during tailwater elevations in the 6 m bin (0.9811, SE 0.0132), followed by 7 m bin (0.9604, SE 0.0088), 8 m bin (0.9517, SE 0.0077), and 9 m bin (0.9483, SE 0.0170) (Figure 3.12; Appendix D, Table D.2). There was a significant difference in CH0 survival rate for passage when tailwater elevations were in the 5 m bin compared to the survival rate of CH0 that passed when tailwater elevations were in the range contained in the 6 m bin.

There were no other significant differences in CH0 turbine passage survival rates for other tailwater bins, based on 95% confidence intervals.

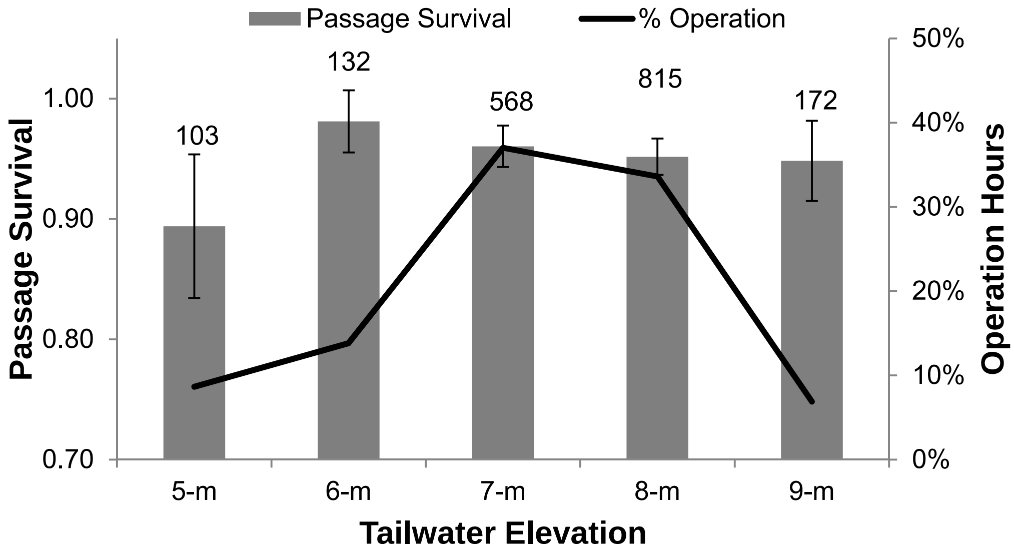

Figure 3.12. Survival Estimates for CH0 Passing through Turbines at B1 with 95% Confidence Interval with Percent Hours of Operation (Black Line) by Tailrace Elevation. Sample sizes are shown above the estimates.

3.3.3 CH0 Tailrace Egress Time at B1

CH0 median tailrace egress time generally decreased with increasing operation condition from low to high discharge (Table 3.6). There was little variation in median egress time for fish passing during Q3, Q4, and BOR operating conditions. The mean and range of tailrace egress times varied greatly between turbine operating conditions.

Table 3.6. Egress Times at B1 for CH0 by Turbine Operating Treatment

Operation Treatment	Median (h)	Mean (h)	Min (h)	Max (h)	SE	N
Q1	0.46	2.17	0.29	68.26	1.45	47
Q2	0.44	1.22	0.32	31.24	0.56	56
Q3	0.39	1.67	0.25	44.93	0.53	116
Q4	0.40	3.81	0.24	622.50	0.68	1148
BOR	0.40	4.33	0.27	127.56	0.68	363

4.0 Results – Bonneville Dam Powerhouse 2

The method used to partition the range of turbine operations for B2 within 1% of peak efficiency into the operations quartiles Q1, Q2, Q3, and Q4 is described in Methods (Section 2.0) and additional details are provided in Appendix A (Table A.2 and Table A.3). Turbine passage survival estimates and other statistics describing passage of CH1, STH, and CH0 through turbines at B2 within turbine operations quartiles are presented in the following sections and are available in Appendix B (Table B.4 and Table B.5.). Data for passage of tagged juvenile salmonids through B2 turbines from years 2008–2012 were used for the analyses. Results in Sections 4.1 through 4.3 are for periods when STSs were deployed in the turbine intakes. Section 4.4 compares survival rates with and without STSs deployed in the turbine intakes.

4.1 Yearling Chinook Salmon (CH1) at B2

4.1.1 CH1 Passage Survival Rates at B2 by Operating Condition

During the survival studies conducted from 2008 through 2012 for CH1, turbines at B2 were operated over the 1% of peak efficiency operating range. CH1 were clustered within certain turbine operating ranges within years of the study because of the turbine operations used in response to power production needs and the differences in river discharge between years (Figure 4.1).

Survival estimates for B2 CH1 detected passing turbines within each of the four operating range quartiles, and the number of detected fish (sample size) used for survival estimates during the spring 2008–2012 studies are shown in Figure 4.2 and Table 4.1. The survival estimates among the quartiles (i.e., Q1 to Q4), differed by less than 0.0075. Survival estimates ranged from 0.9501 for Q3 to 0.9575 for Q2. There were no significant differences between the survival estimates for the quartiles (Appendix B, Table B.4) using 95% confidence intervals. The proportion of fish detections (sample size) within the quartiles was skewed to the lower half of the 1% operating range with 64.4% of the fish passing B2 in the Q1 or Q2 quartiles (Appendix B, Table B.5.). Similar to survival estimates for individual operating quartiles, the difference in survival estimates between the lower and upper halves of the 1% of peak efficiency operating range was only 0.0018. The turbine passage survival estimate for Q1 plus Q2 was 0.9556 (SE 0.0063) and that for Q3 plus Q4 was 0.9538 (SE 0.0090). The turbine passage survival estimates were not significantly different between the lower half (Q1+Q2) and upper half (Q3+Q4) of the 1% operating range (Figure 4.3; Appendix B, Table B.5.).

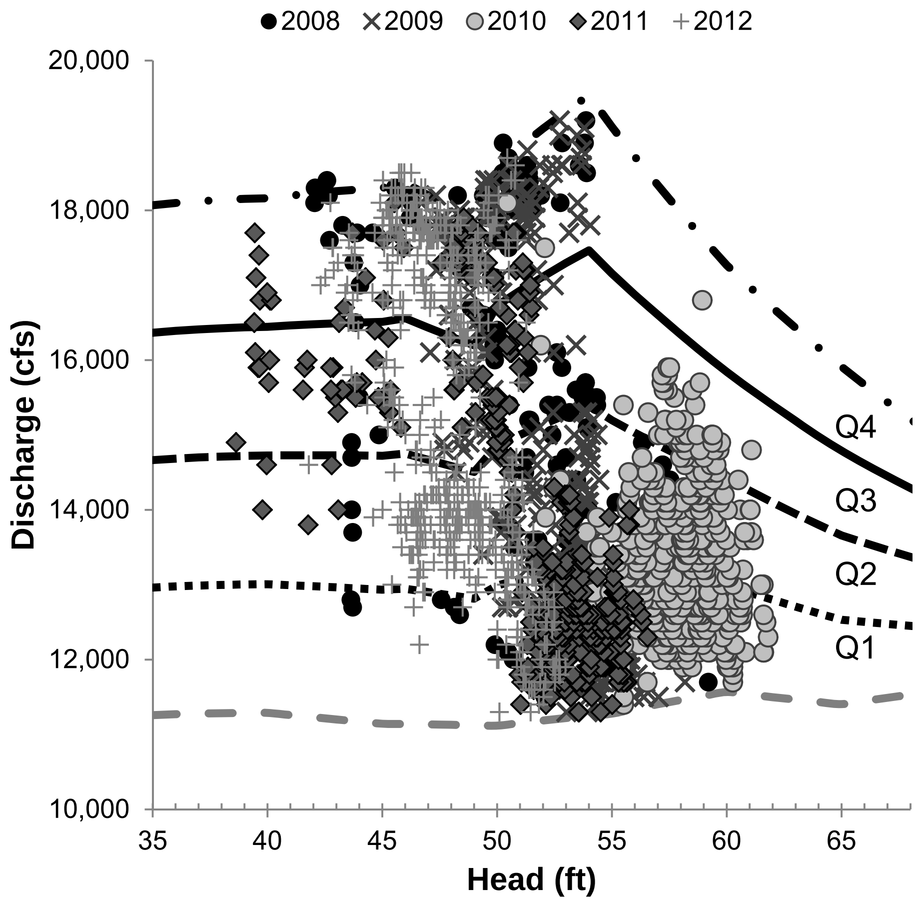

Figure 4.1. Turbine Operating Conditions for CH1 Detected Passing through Turbines at B2 by Study Year. Each point represents the operating condition when an individual CH1 passed through a turbine.

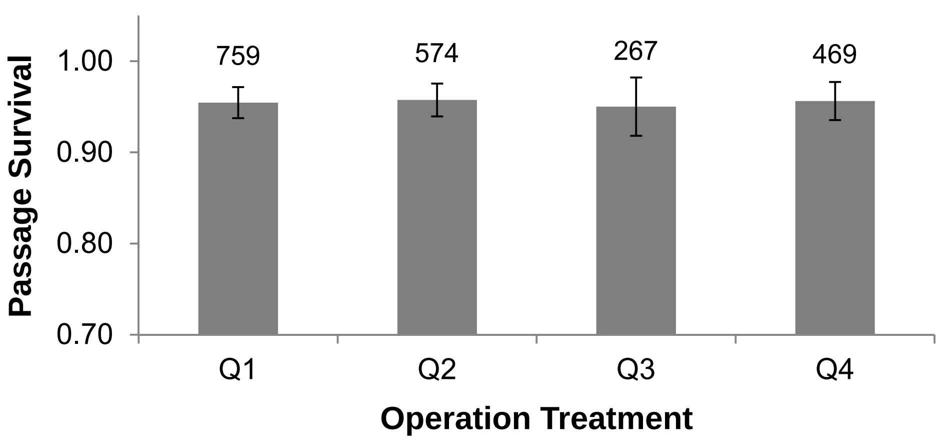

Figure 4.2. Survival Estimates with 95% Confidence Interval for CH1 Passing through B2 Turbines by Operation Treatment. Sample sizes are shown above the corresponding treatment.

Table 4.1. CH1 Survival Estimates and Passage Proportions at B2 by Operation Treatment

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9545	36.7
Q2	0.9575	27.7
Q3	0.9501	12.9
Q4	0.9563	22.7

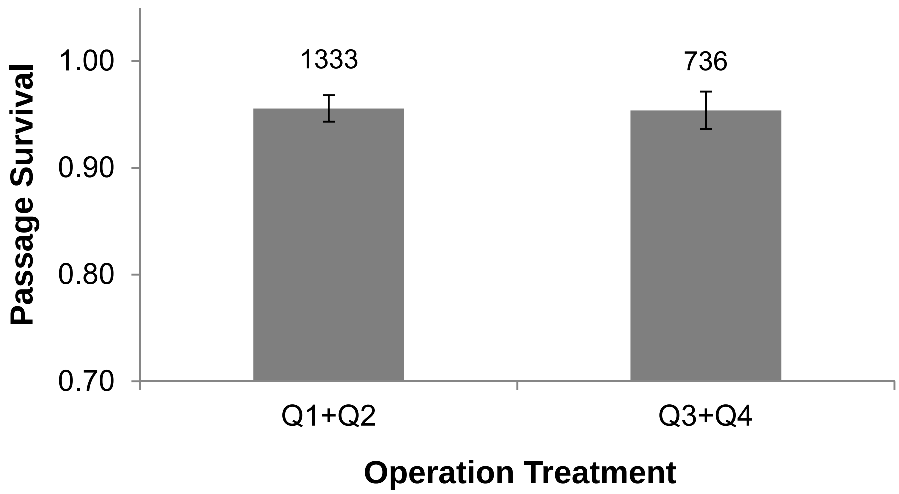

Figure 4.3. Survival Estimates with 95% Confidence Interval for CH1 Passing through B2 Turbines within the Lower and Upper Halves of the 1% of Peak Efficiency Operating Range. Sample sizes are shown above the corresponding treatment.

4.1.2 CH1 Passage Survival Rates at B2 by Tailwater Elevation

CH1 detected passing turbines at B2 were assigned to 1 m tailrace elevation bins relative to MSL that contained the tailrace elevation when they passed into a turbine (Figure 4.4). The proportion of CH1 passing through B2 was highest when tailwater was within the 6 m (24.9%) and 8 m (23.9%) tailwater elevation bins (Figure 4.4; Appendix D, Table D.3). Survival estimates were lowest for CH1 that passed when tailwater was within the 9 m tailrace bin (0.9167, SE 0.0222). The survival estimates for the 5 m, 6 m, 7 m, and 8 m bins were within a 0.0088 range (5 m [0.9515, SE 0.0120]; 6 m [0.9510, SE 0.0106]; 7 m [0.9577, SE 0.0102]; and 8 m [0.9598, 0.0091]). Based on 95% confidence intervals, the survival estimates were not significantly different across the tailwater elevations.

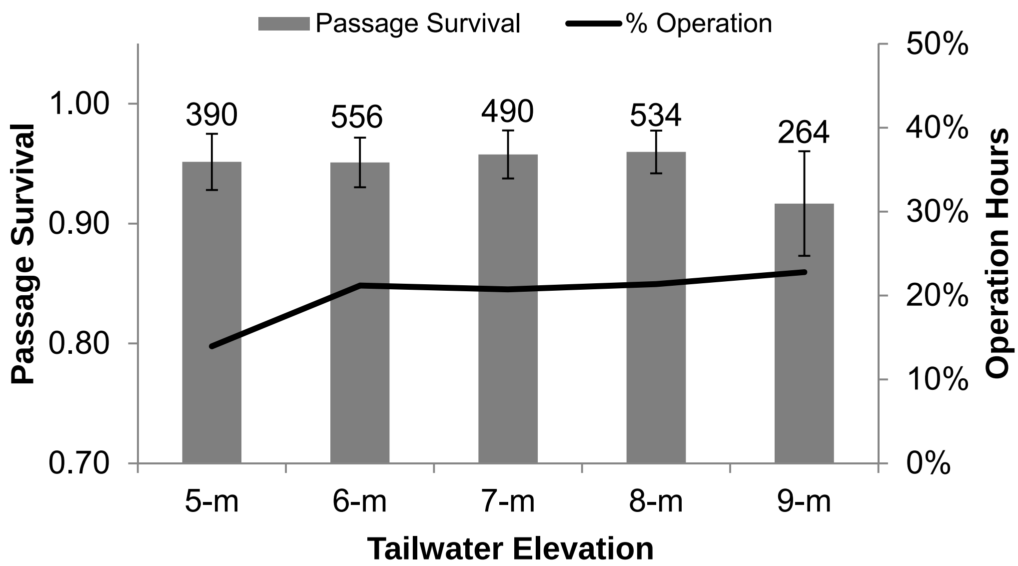

Figure 4.4. Survival Estimates for CH1 Passing through Turbines at B2 with 95% Confidence Interval with Percent Hours of Operation (Black Line) by Tailrace Elevation. Sample sizes are shown above the estimates.

4.1.3 CH1 Tailrace Egress Time at B2

The median tailrace egress time for CH1 decreased with increasing turbine operating condition from low to high discharge (Table 4.2). The mean and range of egress times varied greatly within and between the turbine operation quartiles.

Table 4.2. Tailrace Egress Time at B2 Relative to Turbine Operating Treatment During CH1 Passage

Operation Treatment	Median (h)	Min (h)	Max (h)	Mean (h)	SE	N
Q1	0.65	0.28	18.53	0.77	0.04	514
Q2	0.65	0.25	15.53	0.86	0.06	350
Q3	0.61	0.29	8.61	0.92	0.12	111
Q4	0.55	0.25	3.41	0.65	0.03	141

4.2 Juvenile Steelhead (STH) at B2

4.2.1 STH Passage Survival Rates at B2 by Operating Condition

During the survival studies conducted from 2008 through 2012, passage of STH through B2 turbines was distributed across the turbine 1% of peak efficiency operating range. STH were clustered within certain operating ranges within years of the study because of the way turbines were operated between years to meet power production needs and to accommodate the change in river discharge between years (Figure 4.5).

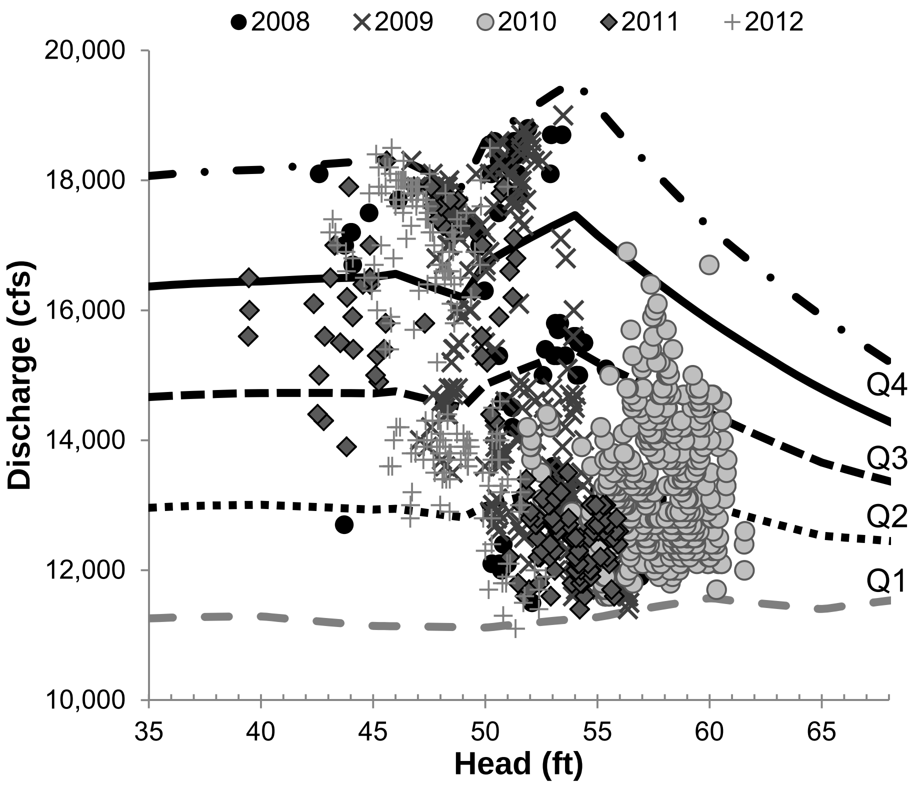

Figure 4.5. Turbine Operating Conditions for STH Detected Passing through Turbines at B2 by Study Year. Each point represents the operating condition when an individual STH passed through a turbine.

Turbine passage survival estimates for STH and corresponding samples sizes during the spring 2008–2012 studies by turbine operation quartile are shown in Figure 4.6. Turbine passage survival rates were highest for quartile Q2, the lower middle quarter of the 1% of peak efficiency operating range, and the lowest survival rate was for STH that passed turbines at discharge within quartile Q1 (Figure 4.6, Table 4.3, Appendix B, Table B.4). There was not a significant difference between the survival estimates for quartiles using 95% confidence intervals. Similarly, the turbine passage survival rate was not significantly different for STH passing B2 turbines in the lower half (0.9128, SE 0.0101) and upper half (0.9152, SE 0.0161) of the 1% of peak efficiency operating range (Figure 4.7). Almost 75% of STH passed in the lower half of the 1% operating range (Q1 plus Q2) (Figure 4.6, Table 4.3, Figure 4.7).

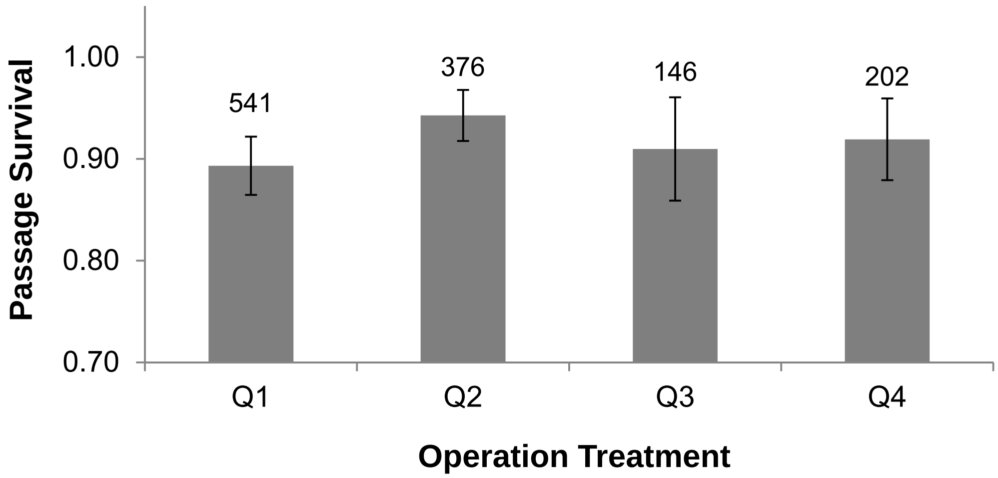

Figure 4.6. STH Survival Estimates through B2 Turbines with 95% Confidence Interval by Operation Treatment. Sample sizes are shown above the corresponding bar.

Table 4.3. STH Survival Estimates and Passage Proportions at B2 by Operation Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.8932	42.8
Q2	0.9427	29.7
Q3	0.9097	11.5
Q4	0.9192	16.0

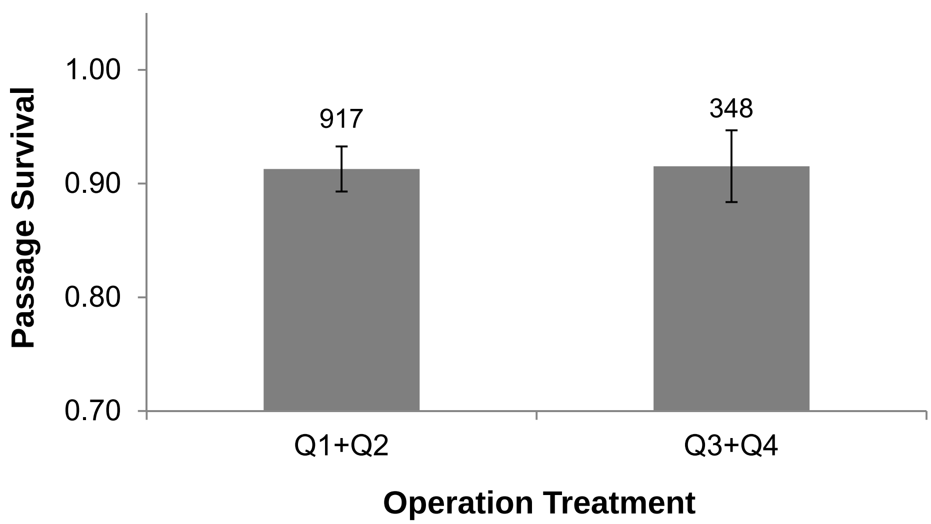

Figure 4.7. STH Survival Estimates with 95% Confidence Interval through the B2 Turbines within the Lower Half and the Upper Half of the 1% of Peak Efficiency Operating Range. Sample sizes are shown above the bars.

4.2.2 STH Passage Survival Rates at B2 by Tailwater Elevation

STH detected passing turbines at B2 were assigned to 1 m tailrace elevation bins relative to MSL that corresponded to the tailrace elevation when the fish passed into turbines. Passage survival estimates and hours of turbine operation for each quartile are shown in Figure 4.8. The highest survival rate was observed for fish that passed when tailwater elevation was in the 7 m bin (0.9846, SE 0.0105). The survival rate of STH for all other bins were similar, ranging from 0.8953 (SE 0.0217) for the 8 m bin to 0.9144 (SE 0.0322) for the 9 m bin (Appendix D, Table D.3). The survival rate of STH passing in the 7 m tailwater elevation bin was significantly greater than for STH passing in the 5 m, 6 m, and 8 m bins, but the survival rates were not significantly different between the 7 m and 9 m bins. A greater number of STH passed when tailwater was in the range of the 5 m tailwater elevation bin based on 95% confidence intervals. The proportion of STH passing through B2 turbines varied by bin (5 m [30.2%], 6 m [27.5%], 7 m [18.2%], 8 m [16.2%], and 9 m [7.9%]) (Appendix D, Table D.3).

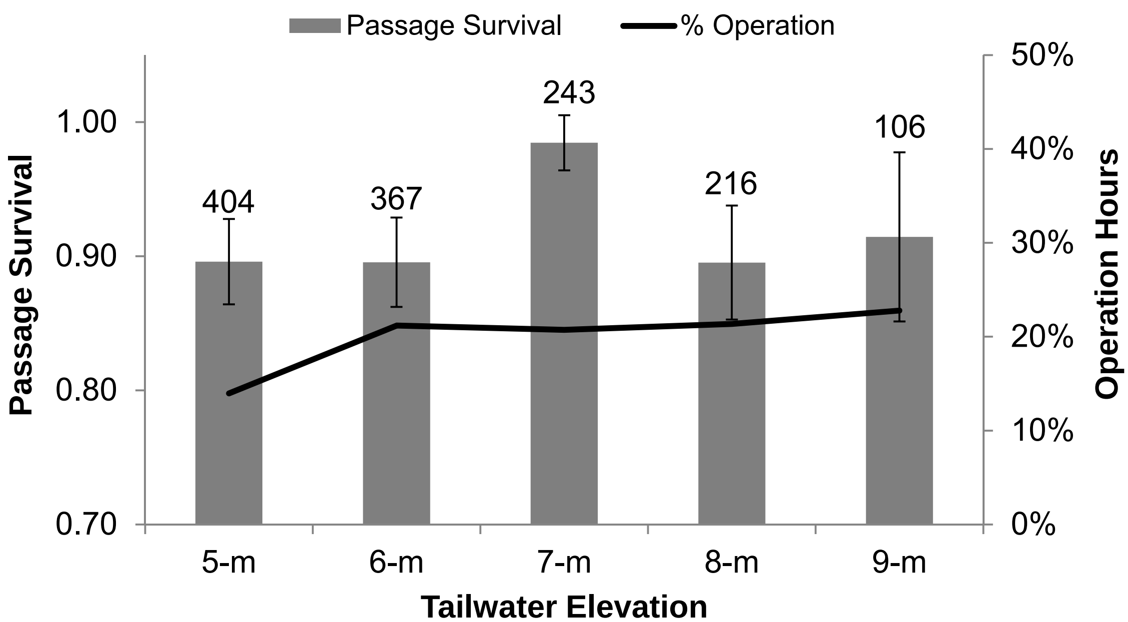

Figure 4.8. Survival Estimates with 95% Confidence Interval for STH with Percent B2 Hours of Turbine Operation by Tailwater Elevation. Sample sizes are shown above the bars.

4.2.3 STH Tailrace Egress Time at B2

B2 STH tailrace egress time by quartile is shown in Table 4.4. The median egress time generally decreased from Q1 to Q4 with increasing turbine discharge. The highest median egress time was 0.72 h for the Q1 operating condition, but the median Q3 egress time was least (0.68 h) (Table 4.4). Minimum egress times were similar between quartiles, while maximum and mean egress times varied.

Table 4.4. Tailrace Egress Time at B2 Relative to Turbine Operating Treatment During STH Passage

Operation Treatment	Median (h)	Min (h)	Max (h)	Mean (h)	SE	N
Q1	0.72	0.26	48.20	1.16	0.16	381
Q2	0.71	0.22	24.13	1.16	0.14	257
Q3	0.68	0.21	70.55	1.67	0.89	79
Q4	0.71	0.22	5.19	0.89	0.10	57

4.3 Subyearling Chinook Salmon (CH0) at B2

4.3.1 CH0 Passage Survival Rates at B2 by Operating Condition

During the survival studies conducted at B2 in the summers of 2008, 2009, 2010, and 2012, the passage of CH0 through turbines was distributed across all quartiles in the 1% of peak efficiency range of turbine operations. Studies were not conducted during summer 2011 because of high river discharge. Detected CH0 were consistently clustered within certain operating ranges within years of the study, reflecting the difference in turbine operations between years that occurred in response to power production needs and differences in river discharge between years (Figure 4.9).

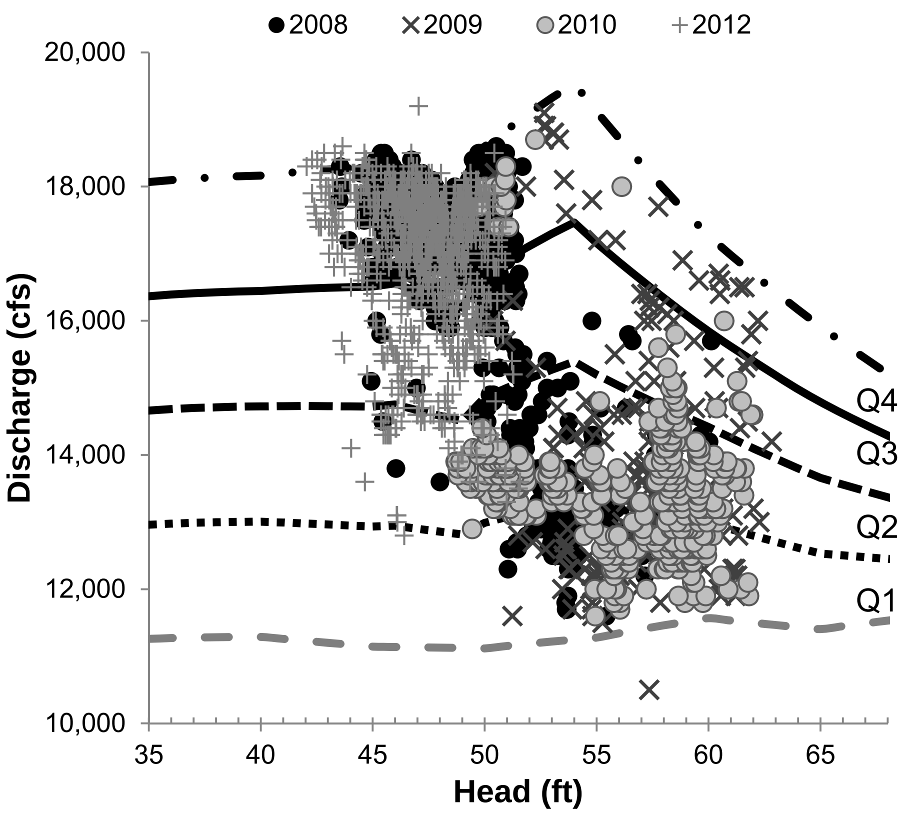

Figure 4.9. Turbine Operating Conditions for CH0 Detected Passing through Turbines at B2 by Study Year. Each point represents the operating condition when an individual CH0 passed through a turbine.

CH0 turbine passage survival rates were not significantly different between quartiles (Figure 4.10, Table 4.5, Appendix B, Table B.4), based on 95% confidence intervals. Unlike CH1 and STH, a higher proportion of CH0 were detected in the Q4 operating range bin (55.0%) due mainly to higher than average flows during summer 2012. Turbine passage proportions for the other quartiles ranged from 11.3% for Q1 to 19.0% for Q2 (Figure 4.10; Appendix B, Table B.4). Turbine passage survival estimates for the lower (Q1 + Q2) and upper (Q3 + Q4) half of the 1% operating range, 0.9397 (SE 0.0086) and 0.9527 (SE 0.0052) respectively, were not significantly different based on 95% confidence intervals (Figure 4.11).

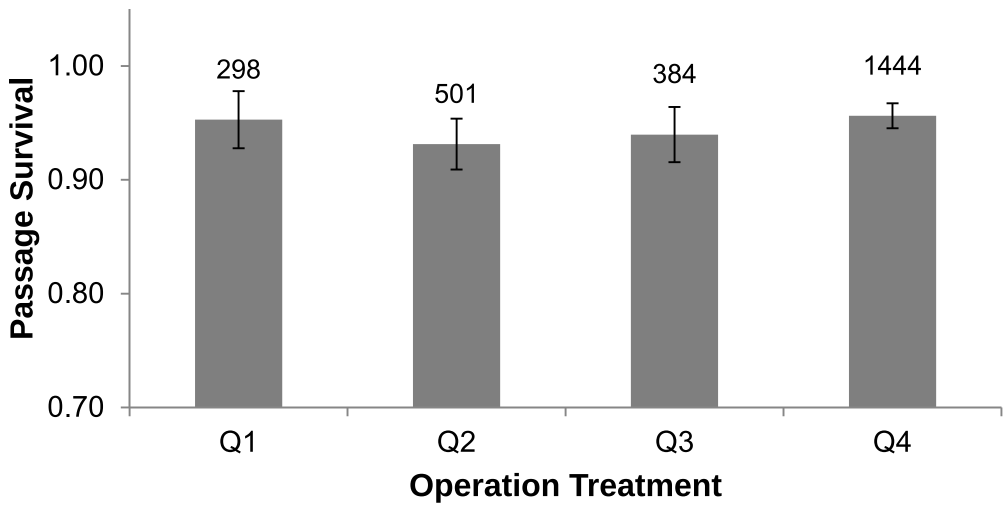

Figure 4.10. CH0 Survival Estimates through B2 Turbines with 95% Confidence Interval by Operation Treatment. Sample sizes are shown above the corresponding bar.

Table 4.5. CH0 Survival Estimates and Passage Proportions at B2 by Operation Treatment Group

Operation Treatment	Survival Estimate	Passage Proportion (%)
Q1	0.9528	11.3
Q2	0.9314	19.1
Q3	0.9397	14.6
Q4	0.9562	55.0

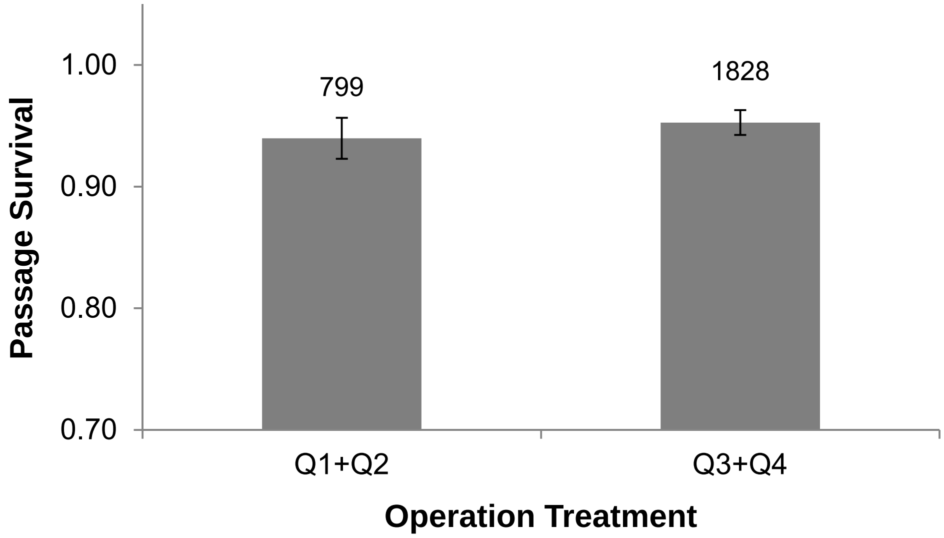

Figure 4.11. Survival Estimates with 95% Confidence Interval for CH0 Passing through B2 Turbines within the Lower and Upper Halves of the 1% of Peak Efficiency Operating Range. Sample sizes are shown above the bars.

4.3.2 CH0 Passage Survival Rates at B2 by Tailwater Elevation

CH0 detected passing turbines at B2 were assigned to 1 m tailrace elevation bins relative to MSL corresponding to the tailrace elevation when the fish passed into turbines. CH0 turbine passage survival estimates and the hours of turbine operation for each bin are shown in Figure 4.12. The highest passage survival rate was observed for CH0 that passed when tailwater elevation was within the 9 m bin (0.9663, SE 0.0104) and lowest survival estimate was observed when tailwater was low, within 5 m bin (0.9102, SE 0.0158). Survival estimates increased with increasing tailwater elevation and the survival rate was significantly greater for the 9 m bin than for the 5 m bin based on 95% confidence intervals. There was not a significant difference between any of the other bins (Figure 4.12; Appendix D, Table D.3). The number of turbine operation hours was higher when tailwater elevation was within the 5 m and 8 m tailwater elevation bins and lower for tailwater elevations in 6 m, 7 m, and 9 m bins. The proportion of CH0 passing B2 turbines varied by tailwater elevation bin (5 m [12.5%], 6 m [10.4%], 7 m [14.7%], 8 m [50.8%], and 9 m [11.6%]).

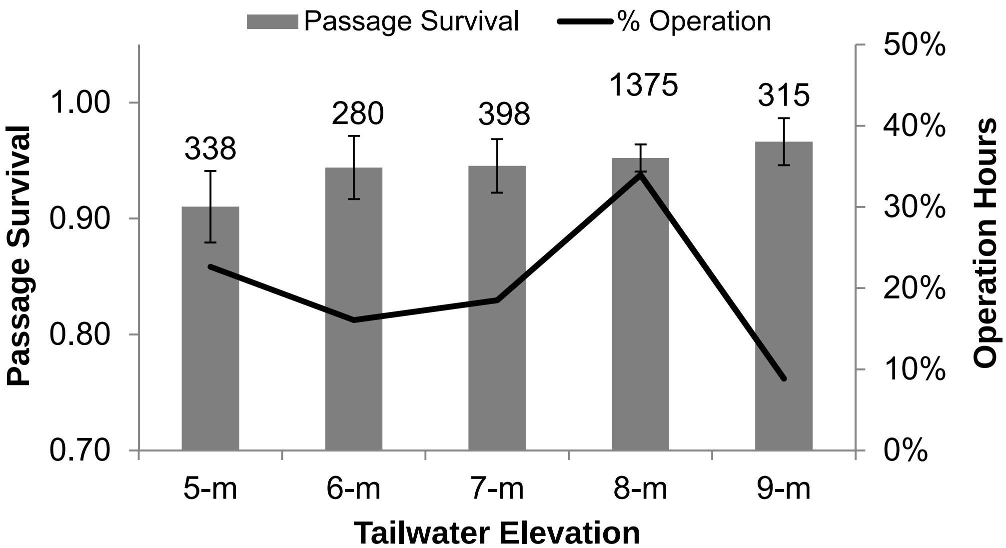

Figure 4.12. Survival Estimates with 95% Confidence Interval for CH0 at B2 with Percent Hours of Turbine Operation by Tailwater Elevation Bin. Sample sizes are shown above the bars.

4.3.3 CH0 Tailrace Egress Time at B2

The tailrace egress time for B2 CH0 by turbine operation quartile is shown in Table 4.6. The median egress time decreased from Q1 to Q4 with increasing turbine discharge. The mean and range of egress times varied within and between turbine operation quartiles.

Table 4.6. Tailrace Egress Time at B2 Relative to Turbine Operating Treatment During CH0 Passage

Operation Treatment	Median (h)	Min (h)	Max (h)	Mean (h)	SE	N
Q1	0.73	0.29	6.15	0.83	0.06	111
Q2	0.71	0.22	8.03	0.85	0.05	272
Q3	0.67	0.21	530.52	2.82	2.01	263
Q4	0.64	0.19	13.90	0.78	0.03	911

4.4 CH1 and STH Turbine Passage Survival Rates at B2 with and without Submerged Traveling Screens

Data were available for the spring out-migration periods in 2008 and 2011 to investigate the turbine passage survival of CH1 and STH at B2 with and without STSs in turbine intakes. Figure 4.13 shows the distribution of CH1 and STH within discharge quartiles of the 1% of peak efficiency band of B2 turbines operating without STSs. The majority of juvenile salmonids observed passed at discharge levels in the upper quarter of the 1% of peak efficiency discharge range (Q4).

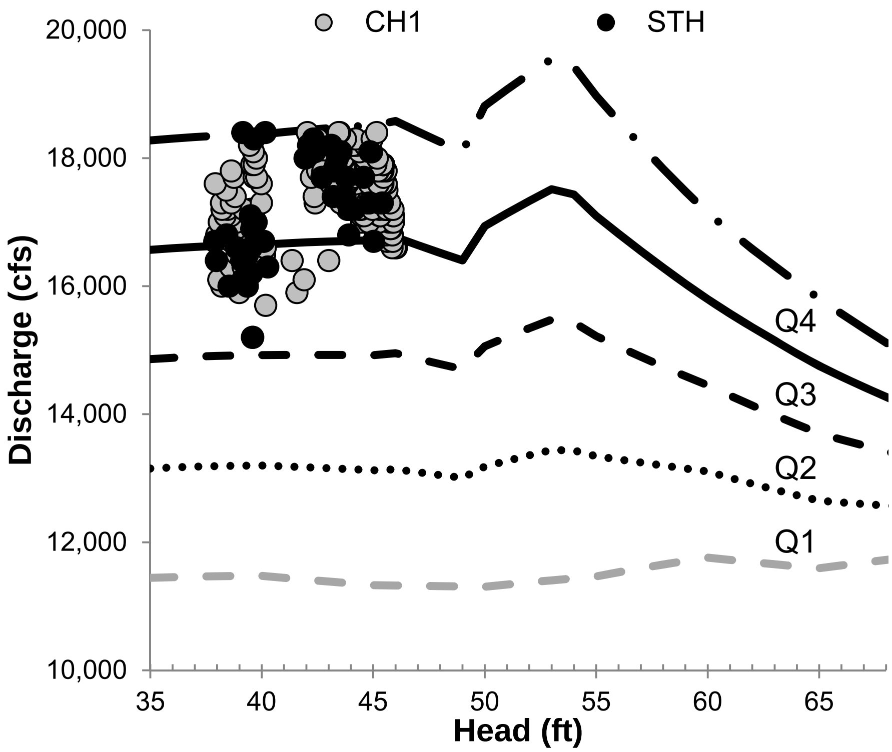

Figure 4.13. The Distribution of CH1 and STH within the 1% of Peak Efficiency Range for B2 Turbines without STSs

The distribution of CH1 and STH within 1% of peak efficiency for B2 turbines with STSs installed in turbine intakes is shown in Figure 4.14. During the period of time that B2 turbines were operating with screens installed in 2008 and 2011, B2 turbines were operating almost exclusively in the upper half of the 1% of peak efficiency discharge range due to high river discharge.

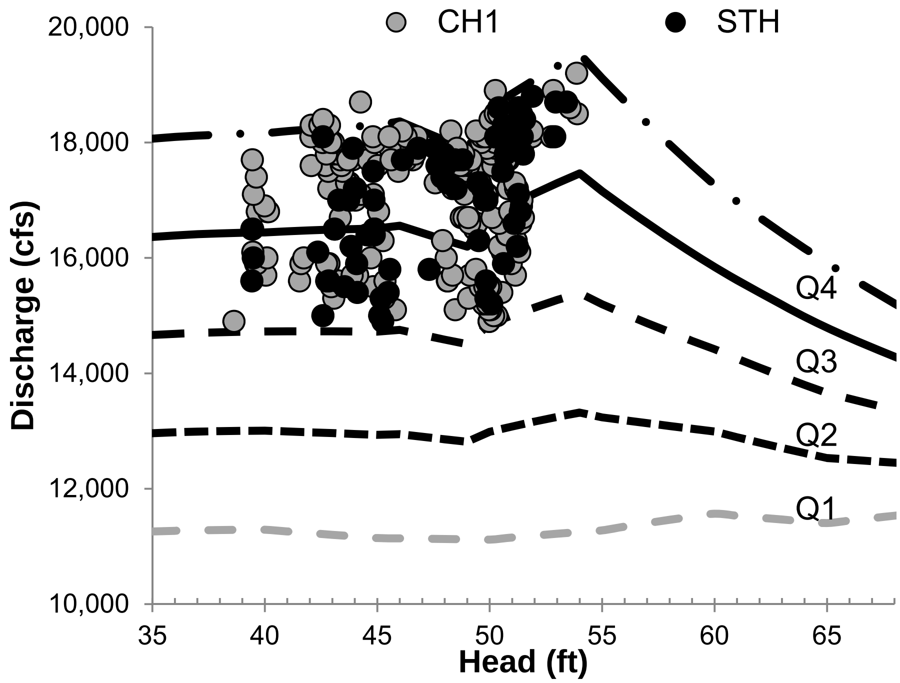

Figure 4.14. The Distribution of CH1 and STH within the 1% of Peak Efficiency Range for B2 Turbines with STSs Installed

In 2008, CH1 passing through turbines at B2 without STSs showed a distinctively lower turbine passage survival rate than those that passed through turbines with STSs installed. However, because sample sizes were small, the observed difference in survival rates was not significant, based on 95% confidence intervals. In 2011 the turbine passage survival rates for CH1 were similar for fish that passed through B2 turbines with and without STSs in the turbine intakes (Figure 4.15).

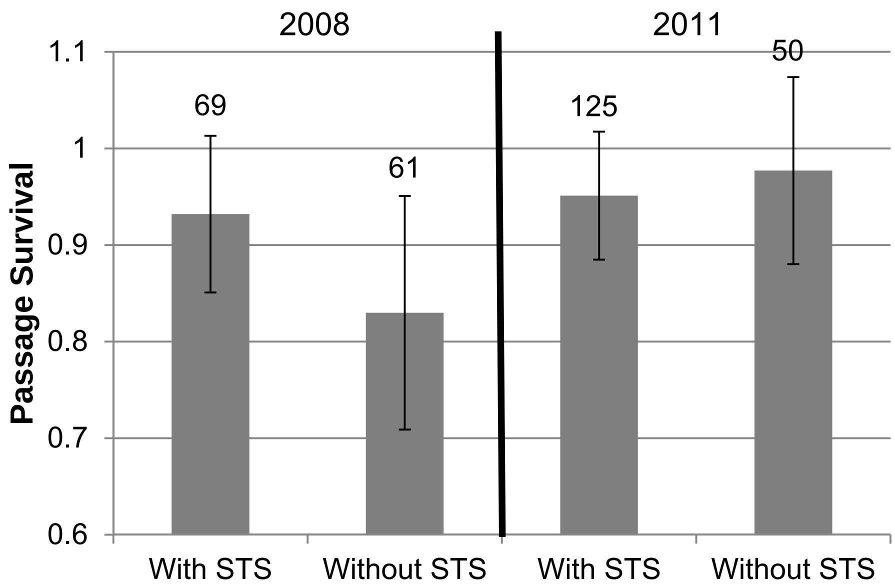

Figure 4.15. Turbine Passage Survival Rate Estimates with 95% Confidence Interval for CH1 that Passed through Turbines at B2 with and without STSs in 2008 and 2011

In both 2008 and 2011, STH showed lower turbine passage survival rates for passage through B2 turbines when STSs were installed in turbine intakes than when they were not installed (Figure 4.16). The differences in the survival rates for STH are large but are not significant because of the large confidence interval for the survival estimates due to the small sample sizes.

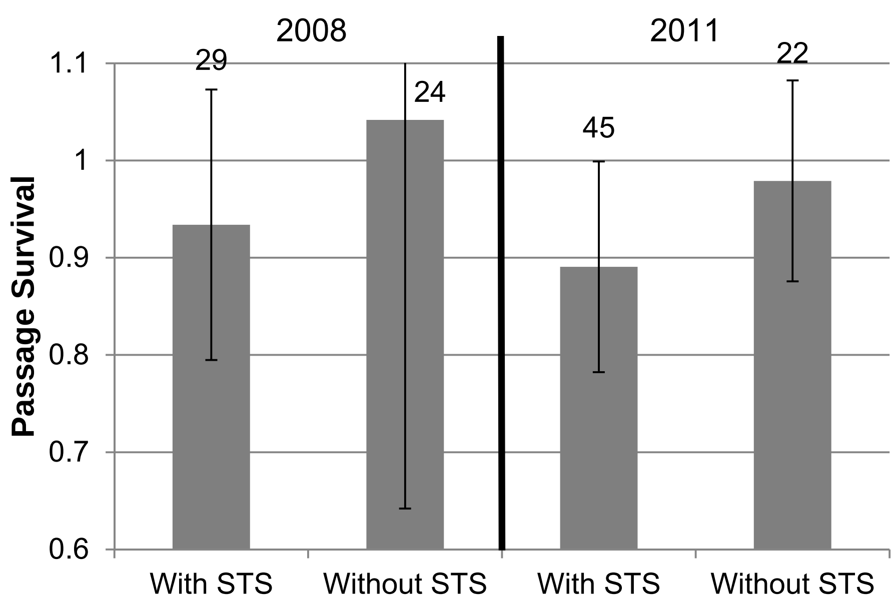

Figure 4.16. Turbine Passage Survival Rate Estimates with 95% Confidence Interval for STH that Passed through Turbines at B2 with and without STSs in 2008 and 2011

5.0 Results – Bonneville Dam Spillway

The methods used to partition the spillbays and discharge rates for the BON spillway are described in under Methods (Section 2.0). Spillway passage survival estimates and other statistics describing passage of CH1, STH, and CH0 through the spillway at BON are presented in the following sections and are also available in Appendix C (Table C.1 through Table C.10). Data for passage of tagged juvenile salmonids through the BON spillway for years 2008 and 2010–2012 were used for the analyses.

5.1 Yearling Chinook Salmon (CH1) at BON Spillway

5.1.1 CH1 Passage Survival Rates at BON by Spillbay

Spillway passage survival estimates for CH1 at BON by individual spillbays for all study years combined (2008, 2010, 2011, and 2012) is shown in Figure 5.1 and Table 5.1. Additional details are given in Appendix C. CH1 spill passage survival rates averaged over all spillbays and all years was 0.936. Estimates of CH1 passage survival through spillbays 5, 6, 10, 14, 16, and 18 were relatively higher (>0.95), while those for spillbays 3, 9, and 13 were relatively lower (<0.92), however, there were no significant differences in survival estimates between bays, based on 95% confidence intervals. There was a trend for more CH1 to pass through spillbays near the ends of the spillway and fewer passing through bays near the center of the spillway. The proportion of CH1 passage through individual spillbays is shown in Table 5.1 (Appendix C, Table C.3).

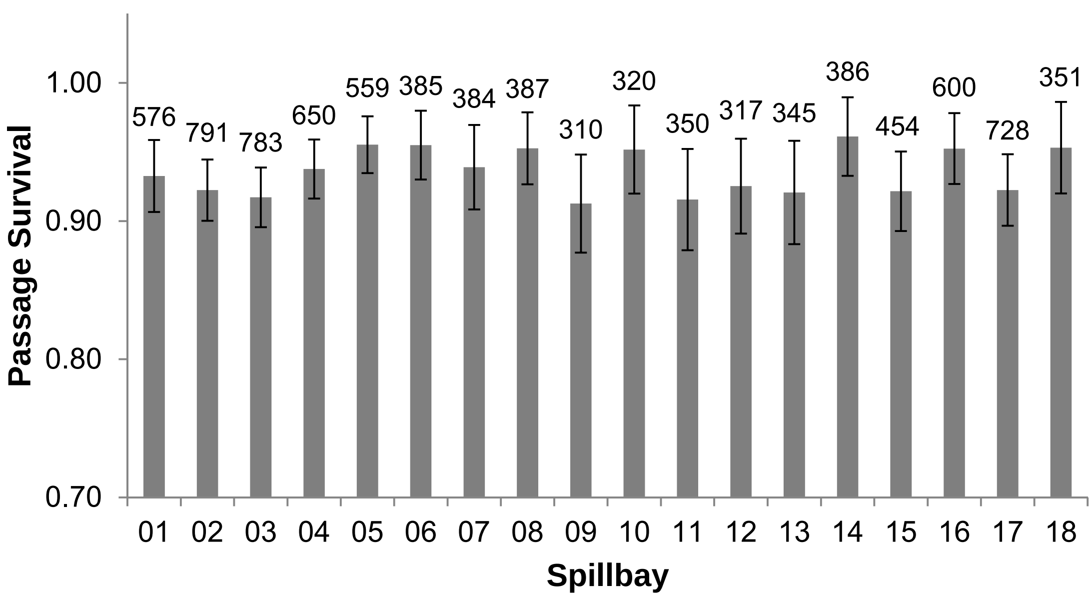

Figure 5.1. Survival Estimates with 95% Confidence Interval for CH1 by Spillbay at BON. Sample sizes are shown above the bars.

5.1.2 CH1 Spillway Passage Survival Rates at BON by Spillway Group

The spillway survival of CH1 was estimated for the five groups of adjacent spillbays shown in Figure 5.2. BON spillbays were divided into five groups because of structural differences between some spillbays. Spillbays 1–3 and 16–18 have deep-flow deflectors (7 ft above MSL), while all other spillbays have shallow-flow deflectors (14 ft above MSL). The spillbays with shallow-flow deflectors were divided into three groups because it was suspected that the middle spillbays (8–12) may have increased erosion on the spill chute and in the stilling basin and tailrace, or rock deposition in the tailrace. The highest survival rate for CH1 was observed for spillbays 4–7 (0.9462, SE 0.0061) and the lowest for spillbays 1–3 (0.9229, SE 0.0068); none of these survival estimates were significantly different, based on 95% confidence intervals. During survival studies from 2008 to 2012, excluding 2009, the highest proportion of CH1 passed through spillbays 1–3 (24.8%) and the lowest through spillbays 13–15 (13.7%) (Appendix C, Table C.4).

Table 5.1. Survival Estimates and Passage Proportions for CH1 by Spillbay at BON

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9326	6.6
2	0.9224	9.1
3	0.9172	9.0
4	0.9377	7.5
5	0.9553	6.4
6	0.9550	4.4
7	0.9390	4.4
8	0.9527	4.5
9	0.9127	3.6
10	0.9518	3.7
11	0.9156	4.0
12	0.9253	3.7
13	0.9207	4.0
14	0.9612	4.5
15	0.9216	5.2
16	0.9525	6.9
17	0.9225	8.4
18	0.9532	4.1

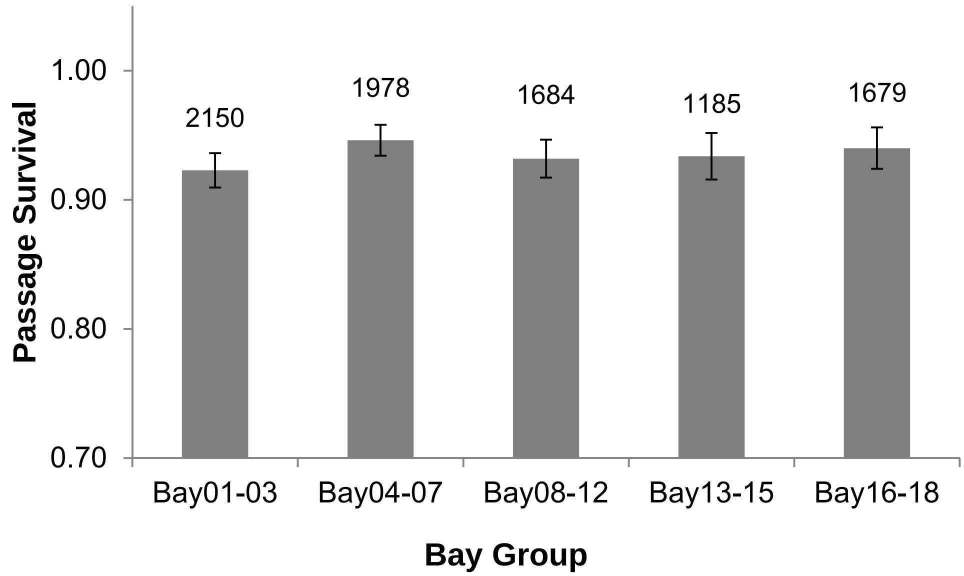

Figure 5.2. Survival Estimates with 95% Confidence Interval for CH1 by Spillbay Groups at BON. Sample sizes are shown above the bars.

5.1.3 CH1 Spillway Passage Survival Rates at BON by Discharge

Spillway passage data for CH1 were grouped into 10 kcfs (narrow) and 20 kcfs (wide) discharge bins and analyzed to evaluate the response of CH1 survival rates to spill discharge level (Figure 5.3, Table 5.2 and Figure 5.4, Table 5.3). The highest proportion of CH1 passed at spill levels contained in the 100 kcfs bin. The 100 kcfs bin also had the most hours of operation as specified in the FPP. There was not a noticeable trend in survival rates across spill levels though there was a marked decrease in survival estimates at flows ≥290 kcfs (0.8563, SE 0.0431). CH1 survival estimates for the narrow 10 kcfs discharge bins revealed higher survival estimates at spill discharges in 130, 150, 170, 220, 250, and 280 kcfs bins (all >0.96). Lower survival estimates were observed for spill discharges in 140, 210, and ≥290 kcfs bins (all <0.92). CH1 spill passage survival estimates between discharge bins were significantly lower at 100, 140, and ≥290 kcfs than for the 250 kcfs bin, based on 95% confidence intervals. In addition, the ≥290 kcfs bin also had significantly lower survival than the 150 kcfs bin. There was not an identifiable trend in survival estimates below the ≥290 kcfs bin. Grouping spill discharge into 20 kcfs (wide) bins revealed higher survival rates for spill discharges in the 220 and 240 kcfs bins (both >0.96), and lower survival estimates for discharges in 100, 180, and ≥280 kcfs bins (all ~0.93) (Appendix D, Table D.5, Table D.6, Table D.7, Table D.8). The CH1 passage survival rate was significantly lower at the 100 kcfs bin than the 240 kcfs bin, based on 95% confidence intervals, but was not significantly different between other bins.

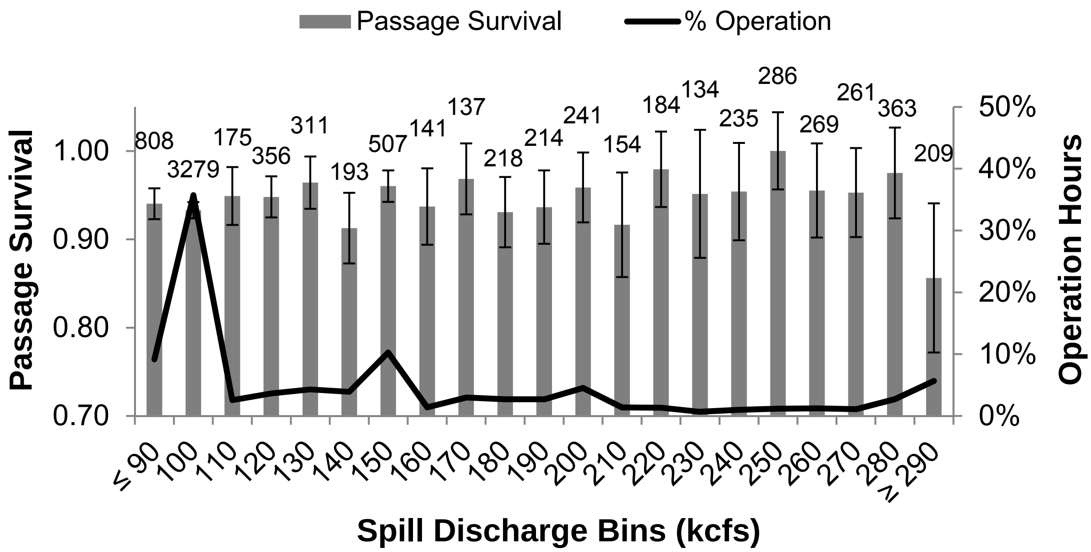

Figure 5.3. Survival Estimates with 95% Confidence Interval for CH1 Passing through the BON Spillway by 10 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.2. Median Spillway Tailrace Egress Time and Survival Estimates for CH1 at BON by 10 kcfs Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Median Egress Time (h)
70	---[(a)]	0.53
80	---[(a)]	0.51
90	0.9404	0.46
100	0.9330	0.41
110	0.9491	0.39
120	0.9481	0.37
130	0.9643	0.35
140	0.9127	0.34
150	0.9603	0.32
160	0.9372	0.31
170	0.9685	0.30
180	0.9308	0.30
190	0.9365	0.30
200	0.9588	0.28
210	0.9165	0.26
220	0.9793	0.26
230	0.9515	0.26
240	0.9541	0.27
250	1.0002	0.28
260	0.9553	0.27
270	0.9530	0.27
280	0.9752	0.28
290	0.8563	0.26
300	---[(b)]	0.28

(a) Survival estimates were calculated for the 70, 80, and 90 kcfs bins combined.
(b) Survival estimates were calculated for the 290 and 300 kcfs bins combined.

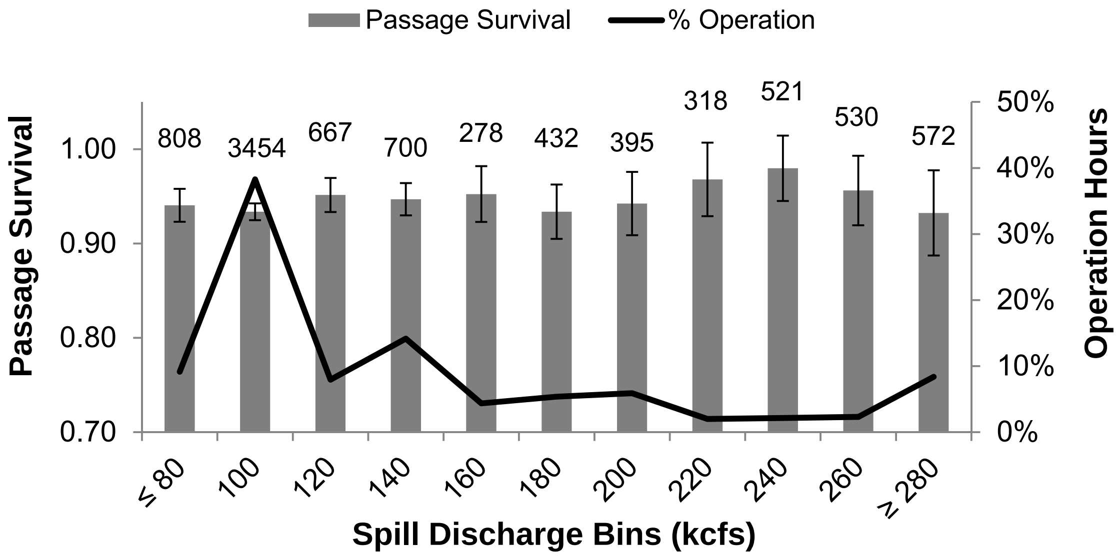

Figure 5.4. Survival Estimates with 95% Confidence Interval for CH1 at BON by 20 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.3. Median Spillway Tailrace Egress Time and Survival Estimates for CH1 at BON by 20 kcfs Discharge Intervals

Discharge (20 kcfs Bins)	Survival Estimate	Median Egress Time (h)
60	---[(a)]	0.53
80	0.9404	0.48
100	0.9336	0.41
120	0.9514	0.36
140	0.9469	0.32
160	0.9524	0.31
180	0.9337	0.3
200	0.9423	0.27
220	0.9679	0.26
240	0.9797	0.27
260	0.9562	0.27
280	0.9324	0.28
300	---[(b)]	0.28

(a) Survival estimates were calculated for the 60 and 80 kcfs bins combined.
(b) Survival estimates were calculated for the 280 and 300 kcfs bins combined.

5.1.4 Spillway Passage Survival Rates of CH1 at BON by Tailwater Elevation

CH1 spillway passage survival rates were examined for the potential influence of tailwater elevation (Figure 5.5; Appendix D, Table D.4). Higher survival estimates were observed for discharges in the range of the 6 m (0.9535, SE 0.0070) and 9 m bins (0.9542, SE 0.0094). The proportion of spillway operations that occurred during spring when tailwater elevations were in the range of the 8 m and 9 m tailwater elevation bins was relatively more frequent than those when tailwater elevations were in the range of 7 m and lower. CH1 survival estimates were not significantly different between any of the tailwater elevation bin groups, based on 95% confidence intervals. Passage proportion varied among the tailwater elevation bin groups (5 m [13.8%], 6 m [19.3%], 7 m [17.5%], 8 m [21.7%], and 9 m [27.6%]) (Appendix D, Table D.4).

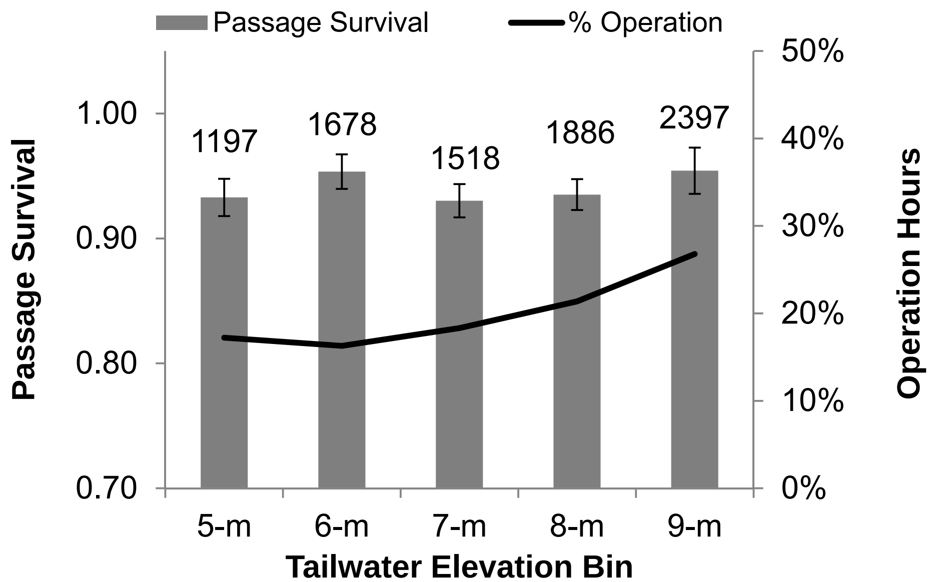

Figure 5.5. Survival Estimates with 95% Confidence Interval for CH1 at BON by Spillway Tailwater Elevation Bins with Percent Spill Operation. Sample sizes are shown above the bars.

5.1.5 CH1 Spillway Tailrace Egress Time at BON

Tailrace egress time for CH1 was examined by grouping egress data by discharge into 10 kcfs and 20 kcfs bins; details for grouping are provided in Appendix F (Table F.4 [10 kcfs increments] and Table F.7 [20 kcfs increments]). Median values for egress time grouped into 10 kcfs spill discharge bins are shown in Table 5.2. There was a consistent decline in egress time with increase spillway discharge to about 200 kcfs, at which point egress time leveled off. The largest sample size in the 10 kcfs discharge groups (N = 2,571) was for the 100 kcfs spill discharge bin; median egress time was 0.41 h. The median egress times for fish passing at discharges contained within the range of the 190 to 230 kcfs discharge bins (N = 204) was about 0.27 h. The median egress time for discharges within the 70 to 180 kcfs bins was about 0.38 h; median egress time was 0.27 h for discharges within the 240 to 300 kcfs bins (Appendix F, Table F.4).

Median egress time values for spill discharge grouped into 20 kcfs bins are shown in Table 5.3. As with the 10 kcfs bins, egress times consistently declined with increasing spillway discharge up to about 200 kcfs, after which egress time leveled off. The largest sample size for 20 kcfs discharge increments (N = 2,713) was also observed for the 100 kcfs spill discharge bin; median egress time was 0.41 h. The median egress time for discharges contained within the 60 to 180 kcfs bins was about 0.39 h; median egress time for discharges contained within the 200 to 300 kcfs bins was about 0.27 h (Appendix F, Table **F**.7).

5.2 Juvenile Steelhead (STH) at BON Spillway

5.2.1 STH Spillway Passage Survival Rates by Spillbay

STH spillway passage survival estimates at BON by individual spillbays for all study years combined (2008, 2010, 2011, and 2012) is shown in Figure 5.6 and Table 5.4 and further detailed in Appendix C. Passage survival estimates averaged 0.942; survival estimates for spillbays 4, 11, 12, 13, 15, and 18 were relatively higher (all >0.95), while survival estimates for spillbays 3, 5, 6, and 9 were relatively lower (all <0.93), though there was not a significant difference in survival between any of the spillbays. As with CH1, STH tended to pass through spillbays near the ends of the spillway, with fewer passing bays near the center of the spillway. Proportions of STH passing through individual spillbays are shown in Table 5.4 (Appendix C, Table C.3).

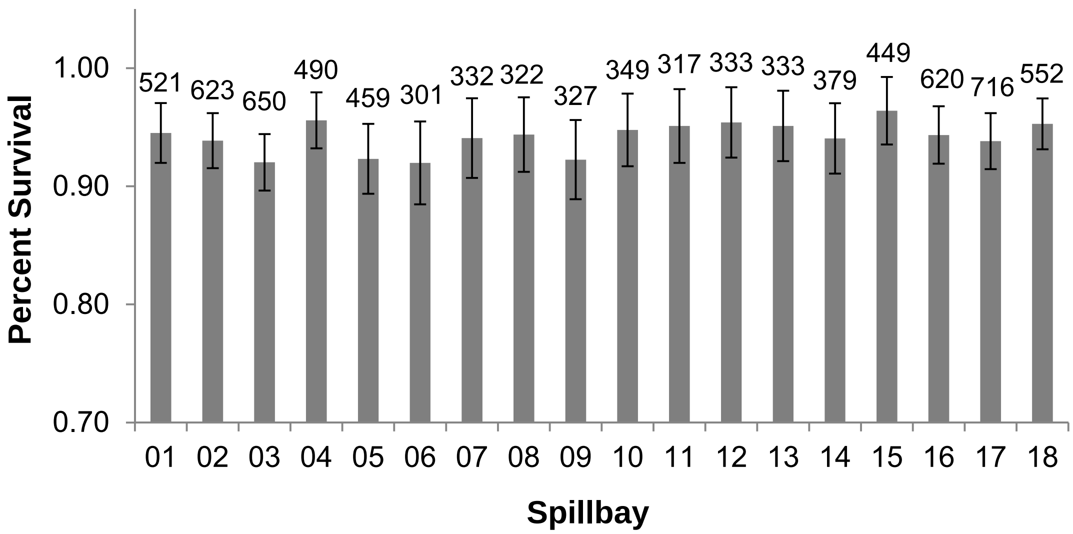

Figure 5.6. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at BON by Spillbay. Sample sizes are shown above the bars.

5.2.2 STH Spillway Passage Survival Rates at BON by Spillbay Group

STH passing the spillway at BON were grouped for estimating survival rates by adjacent spillbays as shown in Figure 5.7. Spillbays were divided into five groups because spillbays 1–3 and 16–18 have deep-flow deflectors (7 ft above MSL) and all other spillbays have shallow-flow deflectors (14 ft above MSL). The spillbays with shallow-flow deflectors were divided into three groups because it was suspected that the middle spillbays (8–12) may have increased erosion on the spill chute, in the stilling basin or tailrace, or rock deposition in the tailrace. The highest survival rate was estimated for STH passing through spillbay group 13–15 (0.9525, SE 0.0087) and the lowest survival rate was estimated for those passing through spillbay group 1–3 (0.9340, SE 0.0071). During survival studies from 2008 to 2012 (excluding 2009), the least STH passed through spillbays 13–15 (14.4%); passage proportions through the remaining spillbay groups were similar: spillbay group 1–3 (22.2%), spillbay group 4–7 (19.6%), spillbay group 8–12 (20.4%), and spillbay group 16–18 (23.4%) (Appendix C, Table C.4). There were no significant differences in STH survival estimates between spillbay groups, based on 95% confidence intervals.

Table 5.4. Spillway Survival Estimates and Passage Proportions for STH at BON by Spillbay

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9451	6.5
2	0.9386	7.7
3	0.9203	8.1
4	0.9558	6.1
5	0.9232	5.7
6	0.9198	3.7
7	0.9408	4.1
8	0.9438	4.0
9	0.9225	4.1
10	0.9477	4.3
11	0.9510	3.9
12	0.9541	4.1
13	0.9511	4.1
14	0.9405	4.7
15	0.9639	5.6
16	0.9434	7.7
17	0.9382	8.9
18	0.9528	6.8

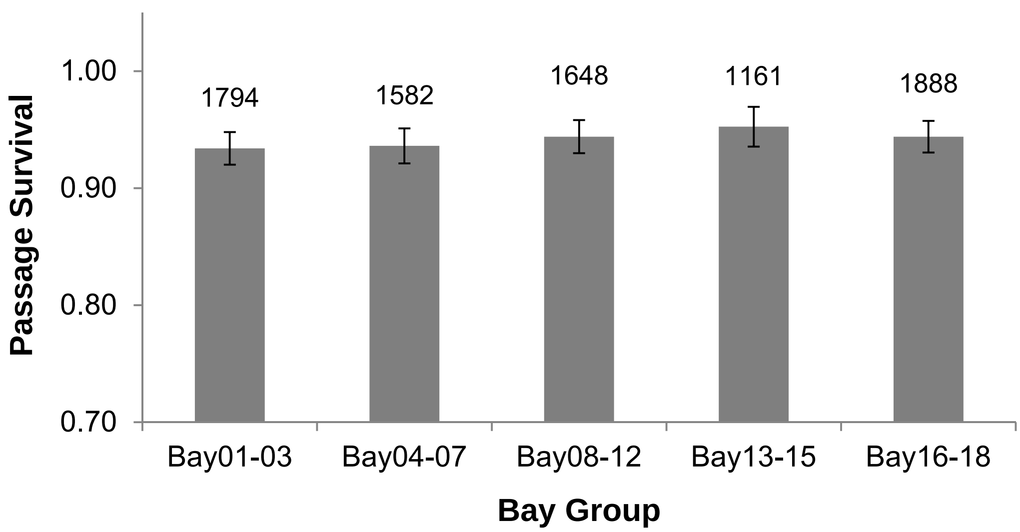

Figure 5.7. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at BON by Spillbay Group. Sample sizes are shown above the bars.

5.2.3 STH Spillway Passage Survival Rates at BON by Discharge

The survival rates of STH was estimated for passage in spill discharge binned into 10 kcfs (narrow) and 20 kcfs (wide) intervals, then analyzed to assess patterns in STH survival related to spill discharge rates (Figure 5.8, Table 5.5 and Figure 5.9, Table 5.6). The highest proportion of STH passed in spill discharges within the range of the 100 kcfs bin, which had the most hours of operation, following requirements for spillway operation in the BON FPP. The results from the narrow 10 kcfs discharge bins indicated higher passage survival estimates for discharges in the 160 and 210 to 250 kcfs bins (all >0.96), whereas lower survival estimates were found for passage in discharges within the 130 and ≥ 290 kcfs bins (both <0.92; Appendix D, Table D.5). Survival estimates for STH passing with spill discharge ≥290 kcfs was significantly lower than survival rate at most other flow levels. Survival estimates for the 230 to 250 kcfs bins were significantly higher than survival estimates for flow bins ≤90, 130, and 140 kcfs, based on 95% confidence intervals. Binning spill discharge into 20 kcfs intervals revealed higher survival estimates for passage in discharges within the range of the 220 to 260 kcfs bins (all >0.96) and lower survival estimates for passage in discharges within the 140 kcfs and ≥280 kcfs bins (both < 0.93; Appendix D, Table D.6). Survival estimates were significantly lower for passage in spill discharges, exceeding 280 kcfs, than for most of the lower flow levels, similar to what was seen in the 10 kcfs bin analysis.

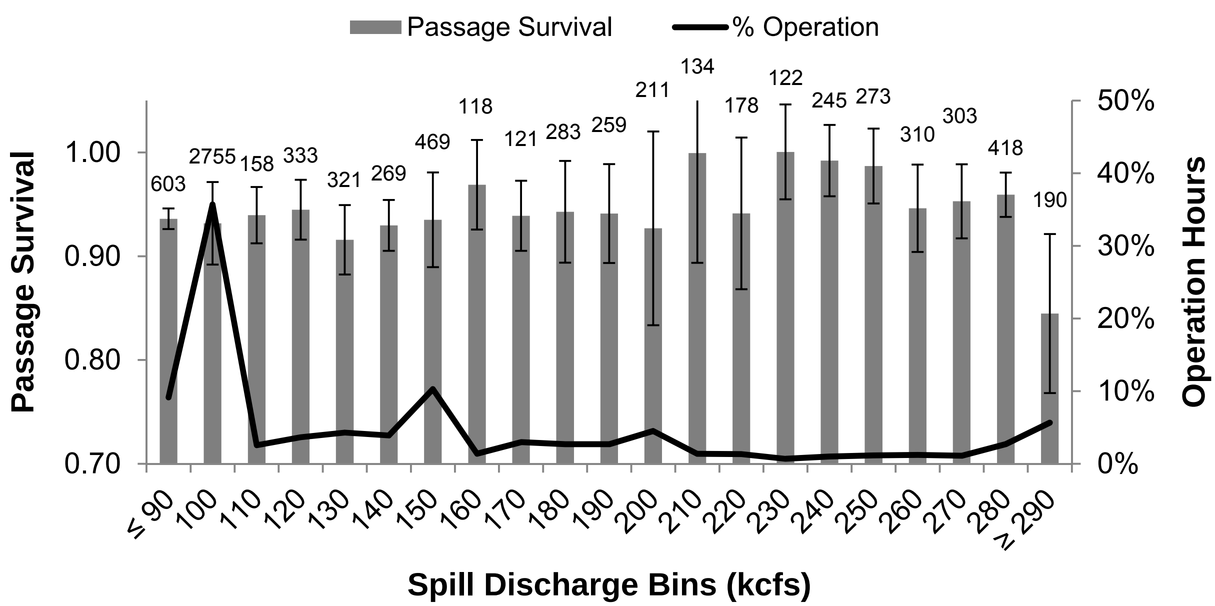

Figure 5.8. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at BON by 10 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.5. Median Spillway Tailrace Egress Time and Survival Estimates for STH at BON by 10 kcfs Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Median Egress Time (h)
70	---[(a)]	0.47
80	---[(a)]	0.47
90	0.9559	0.43
100	0.9374	0.41
110	0.9317	0.38
120	0.9378	0.36
130	0.9446	0.35
140	0.9159	0.32
150	0.9302	0.31
160	0.9442	0.31
170	0.9848	0.31
180	0.9415	0.3
190	0.9643	0.29
200	0.9942	0.29
210	0.9800	0.25
220	0.9604	0.23
230	0.9607	0.31
240	1.0182	0.28
250	0.9906	0.29
260	0.9869	0.29
270	0.9463	0.31
280	0.9530	0.29
290	0.8448	0.29
300	---[(b)]	0.33

(a) Survival estimates were calculated for the 70, 80, and 90 kcfs bins combined.
(b(Survival estimates were calculated for the 290 and 300 kcfs bins combined.

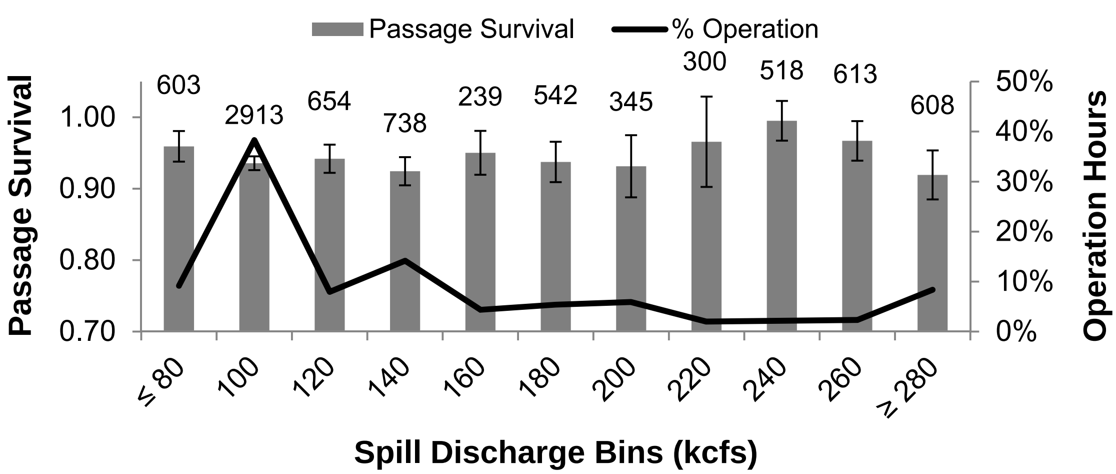

Figure 5.9. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at BON by 20 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

Table 5.6. Median Spillway Tailrace Egress Time and Survival Estimates for STH at BON by 20 kcfs Discharge Intervals

Discharge (20 kcfs Bins)	Survival Estimate	Median Egress Time (h)
60	---[(a)]	0.47
80	0.9559	0.45
100	0.9370	0.4
120	0.9403	0.36
140	0.9248	0.32
160	0.9631	0.31
180	0.9518	0.3
200	0.9866	0.29
220	0.9626	0.29
240	1.0028	0.29
260	0.9670	0.3
280	0.9193	0.29
300	---[(b)]	0.33

(a) Survival estimates were calculated for the 60 and 80 kcfs bins combined.
(b) Survival estimates were calculated for the 280 and 300 kcfs bins combined.

5.2.4 Spillway Passage Survival Rates by Tailwater Elevation

STH spillway survival rates were also investigated to determine if spill passage survival is dependent upon tailwater elevation. STH spill passage survival was estimated for discharges that occurred within the five
1 m tailwater elevation groupings shown in Figure 5.10 (Appendix D, Table D.4). The survival estimates for STH passing when tailwater were within the range of the bin groups ranged from 0.9308 (SE 0.0064) for the 8 m bin to 0.9538 (SE 0.0076) for the 6 m bin. Survival estimates were not significantly different between any of the tailwater elevation groups, based on 95% confidence intervals. The proportion of time that the BON spillway was operating during spring was higher when tailwater was within the range of the 8 m and 9 m tailwater elevation bins than when tailwater was less than the 8 m bin. Passage proportions varied for discharges that occurred when tailwater was within the range of the various elevation bins (5 m [11.0%], 6 m [17.1%], 7 m [16.9%], 8 m [24.2%], and 9 m [30.8%]) (Appendix D, Table D.4).

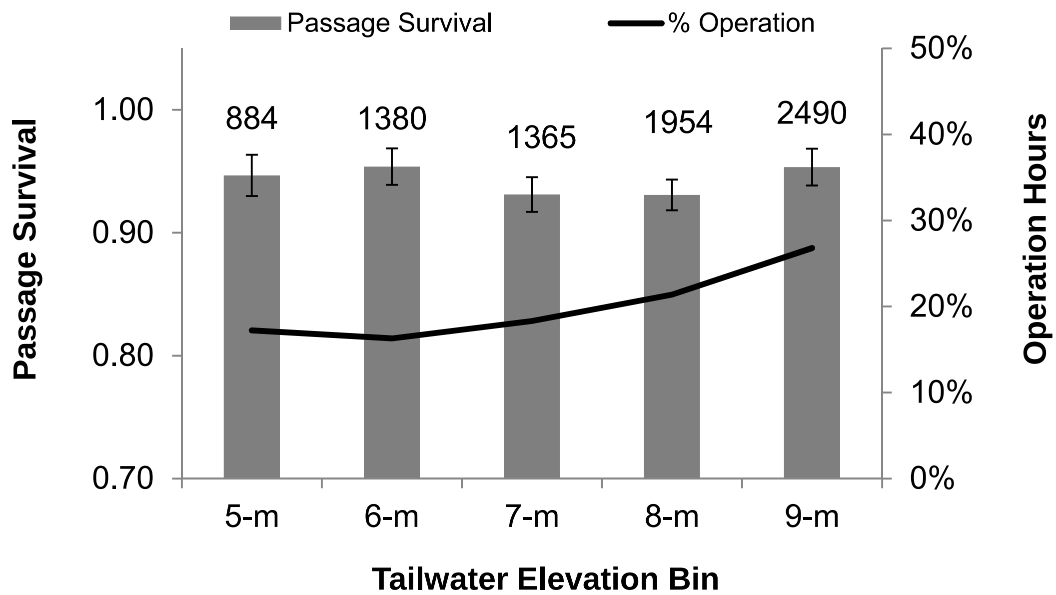

Figure 5.10. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at BON by Tailwater Elevation Bin with Percent Spillway Operation. Sample sizes are shown above the bars.

5.2.5 Spillway Tailrace Egress Time

Tailrace egress time for STH was examined using discharges grouped into 10 kcfs and 20 kcfs bins; details are provided in Appendix F (Table F.5 [10 kcfs increments]) and Table F.8 [20 kcfs increments]). Median tailrace egress values for spill discharge grouped into 10 kcfs bins are shown in Table 5.5. There was a consistent decline in egress time with increase spillway discharge to about 190 kcfs, at which point egress time leveled off. Following the FPP, which specifies spill discharge per bay, the largest sample size in the 10 kcfs discharge bins (N = 2,179) occurred for the 100 kcfs spill discharge; median egress time was 0.41 h. The average of the median egress times for spill discharges within the range of the 70 to 180 kcfs bins was 0.37 h; the average median egress time was 0.29 h for discharges within the range of the 190 to 300 kcfs bins (Appendix F, Table F.5).

Median values for spill discharge grouped into 20 kcfs bins are shown in Table 5.6. The largest sample size for the 20 kcfs discharge increments (N = 2,297) also occurred for the 100 kcfs spill discharge; median egress time was 0.40 h. Median tailrace egress time declined with increase in spill discharge to about 180 kcfs, where the egress time leveled off. The average median egress time for discharges within the range of the 60 to 180 kcfs bins was 0.37 h; average median egress time for spill discharges within the range of the 200 to 300 kcfs bins was 0.30 h (Appendix F, Table F.8).

5.3 Subyearling Chinook Salmon (CH0) at BON Spillway

5.3.1 CH0 Spillway Passage Survival Rates at BON by Spillbay

CH0 spillway passage survival at BON by individual spillbays for all study years combined (2008, 2010, and 2012) is shown in Figure 5.11 and Table 5.7, and further detailed in Appendix C. Passage survival estimates across all spillbays averaged 0.95. There was not a definite trend in survival estimates across the spillway, as was in the case of STH and CH1. Spillbays 2 and 3 had the lowest passage survival rate (0.9286 and 0.9370, respectively), but the other end bays did not follow this lower survival trend and spillbay 1 had one of the higher survival rates (0.9575, SE 0.0095). Spillbay 4 had the highest passage (N = 1,021) and also high survival (0.9596, SE 0.0063). There was no significant difference in survival rates between bays. The proportion of CH0 that passed through individual spillbays is shown in Table 5.7 (Appendix C,
Table C.3).

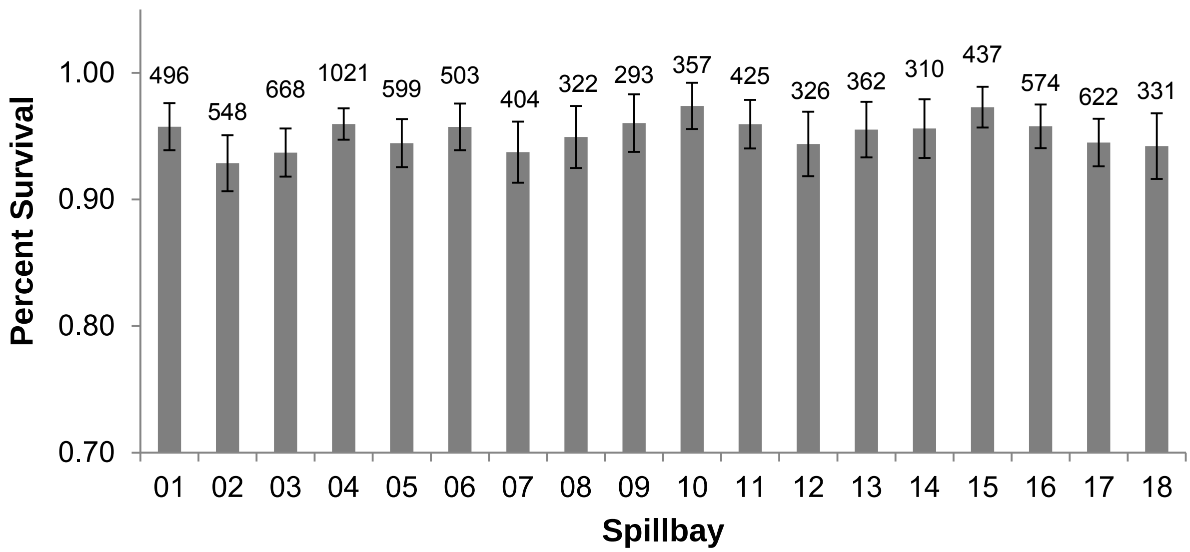

Figure 5.11. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at BON by Spillbay. Sample sizes are shown above the bars.

Table 5.7. Spillway Passage Survival Estimates and Passage Proportions for CH0 at BON by Spillbay

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9575	5.8
2	0.9286	6.4
3	0.9370	7.8
4	0.9596	11.9
5	0.9445	7.0
6	0.9573	5.9
7	0.9374	4.7
8	0.9494	3.8
9	0.9604	3.4
10	0.9739	4.2
11	0.9595	4.9
12	0.9438	3.8
13	0.9552	4.2
14	0.9560	3.6
15	0.9729	5.1
16	0.9578	6.7
17	0.9450	7.2
18	0.9422	3.9

5.3.2 CH0 Spillway Passage Survival Rates at BON by Spillbay Grouping

Similar to CH1 and STH, BON CH0 spillway survival rate was estimated for groups of adjacent spillbays (Figure 5.12). Spillbays were divided into five groups because spillbays 1–3 and 16–18 have deep-flow deflectors (7 ft above MSL); all other spillbays have shallow-flow deflectors (14 ft above MSL). The spillbays with shallow-flow deflectors were divided into three groups, because it was suspected that the middle spillbays (8–12) may have increased erosion or rock deposition in the tailrace. The survival of CH0 passing through the end bays with the deep-flow deflectors was lower (<0.95) than that for passage through the spillbays with shallow-flow deflectors, though none of the survival estimates for any of the spillway groups were significantly different, based on 95% confidence intervals. The highest survival was estimated for passage through spillbays 13–15 (0.9625, SE 0.0059) and the lowest survival rate was estimated for passage through spillbays 1–3 (0.9403, SE 0.0059). During survival studies from 2008, 2010, and 2012, most CH0 passed through spillbays 4–7 (29.4%); the fewest passed spillbays 13–15 (12.9%) (Figure 5.12; Appendix C, Table C.4).

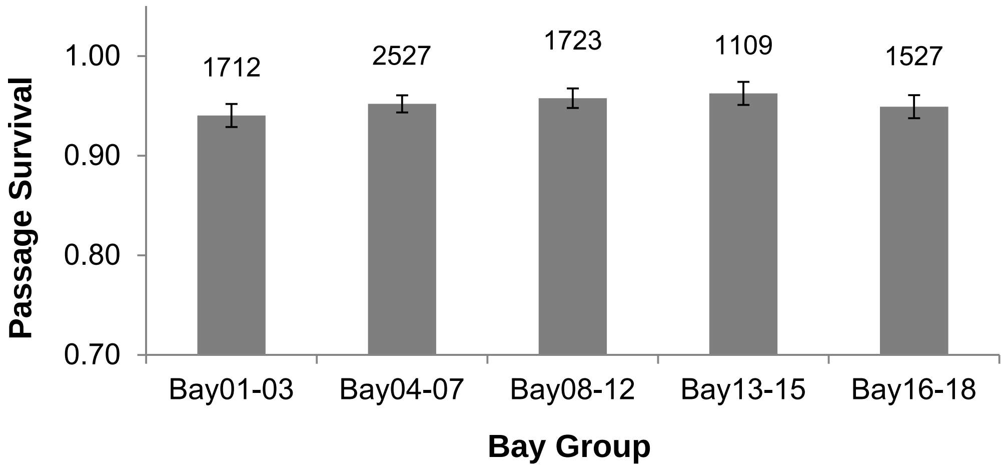

Figure 5.12. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at BON by Spillbay Group. Sample sizes are shown above the bars.

5.3.3 CH0 Spillway Passage Survival Rate at BON by Discharge

The survival rate of CH0 was estimated for passage in spill discharge binned by 10 kcfs (narrow) or 20 kcfs (wide) intervals, then analyzed to identify differences in CH0 survival rates that might result from passage in higher or lower spill discharge (Figure 5.13, Table 5.8, and Figure 5.15, Table 5.9). Unlike CH1 and STH, CH0 spill discharges did not exceed 230 and 220 kcfs for 10 kcfs and 20 kcfs bin intervals, respectively. There was a correlation between spill and survival rates for CH0 ($R^2 = 0.70$, $p < 0.05$) (Figure 5.14), with increased survival rates at higher spill discharge. Survival estimates for the narrow 10 kcfs discharge bins indicate CH0 passing in the 90 and 100 kcfs bins were significantly lower than survival estimates of CH0 passing in spill bins 140 kcfs or greater based on 95% confidence intervals. The survival rate of CH0 passing at the 110 kcfs spill level was significantly lower than that of CH0 passing at the 150, 190, and 210 kcfs spill levels. At the 120 kcfs spill level, the survival rate was significantly lower than the passage survival rate for CH0 passing at the 140, 150, 190, and 210 kcfs spill levels, and at the 130 kcfs spill level the survival rate was significantly lower than that of CH0 passing at the 150 and 190 kcfs spill levels. There was not a significant difference in survival rates between any of the discharge bins 140 kcfs or above.

The survival rate of CH0 for the 20 kcfs (wide) levels was significantly lower for CH0 passing in the ≤80 kcfs bin than that of CH0 passing in discharge bins 120 kcfs or greater based on 95% confidence intervals. For CH0 passing in the 100 kcfs bin, the survival rate was significantly lower than that of CH0 passing in 140 kcfs bins or greater. The survival rate of CH0 passing in the 120 kcfs bin was significantly lower than that of CH0 passing in either the 140 or 180 kcfs discharge bins.

For the narrow 10 kcfs bins, a higher proportion of CH0 passed with discharges within the ≤90 and 150 kcfs bins, 14.9% and 13.9%, respectively (Figure 5.13; Appendix D, Table D.5; Appendix D, Table D**.6**). Operation hours were greatest for spill discharges within the ≤90 and 100 kcfs bins, which is consistent with the FPP for 85 and 95 kcfs spill volumes during CH0 summer passage. A similar trend in survival rate was noted when survival estimates for 20 kcfs discharge bins were evaluated (Figure 5.15).

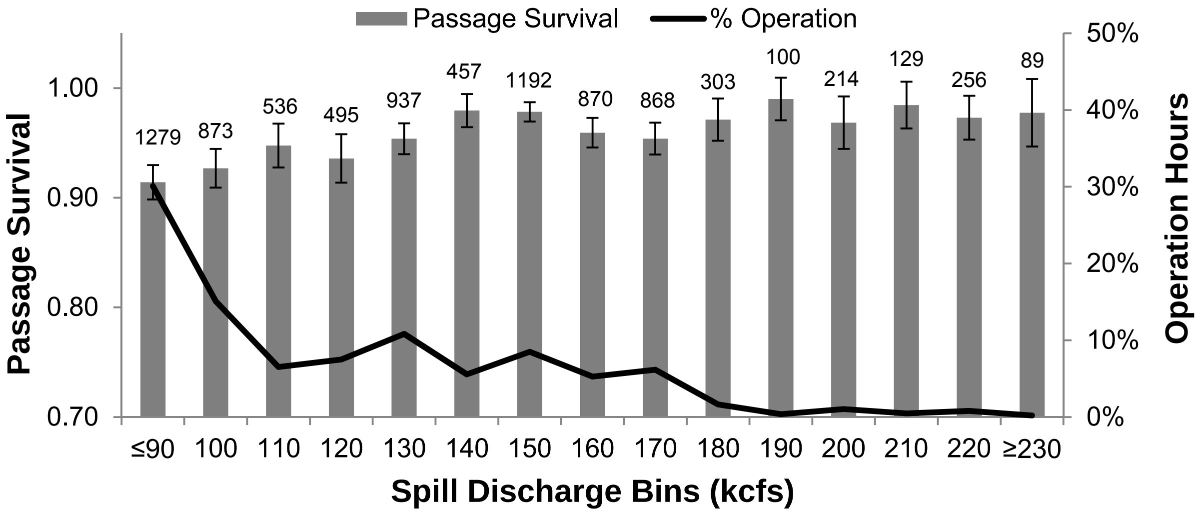

Figure 5.13. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at BON by 10 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

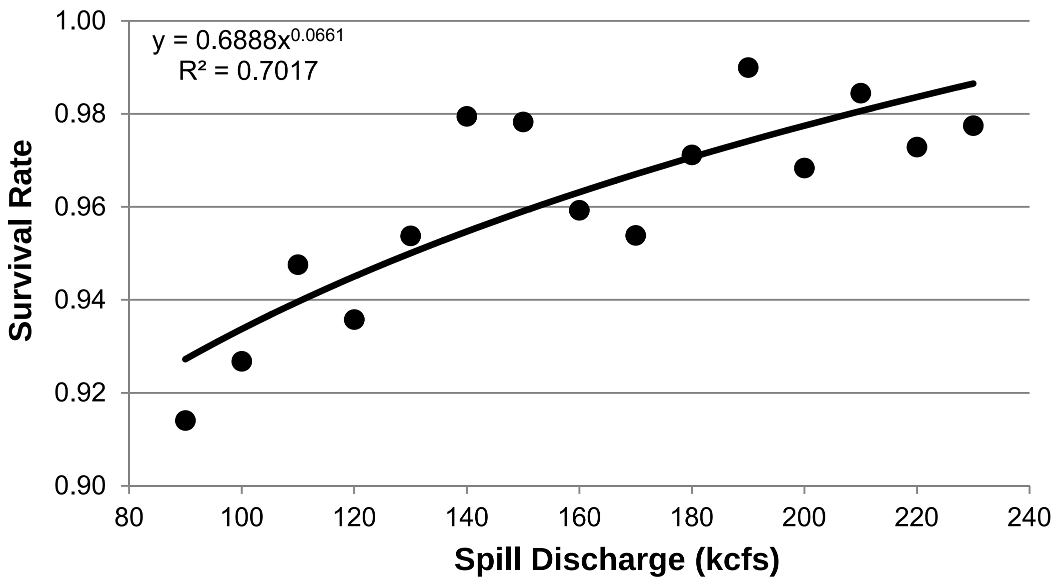

Figure 5.14. Spillway Passage Survival Rate Relative to Spillway Discharge for CH0 at BON

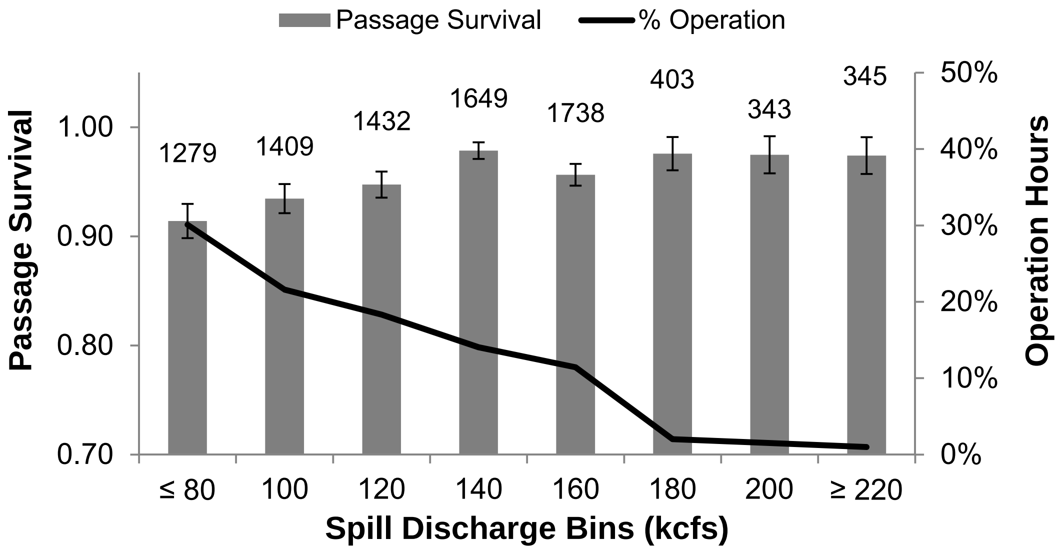

Figure 5.15. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at BON by 20 kcfs Spill Discharge Bins with Percent Spillway Operation. Sample sizes are shown above the bars.

5.3.4 CH0 Spillway Passage Survival Rates at BON by Tailwater Elevation

CH0 survival estimates in spill that occurs when the tailwater is within the range of different elevation bins was examined in conjunction with the hours of spillbay operation (Figure 5.16; Appendix D, Table D.1 and Table D.4). The highest CH0 survival rate was observed for discharges that occurred when tailwater was within the range of the 9 m bin (0.9709, SE 0.0083) and lowest survival estimates were observed for passage in spill discharges within the range of the 5 m bin (0.9050, SE 0.0094). The rate of survival was significantly lower for CH0 passing in 5 m and 6 m tailwater elevation bins than those passing in 7 m, 8 m, and 9 m bins, based on 95% confidence intervals. The survival rate of CH0 passing in the 7 m bin was also significantly lower than that of CH0 passing in the 8 m bin. During the summer survival studies, the BON spillway operation durations were within the range of the 7 m and 8 m tailwater elevation bins the majority of the time, followed by the 5 m and 6 m bins. Passage proportion varied for the different tailwater elevation bins (5 m [11.6%], 6 m [7.9%], 7 m [28.8%], 8 m [46.9%], and 9 m [4.8%]).

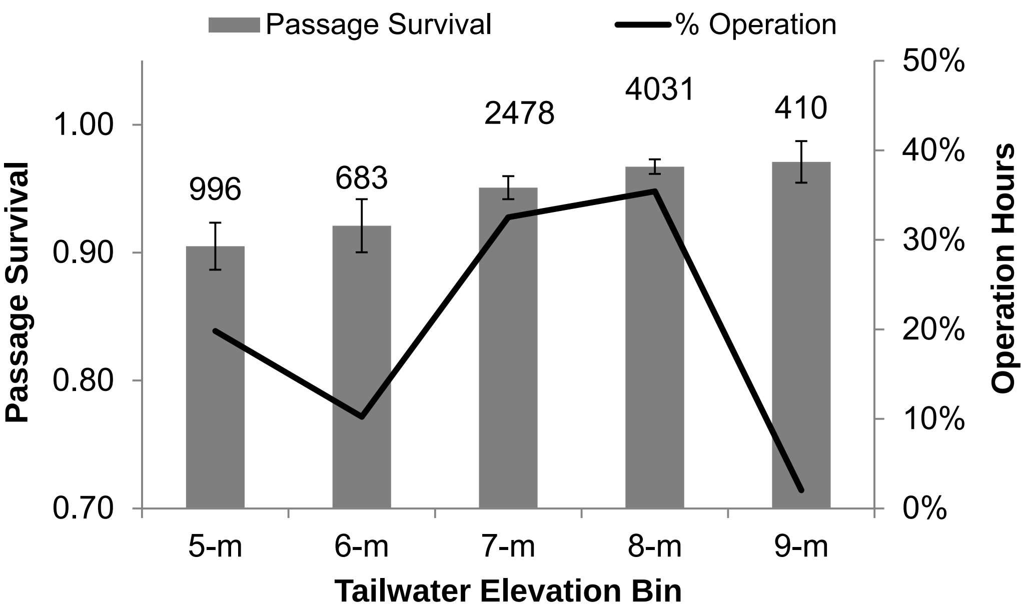

Figure 5.16. Spillway Passage Survival with 95% Confidence Interval for CH0 at BON by Tailwater Elevation Bin with Percent Spillway Operation. Sample sizes are shown above the bars.

5.3.5 CH0 Spillway Tailrace Egress Time and Spillway Passage Survival Rates at BON

Tailrace egress for CH0 was examined using discharges grouped into 10 kcfs and 20 kcfs bins; details are provided in Appendix F (Table F.6 [10 kcfs increments]) and Table F.9 [20 kcfs increments]). Median values of CH0 survival rates and median tailrace egress time for spill discharges grouped into 10 kcfs bins are shown in Table 5.8. The largest sample size for bins in the 10 kcfs discharge increment groups (N = 1,049) occurred at discharges within the 150 kcfs spill discharge bin; median egress time was 0.32 h. Longest median egress time was 0.54 h for spill discharges within the 80 kcfs bin (N = 19), and shortest egress time was 0.25 h for discharges within the 230 kcfs bin (N = 78). The average of the median egress times for spill discharge within the range of the 80 to 140 kcfs bins was 0.43 h; the average median egress time was 0.29 h for discharge within the range of the 150 to 230 kcfs bins (Appendix F, Table F.6).

Median values of CH0 survival rates and median tailrace egress time for spill discharge grouped into 20 kcfs bins are shown in Table 5.9. The largest sample size within the 20 kcfs discharge bin group (N = 1,346) occurred for the 140 kcfs spill discharge bin; median egress time was 0.33 h. The longest median egress time was 0.51 h in the 80 kcfs bin (N = 316) and shortest egress time was 0.25 h in the 220 kcfs bin (N = 320) (Appendix F, Table F.9).

Table 5.8. Median Tailrace Egress Time for CH0 at BON by 10 kcfs Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Median Egress Time (h)
80	---[(a)]	0.54
90	0.9141	0.51
100	0.9268	0.45
110	0.9476	0.41
120	0.9358	0.38
130	0.9538	0.36
140	0.9795	0.34
150	0.9783	0.32
160	0.9593	0.31
170	0.9539	0.30
180	0.9712	0.30
190	0.9900	0.28
200	0.9684	0.28
210	0.9845	0.28
220	0.9729	0.26
230	0.9775	0.25

(a) Survival estimates were calculated for the 80 and 90 kcfs bins combined

Table 5.9. Median Tailrace Egress Time for CH0 at BON by 20 kcfs Discharge Intervals

Discharge (20 kcfs Bins)	Survival Estimate	Median Egress Time (h)
80	0.9141	0.51
100	0.9346	0.44
120	0.9475	0.36
140	0.9786	0.33
160	0.9565	0.30
180	0.9758	0.29
200	0.9748	0.28
220	0.9741	0.25

6.0 Results – The Dalles Dam Spillway

The methods used to partition the spillbays and discharge volumes for TDA spillway are described under Methods (Section 2.0). Spillway passage survival estimates and other statistics describing passage of CH1, STH, and CH0 through the spillway at TDA are presented in the following sections and are also available in Appendix E (Table E.1 through Table E.9). Data for passage of tagged juvenile salmonids through TDA spillway for years 2010–2012 were used for the analyses.

6.1 Yearling Chinook Salmon (CH1) at TDA

6.1.1 CH1 Spillway Passage Survival Rates at TDA by Spillbay

Spillway passage survival estimates for CH1 at TDA through spillbays at the northwest end of the spillway, inside of the new spill wall (spillbays 1–8), are shown in Figure 6.1 (Appendix E, Table E.1 and Table E.4). For combined years 2010 to 2012, CH1 passing through spillbay 3 had the highest survival estimate (0.9611, SE 0.0073) and those passing through the adjacent spillbay, spillbay 2, had the lowest survival estimate (0.9251, SE 0.0100). The difference in CH1 survival rate through spillbays 2 and 3 is significantly different, based on 95% confidence intervals. There was not a significant difference in survival rates between any of the other bays. Survival estimates for CH1 passing through spillbays 1 and 3–8 varied only slightly from each other (all > 0.948). Spillbay 8 passed the highest proportion of CH1 and passage numbers declined consistently across the spillway from spillbay 8 to spillbay 1 for the combined years (Table 6.1).

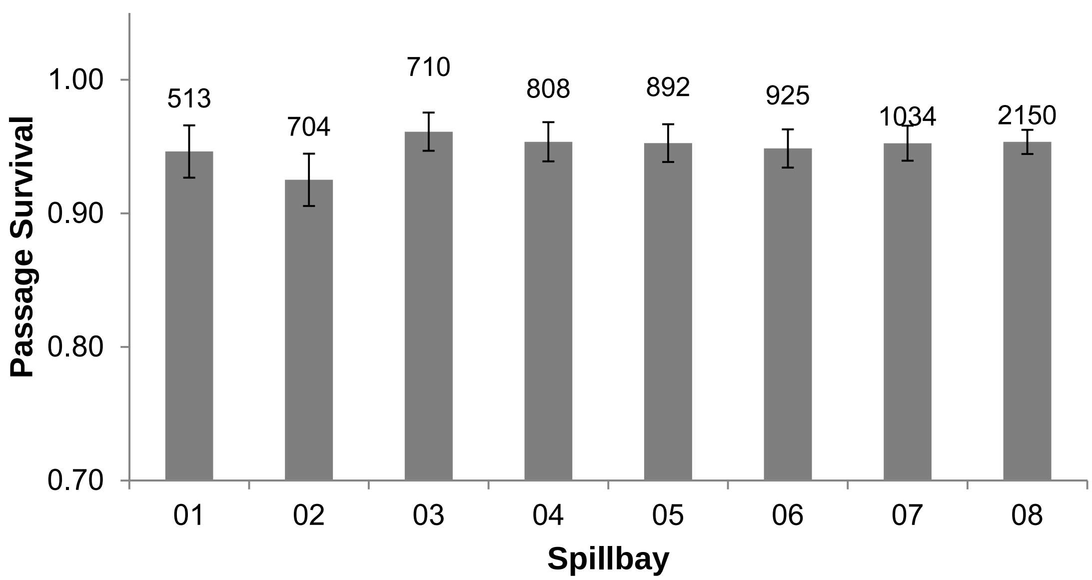

Figure 6.1. Spillway Passage Survival Estimates with 95% Confidence Interval for CH1 at TDA by Spillbay for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.1. Survival Estimates and Passage Proportions for CH1 at TDA by Spillbay within the Spill Wall

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9463	6.6
2	0.9251	9.1
3	0.9611	9.2
4	0.9536	10.4
5	0.9526	11.5
6	0.9486	12.0
7	0.9525	13.4
8	0.9535	27.8

6.1.2 CH1 Spillway Passage Survival Rates at TDA by Spillbay Group

The numbers and survival of CH1 that passed through two sections of TDA spillway, spillbays 1–8 and 9–23, were estimated. Spillbays 1–8 are northwest of the spill wall and spillbays 9–23 southeast of the spill wall. Spill only occurred through spillbays southeast of the spill wall when river discharge exceeded the capacity of the powerhouse and spillbays 1–8. The survival estimate of CH1 passing through spillbays 1–8 (0.9568, SE 0.0026) and spillbays 9–23 (0.9486, SE 0.0102) was not significantly different (Figure 6.2, Appendix E, Table E.5), based on the 95% confidence intervals. Because spillbays 9–23 were only used during high river flow periods, 92.5% of the CH1 detected passing in spill passed through spillbays 1–8. The survival estimate of CH1 that passed through spillbays 9–12 (0.9472, SE 0.0133) was not significantly different from the passage survival estimate through spillbays 13–23 (0.9508, SE 0.0160), which are closer to the predator-inhabited islands near the southeast end of the spillway.

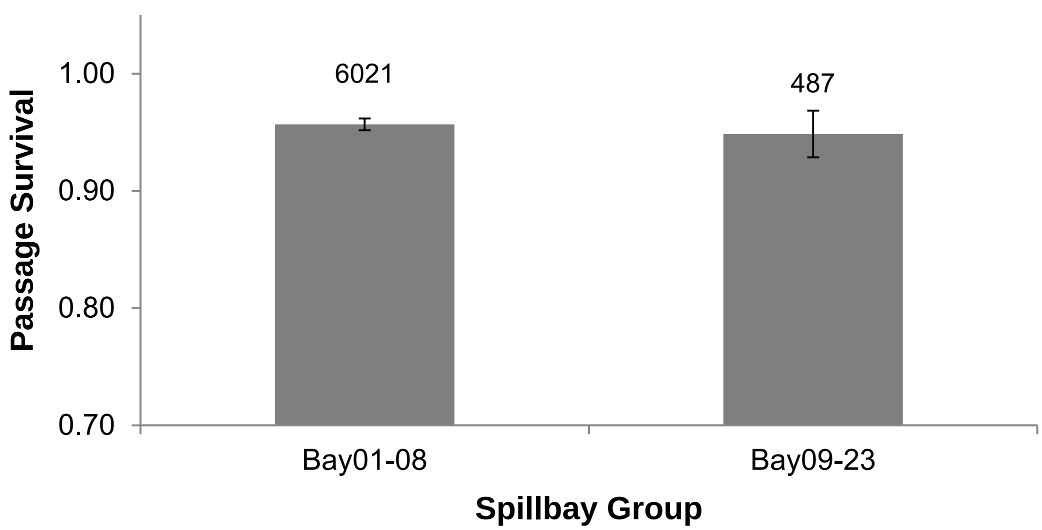

Figure 6.2. Spillway Passage Survival Estimates with 95% Confidence Interval for CH1 at TDA by Spillbay Groups (Spillbays 1–8 and Spillbays 9–23) for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

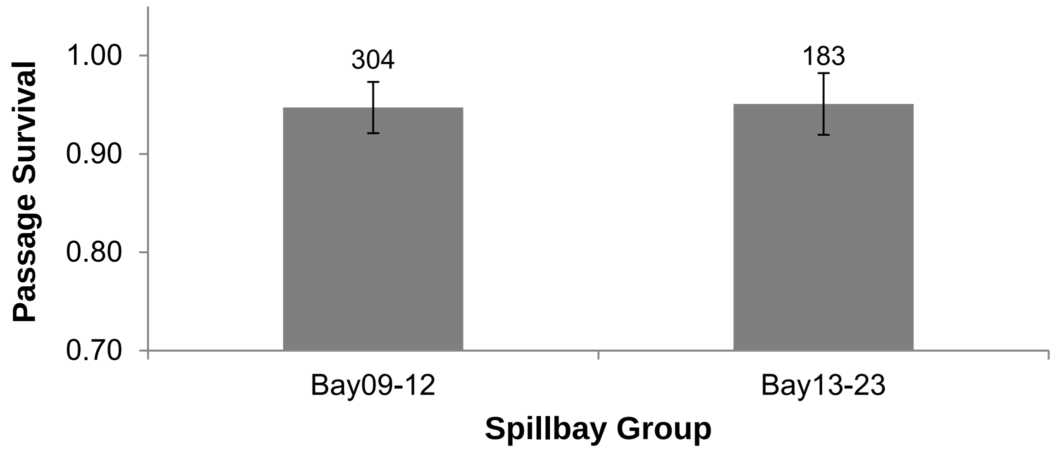

Figure 6.3. TDA Spillway Passage Survival Estimates with 95% Confidence Interval for CH1 at TDA for Spillbays 9–12 and Spillbays 13–23 for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

6.1.3 CH1 Spillway Passage Survival Rates at TDA by Discharge

The survival rates for CH1 that passed through TDA spillbays 1–8 were estimated for discharge rates combined into 10 kcfs (narrow) and 24 kcfs (wide) bins. These survival estimates were analyzed to determine if the survival rate of CH1 passing in spill is dependent upon spill discharge (Figure 6.4 and Figure 6.5; Appendix E, Table E.8 and Table E.9). For the narrow 10 kcfs spill bins, the highest proportion of CH1 passed at spill levels contained in the 100 kcfs bin (19.2%), while the lowest proportion passed when spill discharge was in the 140 kcfs bin (2.5%). The lowest survival estimate was observed for CH1 that passed in spill discharge ≤70 kcfs (0.9364, SE 0.0086) and highest survival estimate was observed for CH1 that passed when spill discharge was within the 150 kcfs bin (0.9675, SE 0.0097) (Figure 6.4, Table 6.2). None of the CH1 survival estimates were significantly different. Similarly, for spill discharge grouped into the wide 24 kcfs intervals, the lowest CH1 survival was observed for passage when spill discharge was ≤72 kcfs bin (0.9405, SE 0.0060) and the highest CH1 survival was observed for passage in spill discharge ≥168 kcfs bin (0.9645, SE 0.0059). The difference in CH1 survival for the two passage groups (≤72 kcfs and ≥168 kcfs) was significantly different (Figure 6.5, Table 6.3), based on 95% confidence intervals.

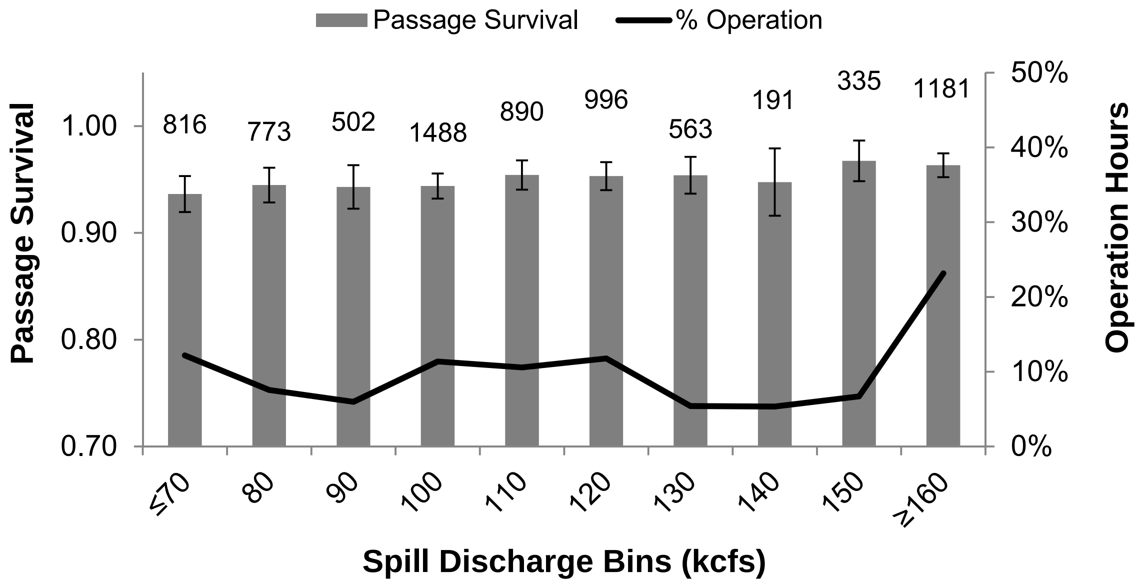

Figure 6.4. Spillway Passage Survival Estimates with 95% Confidence Interval with Percent Spillway Operation for CH1 at TDA by 10 kcfs Spill Discharge Bins for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.2. Spillway Passage Survival Estimates and Passage Proportions for CH1 at TDA by 10 kcfs Spill Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 70	0.9364	10.5
80	0.9448	10.0
90	0.9430	6.5
100	0.9439	19.2
110	0.9542	11.5
120	0.9532	12.9
130	0.9540	7.3
140	0.9476	2.5
150	0.9675	4.3
≥ 160	0.9634	15.3

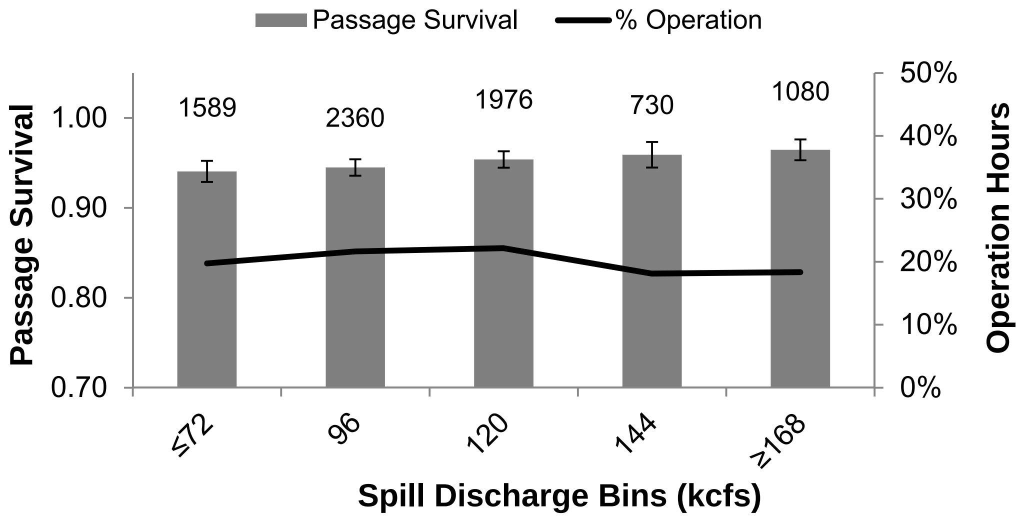

Figure 6.5. Spillway Passage Survival Estimates with 95% Confidence Interval with Percent Spillway Operation for CH1 at TDA by 24 kcfs Spill Discharge Bins for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.3. Spillway Passage Survival Estimates and Passage Proportions for CH1 at TDA by 24 kcfs Spill Discharge Intervals

Discharge (24 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 72	0.9405	20.5
96	0.9449	30.5
120	0.9538	25.6
144	0.9590	9.4
≥ 168	0.9645	14.0

6.1.4 CH1 Spillway Egress Time at TDA by Spillbay Discharge

Tailrace egress time for CH1 at TDA was evaluated by grouping spill discharge into 24 kcfs bins. CH1 median tailrace egress time was slowest at low discharge and median egress time decreased as spill discharge increased (Table 6.4, Table F.10).

Table 6.4. Tailrace Egress Time for CH1 at TDA by 24 kcfs Spill Discharge Intervals

Discharge (24 kcfs Bins)	Median Egress Time (h)
≤ 48	0.47
72	0.36
96	0.27
120	0.21
144	0.16
≥ 168	0.14

6.2 Juvenile Steelhead (STH) at TDA

6.2.1 STH Spillway Passage Survival Rates at TDA by Spillbay

STH spillway passage survival estimates at TDA through spillbays at the northwest end of the spillway, inside of the new spill wall (spillbays 1–8), are shown in Figure 6.6 (Appendix E, Table E.2 and Table E.4). STH that passed through Spillbay 4 had the highest survival estimate (0.9790, SE 0.0052) and lowest survival was observed for STH that passed through spillbay 7 (0.9565, SE 0.0062). STH survival rates were not significantly different between any of the spillbays, based on the 95% confidence intervals. Between 2010 and 2012, spillbay 8 passed the highest number of STH and passage numbers decreased from spillbay 8 to spillbay 1 (Table 6.5).

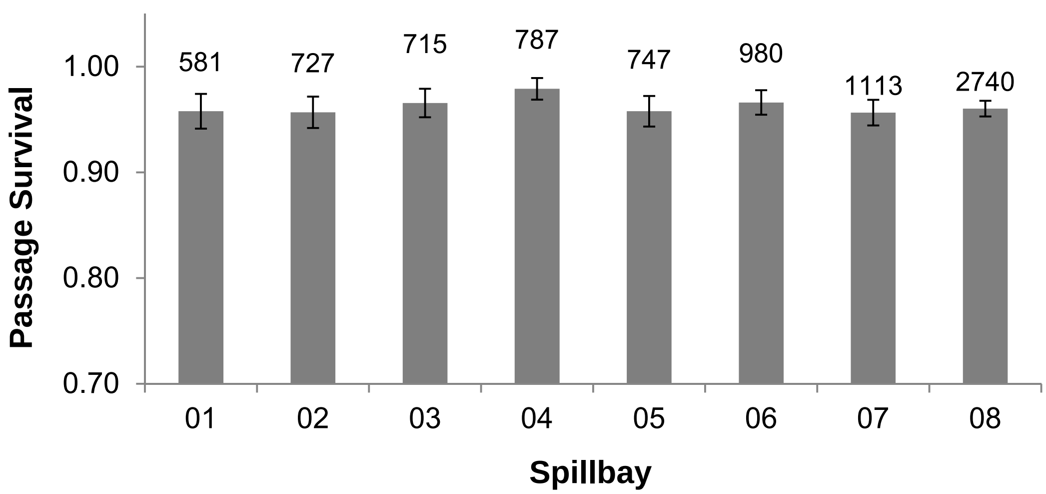

Figure 6.6. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at TDA by Spillbay for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.5. Survival Estimates and Passage Proportions for STH at TDA by Spillbay within the Spill Wall

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9578	6.9
2	0.9568	8.7
3	0.9656	8.5
4	0.9790	9.4
5	0.9578	8.9
6	0.9661	11.7
7	0.9565	13.3
8	0.9603	32.6

6.2.2 STH Spillway Passage Survival Rates at TDA by Spillbay Group

The survival rates were estimated for STH that passed through spillbays 1–8 and 9–23 at TDA. Spillbays 1–8 are northwest of the spill wall and spillbays 9–23 are southeast of the spill wall. Spill only occurred through spillbays southeast of the spill wall when river discharge exceeded the capacity of the powerhouse and spillbays 1–8. The survival estimate for STH passing southeast of the spill wall (0.9802, SE 0.0056) was higher, but not significantly different than that of STH passing through spillbays 1–8 (0.9683, SE 0.0022) (Figure 6.7, Appendix E, Table E.5), based on the 95% confidence intervals. Because spillbays 9–23 were only open when river flow was very high, 90.8% of the STH passed through spillbays 1–8. Survival estimates of STH passing through spillbays 9–12 compared to that of STH that passed through spillbays 13–23, which are closer to the predator-inhabited islands near the southeast end of the of the spillway, were not significantly different (0.9813, SE 0.0069 and 0.9784, SE 0.0096, respectively) (Figure 6.8, Appendix E, Table E.6).

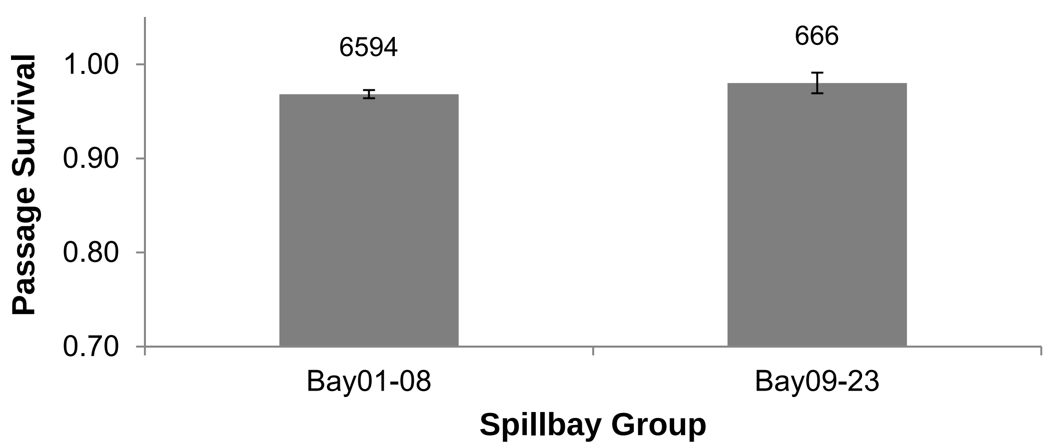

Figure 6.7. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at TDA by Spillbay Groups, Spillbays 1–8 and Spillbay 9–23 for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

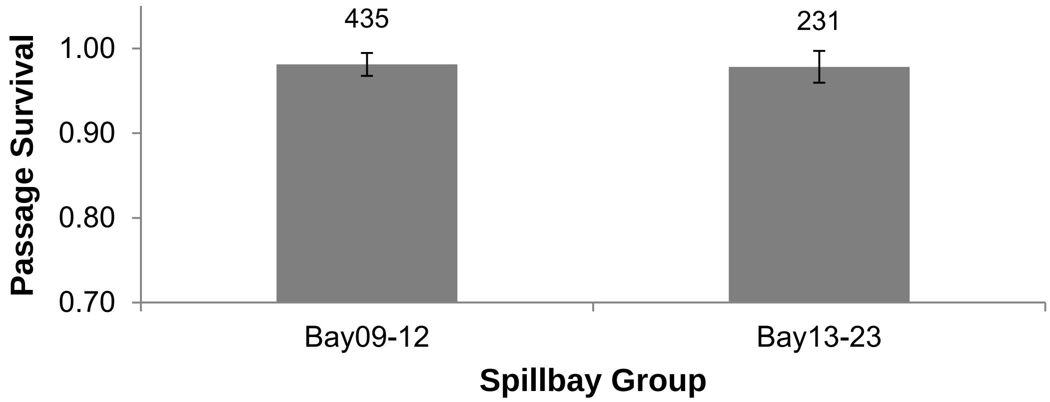

Figure 6.8. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at TDA for Spillbay Groups 9–12 and 13–23 for Combined Years (2011 and 2012). Sample sizes are shown above the bars.

6.2.3 STH Spillway Passage Survival Rates at TDA by Discharge

Survival rates were estimated for STH that passed through TDA spillbays 1–8 for discharge rates combined into narrow (10 kcfs) and wide (24 kcfs) bins. These estimates were analyzed to determine if the survival rates of STH passing in spill is dependent upon spill discharge level (Figure 6.9 and Figure 6.10; Appendix E, Table E.8 and Table E.9). For the narrow 10 kcfs spill discharge bins, the highest proportion of STH passed at bins between 100 and 120 kcfs and ≥160 kcfs; the least number of fish passed the 140 kcfs bin (2.67%). As expected, the hours of spill were higher in these bins (i.e., 100–120 kcfs), with the ≥160 kcfs bins having the greatest percentage of operating hours. The lowest STH survival estimate was observed for passage in spill discharges within the 90 kcfs bin (0.9349, SE 0.0110) and highest survival estimate was observed for discharges within the 150 kcfs bin (0.9839, SE 0.0060) (Figure 6.9, Table 6.6). STH survival estimates were significantly higher at spill levels of 150 kcfs and higher than those for STH that passed in spill at discharges of 130 kcfs or less, based on the 95% confidence intervals. Similarly, for the wide 24 kcfs bin intervals, lowest STH survival estimate was observed for passage in the ≤72 kcfs bin (0.9521, SE 0.0058) and highest survival estimate was observed for passage in the 144 kcfs bin (0.9803, SE 0.0046) (Figure 6.10, Table 6.7). The survival rate of STH passing in spill with discharge within the upper two bins were significantly higher than that of STH passing the spill with discharge within the range of the lowest three bins.

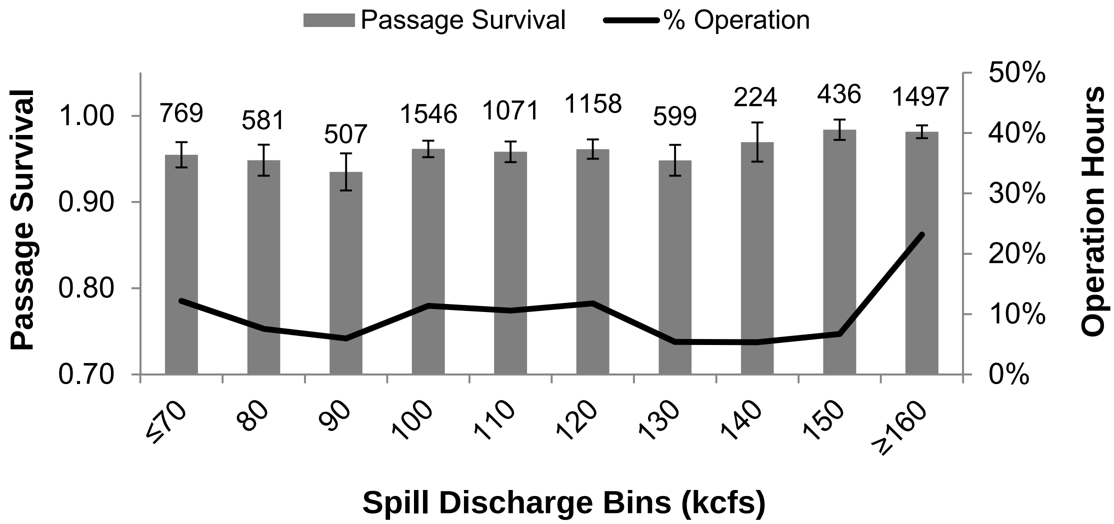

Figure 6.9. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at TDA by 10 kcfs Spill Discharge Bins Including Percent Spillway Operation for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.6. Spillway Passage Survival Estimates and Passage Proportions for STH at TDA by 10 kcfs Spill Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 70	0.9548	9.2
80	0.9485	6.9
90	0.9349	6.1
100	0.9616	18.4
110	0.9583	12.7
120	0.9614	13.8
130	0.9484	7.1
140	0.9695	2.7
150	0.9839	5.2
≥ 160	0.9815	17.9

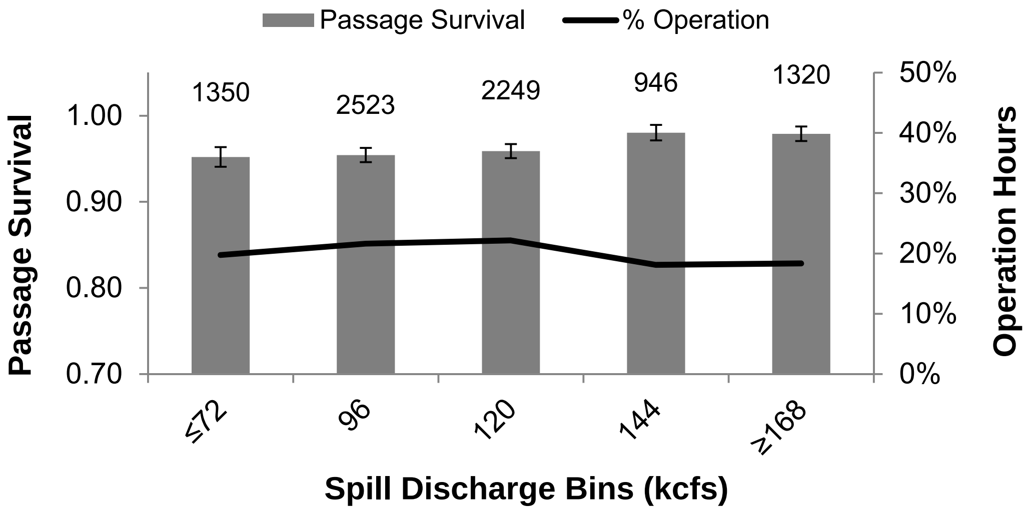

Figure 6.10. Spillway Passage Survival Estimates with 95% Confidence Interval for STH at TDA by 24 kcfs Spill Discharge Bins Including Percent Spillway Operation for Combined Years (2010, 2011, and 2012). Sample sizes are shown above the bars.

Table 6.7. Spillway Passage Survival Estimates and Passage Proportions for STH at TDA by 24 kcfs Spill Discharge Intervals

Discharge (24 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 72	0.9521	16.1
96	0.9543	30.1
120	0.9589	26.8
144	0.9803	11.3
≥ 168	0.9790	15.7

6.2.4 STH Spillway Egress time at TDA by Spillbay Discharge

Tailrace egress time for STH at TDA was analyzed by grouping spill discharge into 24 kcfs bins. Median tailrace egress time was slowest at low discharge, decreasing as spill discharge increased (Table 6.8, Table F.11).

Table 6.8. Tailrace Egress Time for STH at TDA by 24 kcfs Spill Discharge Intervals

Discharge (24 kcfs Bins)	Median Egress Time (h)
≤ 48	0.42
72	0.33
96	0.25
120	0.20
144	0.15
≥ 168	0.14

6.3 Subyearling Chinook Salmon (CH0) at TDA

6.3.1 CH0 Spillway Passage Survival Rates at TDA by Spillbay

The estimated survival rates of CH0 at TDA that passed through spillbays at the northwest end of the spillway, inside of the new spill wall (spillbays 1–8), are shown in Figure 6.11 (Appendix E, Table E.1 and Table E.4). For the 2010 and 2012 combined years, spillbays 2, 3, and 4 had the highest CH0 survival rate (0.9519, SE 0.0084; 0.9520, SE 0.0079; and 0.9516, SE 0.0078, respectively) and CH0 that passed through spillbay 1 had the lowest survival rate (0.9352, SE 0.0123). There were no significant differences in CH0 survival rates between spillbays, based on the 95% confidence intervals. For 2010 and 2012 combined, spillbay 8 passed the largest number of CH0, and numbers consistently decreased from spillbay 8 to spillbay 1 (Table 6.9).

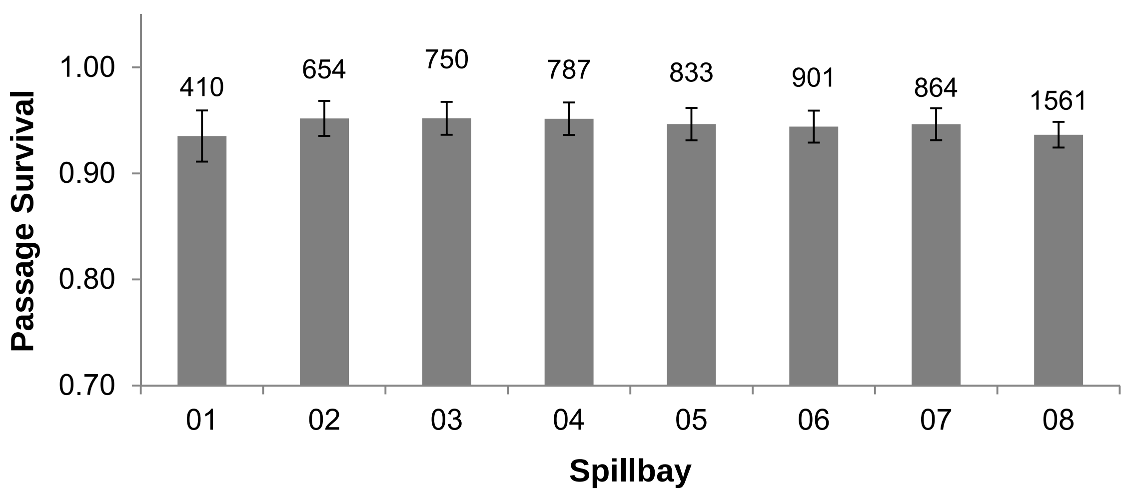

Figure 6.11. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at TDA by Spillbay for Combined Years (2010 and 2012). Sample sizes are shown above the bars.

Table 6.9. Spillway Passage Survival Estimates and Passage Proportions for CH0 at TDA by Spillbay within the Spill Wall

Spillbay	Survival Estimate	Passage Proportion (%)
1	0.9352	6.1
2	0.9519	9.7
3	0.9520	11.1
4	0.9516	11.6
5	0.9465	12.3
6	0.9441	13.3
7	0.9464	12.8
8	0.9365	23.1

6.3.2 CH0 Spillway Passage Survival Rates at TDA by Spillbay Grouping

The survival rates were estimated for CH0 that passed through spillbays 1–8 and 9–23 at TDA. Spillbays 1–8 are northwest of the spill wall and spillbays 9–23 southeast of the spill wall. Spill only occurred through spillbays southeast of the spill wall when river discharge exceeded the capacity of the powerhouse and spillbays 1–8. The survival rates of CH0 were not significantly different between spillbays 1–8 (0.9549, SE 0.0029) and spillbays 9–23 (0.9650, SE 0.0156) (Figure 6.12, Appendix E, Table E.5), based on the 95% confidence intervals.

Because spillbays 9–23 were only open during periods of high flow, 97.3% of the CH0 detected passing in spill passed through spillbays 1–8. The survival rate of CH0 that passed through spillbays 9–12 was not significantly different from that of those that passed through spillbays 13–23 (0.9453, SE 0.0270 and 0.9855, SE 0.0144, respectively), even though spillbays 13–23 are closer to the predator-inhabited islands near the southeast end of the spillway (Figure 6.3; Appendix E, Table E.6). However, the rate of survival of CH0 that passed toward the southeast end of the spillway during high flows was about 0.04 higher than for CH0 that passed through spillbays closer to the spill wall.

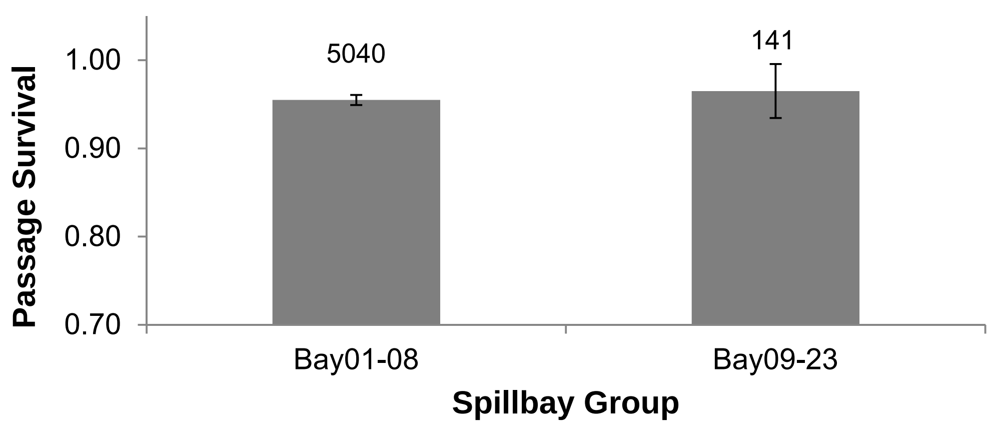

Figure 6.12. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at TDA by Spillbay Groups 1–8 and 9–23 for 2012. Sample sizes are shown above the bars.

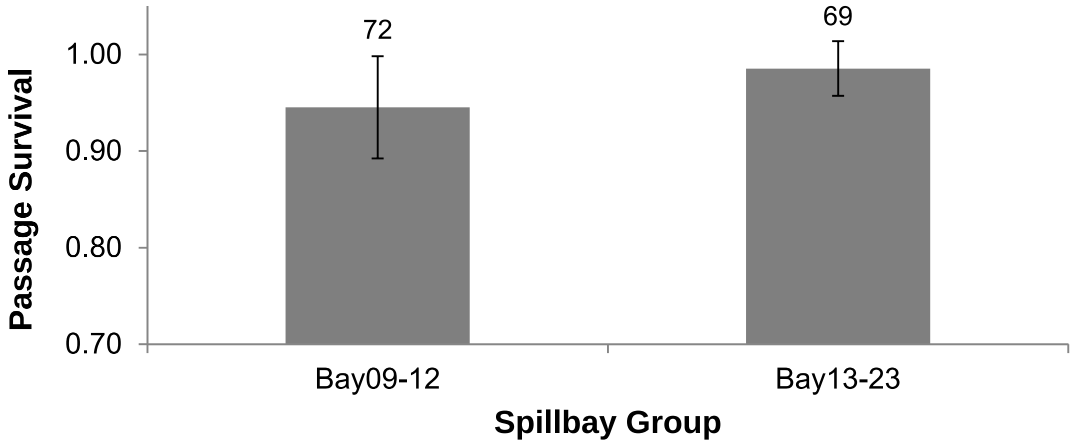

Figure 6.13. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at TDA by Spillbay Groups 9–12 and 13–23 for 2012. Sample sizes are shown above the bars.

6.3.3 CH0 Spillway Passage Survival Rates at TDA by Discharge

Survival rates for CH0 that passed through TDA spillbays 1–8 were estimated for discharge rates combined into narrow (10 kcfs) and wide (24 kcfs) bins. These estimates of survival rate were analyzed to determine if the survival estimate of CH0 passing in spill is dependent upon spill discharge level (Figure 6.14 and Figure 6.15; Appendix E, Table E.8 and Table E.9). For the narrow 10 kcfs spill intervals, the highest proportion of CH0 passed the spillway in discharge within the 130 kcfs bin (36.0%). The lowest survival estimate was observed for CH0 that passed in spill discharge ≤70 kcfs (0.8305, SE0.0225) and the highest survival estimate was observed for CH0 that passed at discharge within the 140 kcfs spill discharge bin (0.9704, SE 0.0072) (Table 6.10). There was a discernable trend of increased CH0 survival with increasing discharge, especially for passage in discharges less than about 90 kcfs (Figure 6.16). When spillway discharge was ≤70 kcfs, CH0 survival rate was significantly lower than when spillway discharge was ≥90 kcfs, and survival rates for CH0 passing in discharges within the 80 kcfs spill bin were significantly lower than the survival rates in discharge bins ≥110 kcfs, based on the 95% confidence intervals. Similarly, for the wide 24 kcfs bin intervals, lowest CH0 survival estimate was observed at discharges ≤72 kcfs (0.8673, SE 0.0134), and highest survival estimate was observed in the 144 kcfs bin (0.9699, SE 0.0057). The CH0 survival estimate for passage at discharge levels ≤72 kcfs was significantly lower than that for passage at discharges within all other 24 kcfs discharge bins (Table 6.11).

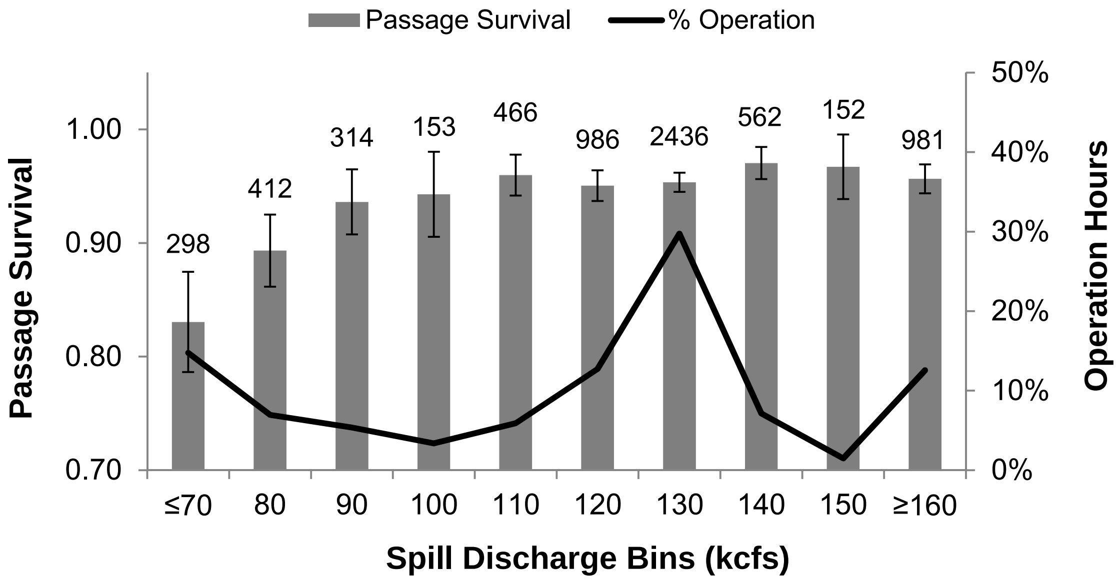

Figure 6.14. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at TDA by 10 kcfs Spill Discharge Bins Including Percent Spillway Operation for Combined Years (2010 and 2012). Sample sizes are shown above the bars.

Table 6.10. Spillway Passage Survival Estimates and Passage Proportions for CH0 at TDA by 10 kcfs Spill Discharge Intervals

Discharge (10 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 70	0.8305	4.4
80	0.8933	6.1
90	0.9362	4.6
100	0.9429	2.3
110	0.9598	6.9
120	0.9505	14.6
130	0.9535	36.0
140	0.9704	8.3
150	0.9671	2.3
≥ 160	0.9565	14.5

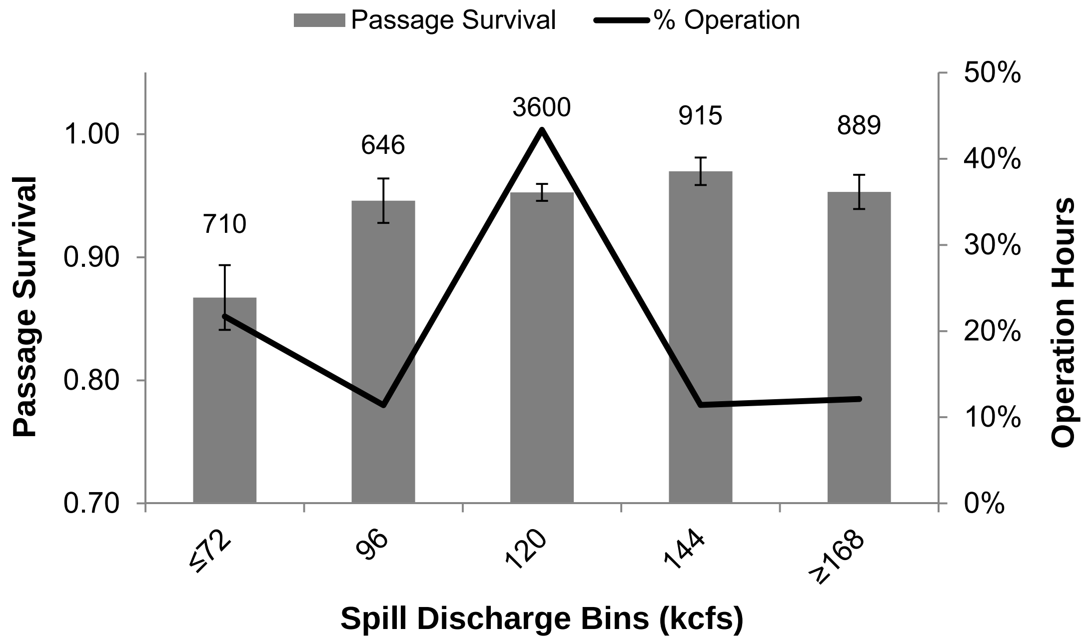

Figure 6.15. Spillway Passage Survival Estimates with 95% Confidence Interval for CH0 at TDA by 24 kcfs Spill Discharge Bins Including Percent Spillway Operation for Combined Years (2010 and 2012). Sample sizes are shown above the bars.

Table 6.11. Spillway Passage Survival Estimates and Passage Proportions for CH0 at TDA by 24 kcfs Spill Discharge Intervals

Discharge (24 kcfs Bins)	Survival Estimate	Passage Proportion (%)
≤ 72	0.8673	10.5
96	0.9460	9.6
120	0.9527	53.2
144	0.9699	13.5
≥ 168	0.9531	13.2

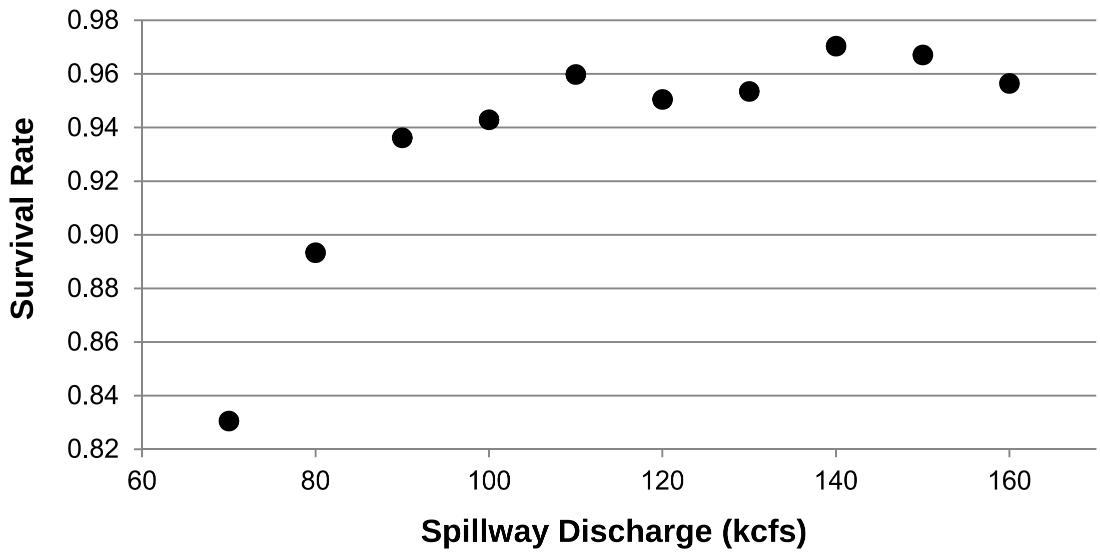

Figure 6.16. Spillway Passage Survival Rate for CH0 at TDA by Spillway Discharge at Spillbays 1–8

6.3.4 CH0 Spillway Egress Time at TDA by Spillbay Discharge

CH0 tailrace egress time at TDA was analyzed by grouping spill discharge into 24 kcfs bins. Median tailrace egress time was highest at low discharge and decreased as spill discharge increased (Table 6.12, Appendix F; Table F.12).

Table 6.12. Tailrace Egress Time for CH0 at TDA by Spill Volume in 24 kcfs Intervals

Discharge (24 kcfs Bins)	Median Egress Time (h)
≤ 48	0.42
72	0.35
96	0.30
120	0.22
144	0.19
168	0.17
216	0.24
240	0.23
≥ 312	0.16

7.0 Discussion

7.1 Bonneville Dam Powerhouse 1

Physical and numeric turbine model studies have indicated that, in general, for most large Kaplan turbines, operation of turbine units at an open geometry configuration improves hydraulic conditions in the turbine environment, better aligns wicket gates with stay vanes, and maximizes the open space between runner blades and water velocity through the runner. These results have led to the hypothesis that the operating point for B1 turbines most likely to optimize juvenile salmonid turbine passage survival is above the upper limit of the 1% of peak efficiency operating range.

Analysis of the rates of survival of CH1, STH, and CH0 passing through B1 turbines was conducted by dividing turbine discharge within the 1% of peak efficiency discharge range into 4 equal groups, quartiles Q1, Q2, Q3, and Q4. A significant difference in survival rates was detected for CH1 for which the survival rate was better in the lower half of the 1% of peak efficiency operating range curve (Q1 and Q2) than in the upper quarter (Q4), though the single-release survival estimate for Q4 was 0.9534. The rate of survival for STH was also significantly higher in the lower quarter of the operating range (Q1) than the upper half of the operating range (Q3 and Q4). The survival rate of STH in the Q4 operating range was higher than in Q2 and Q3, though this difference was not significant. There was not a significant difference in survival rates between discharge quartiles for CH0, though the survival estimates were higher in the upper half of the operating range (Q3 and Q4) than the lower half (Q1 and Q2). Few fish passed in the lower half of the operating range, resulting in large confidence intervals.

Two B1 turbine operating ranges above the upper level of the 1% of peak efficiency range were included in analysis of the effect of discharge on juvenile salmonid passage survival. These were the best operating range (BOR), which included discharges between the upper bound of the 1% of peak efficiency and the best operating point (BOP), and above best operating point (ABOP) discharge range. ABOP extended from BOP to the turbine generator limit. There was not a significant difference in the survival rates of CH1, STH, or CH0 when turbines were operated at BOR or ABOP compared to survival rates within any of the discharge quartiles (Q1–Q4) within the 1% of peak efficiency operating range.

The effect of turbine discharge on turbine passage survival was investigated by grouping discharges into four ranges and comparing the survival estimates for CH1, STH, and CH0. The four ranges were discharges within 1% of peak efficiency (LL–UL), from the lower limit of the 1% of peak efficiency range to best operating point (LL–BOP), the BOR, and ABOP. No significant differences in survival rates were detected between survival estimates for CH1 and STH for any of these turbine discharge groups. Also, no significant differences were detected for CH0 between the LL–UL and LL–BOP groups. B1 turbines were not operated above BOP in summer, so no survival estimates were available for ABOP discharge ranges for CH0.

The analysis results of the effect of turbine discharge on the survival rates of juvenile salmonids passing through B1 turbines suggest that there is not a significant turbine operation effect on fish survival. Balloon tag studies of juvenile salmonid passage through turbines that introduced test fish into B1 turbines at the wicket gates found that turbine operation (discharge) did not affect survival rates, but that the survival rates for juvenile salmonids did depend upon the route they took through the turbine; those passing near the ends of turbine blade had the lowest survival rates and those passing near the runner hub had the highest (Normandeau Inc. and Skalski 2000).

At B1, tailwater elevation is directly affected by turbine discharge; higher powerhouse discharge results in higher tailwater elevation, because the B1 powerhouse has a dedicated tailrace channel that is a little wider than that of the B1 powerhouse. Juvenile salmonids passing B1 turbines were assigned to one of five tailwater elevation groups (referenced to MSL) that contained the tailwater elevation at the time they passed into the powerhouse tailrace. These bins were 5 m (<5.5 m), 6 m (5.5 m to <6.5 m), 7 m (6.5 m to <7.5 m), 8 m (7.5 m to <8.5 m), and 9 m (≥8.5 m). Migrant STH and CH0 passing in turbine discharge into <5 m tailwater elevations appeared to have lower survival rates than those at higher tailwater elevations, though not significantly different. Survival rates for CH1 at the 5 m tailwater elevation level were not significantly different than at other tailwater elevations. Comparison of the differences in survival rates between the 5 m bin and other tailwater elevation groups was affected by the low sample size and resulting wide confidence limit for the lowest tailwater group. The small sample size for the less than or equal to 5 m bin resulted from B2 being designated as the priority powerhouse for operation during lower river flow periods, which typically occur during the summer when CH0 are out-migrating.

While not significantly different given the sample sizes available for analysis, it appears that the survival rates of STH and CH0 might be lower at low tailwater levels. This finding would be consistent with early tagging studies that found a trend of lower juvenile salmonid survival rates through the B2 tailrace at lower tailwater levels (Ledgerwood et al. 1991).

Median B1 tailrace egress time decreased with increased turbine discharge for CH0, CH1, and STH, though none of these trends was significant due to wide confidence intervals. Median tailrace egress times were quite consistent, ranging from 0.46 h at Q1 to 0.30 h at ABOP for CH1, 0.63 h at Q3 to 0.42 h at ABOP for STH, and 0.46 h at Q1 to 0.39 h at Q3 for CH0. Median B1 tailrace egress times were quite consistent across all discharges considered, suggesting good overall fish egress out of the tailrace.

7.2 Bonneville Dam Powerhouse 2

Because of increased injury and mortality of juvenile salmonids in gatewells at higher turbine discharge levels, B2 turbines have been operated in the lower half of the 1% of peak efficiency operating range whenever possible to reduce injury to juvenile salmonids diverted into the gatewells. This turbine operation strategy results in reduced hydraulic capacity at B2. In addition, there is concern that while operating turbines at lower discharge may be better for guided fish, low turbine discharge may negatively affect survival of juvenile salmonids in the draft tubes because of exposure to low flow quality resulting from high turbulence and other conditions.

Analysis of the effect of discharge on juvenile salmonid survival used the same turbine discharge groups described above for B1. There were no significant differences detected in survival rates for CH1, STH, and CH0 between quartile discharge groups within 1% of peak efficiency. Neither were significant differences in survival rates detected for any juvenile salmonid group between the lower and upper halves of the 1% of peak efficiency discharge range.

In 2008 and 2011, the STSs at B2 were removed for a short time in spring due to high flows and high levels of debris in the river. In 2008, there appeared to be a difference in survival rates, with higher estimated survival rates for CH1 with screens in and higher survival rates for STH without the screens; however, the observed differences in survival estimates were not significantly different due to small sample sizes. In 2011, survival rates were similar with or without the STSs in turbines for CH1, but followed a similar trend to 2008 for STH, where survival rates were higher when the STSs were removed, though again not significantly different due to the small sample size.

Results of the analysis did not show a significant difference in survival rates for unguided CH1, STH, or CH0 between the lower and upper half of the operating range at B2. There was also no significant difference found between any of the four range bins (Q1–Q4). This suggests that the B2 turbines can be operated throughout their entire range of operation without changing survival rates through the turbines. This will allow managers to focus on fine-tuning turbine operations to optimize the survival rate of guided fish in the gatewell with less concern about the survival rate of turbine-passed fish.

The rate of survival of STH and CH0 was significantly lower when the tailwater elevation for fish passing at B2 was less than 5 m. The survival rate was also lower for CH1 when the tailwater elevation was less than 5 m, but this difference was not significantly different from that for other tailwater elevation groups.

Tailrace egress times for CH1 through the B2 tailrace showed some dependence on discharge, with a trend of decreasing median egress time from 0.65 h at Q1 to 0.55 h at Q4. STH migrants did not show a relationship between turbine discharge and tailrace egress with the median time of egress; all discharge quadrants were very near 0.70 h. CH0 migrants, like CH1 migrants, showed a trend of decreasing median egress time with increasing turbine discharge, with a median egress time of 0.73 h at Q1, decreasing to 0.64 h at Q4. No significant difference in median tailrace egress was detected for any juvenile salmonid run.

7.3 Bonneville Dam Spillway

BiOp and other studies over the last several years have indicated that the rate of survival through the BON spillway is lower than other dam passage routes. There is concern that erosion of the stilling basin and ogees of several spillbays and movement and accumulation of rock within the stilling basin may be contributing to lower survival rates.

The survival rates of CH1, STH, and CH0 migrants passing in spill at BON was investigated by examining fish survival rates through individual spillbays, groups of spillbays, and by discharge using data from BiOp studies conducted at BON in 2008 and 2010 through 2012.

No significant differences in spill passage survival rates between individual spillbays were detected for CH1, STH, and CH0. All juvenile salmonid groups showed a general trend for larger numbers of fish passing through spillbays at the ends of the spillway than through spillbays in the middle of the spillway.

BON spillbays were divided into five groups for further analysis of potential relationships between spillbay of passage and passage survival. Two of the groups, spillbays 1–3 and 16–18 are equipped with deep-flow deflectors. The three remaining groups all contain spillbays equipped with shallow-flow deflectors. Spillbays 8–12 are suspected of having structural damage and rock present in their stilling basins and spillbays 4–7 and 13–15 bracket spillbays 8–12. No significant differences were detected for any juvenile salmonid group for any of the spillbay groups. Spillbay group 8–12 did not show any significant difference in survival rate with other groups or any trends that differentiated it from other groups. The analysis did not produce any results to support the contention that spillbay erosion and/or rocks in the stilling basin were differentially affecting juvenile salmonid survival. In addition, there were no significant differences in spillbay group survival rates that would support the conclusion that passage survival over deep or shallow deflectors was different.

The effect of spillbay discharge level on juvenile salmonid survival rates was investigated by dividing detected fish into both narrow (10 kcfs) and wide (20 kcfs) discharge bins. This resulted in 21 narrow spillbay discharge bins and 11 wide discharge bins in spring for CH1 and STH, and 15 narrow spillbay discharge bins and 8 wide discharge bins in summer for CH0. During the spring study period the majority of juvenile salmonids passed when spill discharge was in the 100 kcfs bin, which corresponded to the preferred spillbay discharge level specified in the FPP for each study year and consequently, the discharge with the most operating hours. In summer, more juvenile salmonids passed when spill discharge was in the narrow 90 kcfs bin, followed by the narrow 100 kcfs bin. In general, survival rates by discharge group varied without distinct pattern for CH1 and STH across discharge groups, with the exception of a definite decrease in survival rates for both groups at the highest discharge. In contrast, CH0 showed a definite increase in survival rate with increasing spillbay discharge through the highest discharges that occurred. The survival rate for CH1 was significantly different for discharges ≥290 kcfs than most other spillbay discharge bins. Also, for CH1 a significant difference in survival rates between the 100 and 240 kcfs wide bins was detected, but is believed to be sample size related because neither group has the highest or lowest survival rate estimate. As for STH, spill passage survival was significantly lower for the narrow ≥290 kcfs bin and the wide ≥280 kcfs bin than those for other discharge groups.

Spill discharge rates above about 230 kcfs did not occur in the summer at BON. However, there was a distinct trend of increasing passage survival rates with increasing discharge with a high correlation coefficient. There was a significant difference in survival rate estimates for CH0 at many of the discharge levels in the narrow (10 kcfs) bins for discharge rates of 130 kcfs and lower compared to discharge rates of 140 kcfs and above. Survival rate estimates for CH0 passing in the 90 and 100 kcfs spill discharge bins were significantly lower than those of CH0 passing in bins 140 kcfs or greater. The survival rate of CH0 passing at the 110 kcfs spill level was significantly lower than that of CH0 passing at the 150, 190, and 210 kcfs spill levels. The passage survival rate was significantly lower for the 120 kcfs bin than for CH0 passing in the 140, 150, 190, and 210 kcfs bins, and the 130 kcfs bin survival rate was significantly lower than that of CH0 passing at 150 and 190 kcfs spill levels. There was not a significant difference in survival between any of the discharge bins 140 kcfs or above.

For the wide (20 kcfs) discharge bins, there was also a significant difference in survival rate between the lower three discharge bins and many of the bins of 140 kcfs and greater. The survival rate of CH0 for the 20 kcfs bins was significantly lower for CH0 passing in the ≤80 kcfs bin than for CH0 passing in discharge bins 120 kcfs or greater. For CH0 passing in the 100 kcfs bin, the survival rate was significantly lower than that of CH0 passing in 140 kcfs bins or greater. Survival of CH0 passing at 120 kcfs was significantly lower than that of CH0 passing in either the 140 or 180 kcfs discharge bins.

There were no trends in survival rates for CH1 or STH with increased spillway tailwater elevation. However, the rate of survival was significantly lower for CH0 passing in spill when tailwater elevations were <6.5 m. Following the CH0 trend of increasing survival rate with increasing spillbay discharge, a trend in increased spill passage survival rate with increased tailwater elevation was observed for CH0.

The rate of survival was significantly lower for CH0 passing in 5 m and 6 m tailwater elevation bins than for those passing in 7 m, 8 m, and 9 m bins. The survival rate of CH0 passing in the 7 m bin was also significantly lower than that of CH0 passing in the 8 m bin.

Median tailrace egress time decreased with increasing discharge rate for all three juvenile salmonid runs. Median egress times for narrow (10 kcfs) 70 and 300 kcfs spill bins was 0.53 h and 0.28 h, respectively, for CH1 and 0.47 h and 0.33 h, respectively, for STH. The shortest tailrace egress time was observed for CH0 passing in discharges within the narrow 230 kcfs bin and the median egress times decreased from 0.54 h for the 80 kcfs discharge group to 0.25 h for the 230 kcfs discharge group. Similar trends in median egress times were observed for the wide (20 kcfs) bins.

7.4 The Dalles Dam Spillway

High river flows in recent years have forced spill at TDA using spillbays outside (southeast) of a new extended spill wall built between spillbays 8 and 9. Spill from bays outside the new spill wall may carry juvenile salmonids into areas along the southern shore of the river immediately below the dam that has been shown to be habitat for large populations of predators. There is concern that juvenile salmonids that pass the dam in spill from gates outside the spill wall will have lower survival rates than fish passing through bays within the spill wall.

Survival rates for juvenile salmonids passing through individual spillbays within the spill wall (spillbay 1–8) were examined to determine if survival rates were different through any of the bays. No significant difference in survival performance through any spillbay within the spill wall was detected for STH or CH0. There was a significant difference in survival for CH1 with lower survival rates through spillbay 2 than spillbay 3. CH1 passing through spillbay 2 had the lowest or second lowest survival rates during all 3 study years. In addition, for all three runs the largest number of fish passed through spillbays near the wall (spillbays 7 and 8), decreasing across the group of bays and reaching a minimum at spillbay 1.

The survival rates for juvenile salmonids passing through spillbay groups 1–8, 9–23, 9–12, and 13–23 were estimated. Because spill outside of the spill wall was infrequent in the years included in this analysis, 92.5%, 90.8%, and 97.3% of detected CH1, STH, and CH0, respectively, passed through spillbays 1–8 inside of the new spill wall. No significant differences in the survival rates between passage through spillbays inside (spillbays 1–8) and those outside (spillbays 9–23) the spill wall were found for CH1, STH, or CH0. Also, no significant differences were detected for CH1, STH, or CH0 that passed through spillbays outside but nearer the spill wall (spillbays 9–12) and those that passed outside the spill wall and nearer predator habitat (spillbays 13–23).

The analysis did not find any evidence that juvenile salmonids passed in spill outside of the new spill wall during high river discharge events survived at a lower rate than those that passed through spillbays inside of the spill wall. Predation has been shown to be higher for juvenile salmonid migrants that move through the islands near the Oregon shore in the tailrace downstream of the spillway during normal river flow conditions (Martinelli and Shively 1998; Duran et al. 2003). Our results indicate that during high river flows, the south shore island area may be much less favorable habitat for predators. During high river flow conditions in 2011 and 2012, the south shore islands near the Oregon shore were underwater and flow seemed quite high in that area which may have reduced its suitability for predators.

Similar to analysis of the effect of discharge rate on juvenile salmonid survival conducted for the BON spillway, juvenile salmonids passing in spill at TDA were assigned to spillway discharge groups that contained the discharge rate that was occurring at the time of their passage. Two discharge group sizes were used, narrow (10 kcfs) and wide (24 kcfs). Analysis was limited to those fish that passed through spillbays 1–8 inside the spill wall. For the narrow-width bins there were no significant differences in spill passage survival rates between discharge groups for CH1, and the passage survival rate for STH was significantly higher for the 150 kcfs and 160 kcfs bins than that for all bins ≤130 kcfs. Spill passage survival rates for CH0 were significantly lower for the ≤70 kcfs bin compared to all discharge bins ≥90 kcfs. Survival rates of CH0 in the 80 kcfs bin was significantly lower than CH0 passing in flows of 110 kcfs or greater. A similar trend was noticed in spill passage survival estimates for CH0 within wide discharge groups, where the survival rate for the wide ≤72 kcfs group was significantly lower than that for any other of the wide discharge groups. Spill passage survival rates for CH1 within wide (24 kcfs) discharge groups were significantly different for ≤72 kcfs and ≥68 kcfs discharge bins. A significant difference was detected in spill passage survival for STH between the high survival rates for the wide 144 kcfs and ≥168 kcfs bins and the lower survival rates observed for ≤72 kcfs, 96 kcfs, and 120 kcfs bins.

CH0 that passed through spillbays within the spill wall experienced significantly lower survival rates passing in low discharge rate spill than in high discharge rate spill. These results indicate that spill discharge less than 90 kcfs should be avoided in the summer when CH0 are out-migrating.

The spillway median egress time for all juvenile salmonid runs, CH1, STH, and CH0 decreased with increasing spillbay discharge and were very similar for all runs. Median egress times for the wide (24 kcfs) spillbay discharge groups ≤48 kcfs and ≥168 kcfs were 0.47 h and 0.14 h, respectively, for CH1 and 0.42 h and 0.14 h, respectively for STH. The median egress times for wide discharge groups ≤48 kcfs and ≥312 kcfs were 0.42 h and 0.16 h, respectively, for CH0.

8.0 Conclusions and Recommendations

Based on the data available for this metadata analysis we make the following conclusions:

8.1 Bonneville Dam Powerhouse 1

- There is not a significant difference in survival rate between operating within the 1% of peak efficiency operating range, above the upper limit of 1% of peak efficiency operating range to the best operating point, or from the best operating point to the generator limit for CH1, STH, or CH0.
- Tailrace egress time is good across the range of turbine operating conditions and deceases with increase in discharge level.
- Estimated survival rates across the range of tailwater elevations are not significantly different. However, there is a trend toward lower survival rate at tailwater elevations less than 5 m. This trend is not significantly different due large confidence intervals because of the small samples sizes.

8.2 Bonneville Dam Powerhouse 2

- There is not a significant difference in the survival rate of CH1, STH, or CH0 passing through the turbines at B2 across the turbine operating range.
- The survival rate of STH and CH0 is lower for fish passing in the 5 m tailrace elevation bin.
- Tailrace egress time is good across the range of turbine operating conditions and deceases with increase in discharge level, except for STH where egress time changed little between discharge levels.
- The passage survival rate of STH was higher in both 2008 and 2011 with the STSs removed, though there was not a significant different due to the small sample size and large error bars.
- The survival rate of CH1 in 2008 was higher with STSs installed and survival was similar in 2011 with STSs installed or removed, though the sample sizes were too small to make a statistical comparison.

8.3 Bonneville Spillway

- There was not a significant difference in the rate of survival for CH1, STH, or CH0 passing through spillbays where there was damage to the spillbays or the potential of rock deposition in the stilling basin compared to spillbays without such conditions.
- The survival rate for CH1, STH, and CH0 passing through spillbays 1–3 was lower, though not significantly different.
- The rate of survival was lower for CH1 and STH passage at spillway discharges greater than 290 kcfs.
- The rate of survival was lower for CH0 passage at spillway discharges ≤100 kcfs.
- The rate of survival was lower for CH0 when the tailrace elevation was <6.5 m.

- Tailrace egress time for CH1, STH, and CH0 generally decreased with increasing spillway discharge.

8.4 The Dalles Dam Spillway

- There were no significant differences in rate of survival for CH0, CH1, or STH that passed through TDA spillway at spillbays 1–8 within the new spill wall compared to survival rates for those passing through spillbays outside of the spill wall at spillbays 9–23 during high river flows.
- The rate of survival of CH1 in the wide bin grouping was significantly lower when spill discharge was ≤72 kcfs than at high discharge levels.
- The rate of survival of STH is significantly higher at spill levels at 150 kcfs or higher than spill levels 130 kcfs or lower.
- The rate of survival of CH0 declines with reduced discharge and declines rapidly below 80 kcfs.

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Appendix A

Bonneville Dam Powerhouse 1 and Powerhouse 2 Operating Condition Ranges

Appendix A

Bonneville Dam Powerhouse 1 and Powerhouse 2 Operating Condition Ranges

As detailed in the Section 2.0 Methods, operation levels for B1 were divided into six treatments (Q1, Q2, Q3, Q4, BOR, and ABOP) and B2 was divided into four treatments (Q1, Q2, Q3, and Q4). The following tables provide the modeled discharge level (cfs) relative to head differential (ft) as derived from the 2013 FPP (http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/).

Table A.1. BON B1 Discharge (cfs) by Operation Treatment and Head (ft)

	Discharge (cfs)				
Head (ft)	Q1	Q2	Q3	Q4	BOP
38	7633	8061	8490	8918	10627
39	7623	8044	8465	8886	10654
40	7613	8027	8440	8854	10677
41	7643	8085	8527	8969	10759
42	7671	8140	8608	9077	10837
43	7697	8192	8686	9180	10910
44	7722	8241	8759	9278	10979
45	7745	8287	8828	9370	11045
46	7762	8313	8865	9416	11109
47	7778	8338	8899	9459	11170
48	7792	8362	8931	9500	11227
49	7807	8384	8962	9539	11282
50	7819	8405	8990	9575	11333
51	7835	8430	9024	9618	11356
52	7830	8413	8995	9577	11378
53	7825	8396	8966	9537	11398
54	7820	8380	8939	9499	11418
55	7892	8517	9143	9768	11465
56	7904	8539	9173	9808	11478
57	7916	8559	9203	9846	11518
58	7926	8579	9231	9883	11557
59	7937	8598	9258	9918	11594
60	7947	8616	9284	9952	11630
61	7955	8613	9272	9930	11610
62	7961	8610	9260	9909	11591
63	7967	8608	9248	9889	11572
64	7972	8604	9236	9868	11519

Table A.2. BON B2 Operation Range (with STS) Discharge (cfs) Grouped by Operation Treatment and Head (ft)

	Discharge (cfs)			
Head (ft)	Q1	Q2	Q3	Q4
35	12961	14664	16366	18068
36	12978	14684	16391	18097
37	12990	14700	16411	18121
38	12998	14712	16425	18139
39	13004	14720	16437	18153
40	13007	14725	16444	18162
41	12994	14728	16463	18197
42	12980	14729	16479	18228
43	12965	14728	16492	18255
44	12949	14725	16502	18278
45	12933	14722	16510	18299
46	12946	14753	16559	18366
47	12901	14668	16434	18200
48	12857	14585	16312	18040
49	12815	14506	16196	17887
50	12988	14858	16728	18598
51	13078	15002	16926	18850
52	13163	15139	17115	19091
53	13245	15271	17297	19323
54	13321	15393	17464	19536
55	13237	15197	17156	19115
56	13187	15031	16874	18718
57	13137	14870	16603	18336
58	13088	14714	16341	17967
59	13039	14563	16087	17611
60	12992	14417	15842	17267
61	12894	14255	15617	16978
62	12798	14099	15399	16699
63	12707	13947	15188	16428
64	12617	13800	14983	16166
65	12532	13659	14785	15912
66	12504	13560	14615	15671
67	12477	13464	14450	15437
68	12452	13371	14291	15210
69	12426	13281	14135	14990
70	12401	13193	13984	14775

Table A.3. BON B2 Operation Range (without STS) Discharge (cfs) Grouped by Operation Treatment and Head (ft)

Head (ft)	Discharge (cfs)			
	Q1	Q2	Q3	Q4
35	13152	14861	16569	18277
36	13168	14881	16593	18306
37	13181	14898	16614	18331
38	13190	14910	16630	18350
39	13196	14919	16641	18364
40	13199	14924	16649	18374
41	13186	14927	16668	18409
42	13172	14928	16685	18441
43	13157	14927	16698	18468
44	13141	14925	16709	18493
45	13125	14921	16718	18514
46	13138	14953	16767	18581
47	13093	14867	16641	18415
48	13049	14785	16520	18255
49	13006	14705	16403	18101
50	13182	15060	16939	18817
51	13272	15206	17139	19072
52	13359	15345	17330	19316
53	13442	15478	17515	19551
54	13435	15434	17432	19431
55	13343	15221	17098	18975
56	13294	15056	16819	18581
57	13245	14898	16550	18202
58	13198	14744	16290	17836
59	13151	14595	16039	17483
60	13106	14451	15797	17142
61	13007	14291	15574	16857
62	12913	14136	15359	16582
63	12822	13986	15151	16315
64	12733	13841	14948	16056
65	12648	13701	14753	15806
66	12622	13605	14587	15570
67	12597	13512	14426	15341
68	12573	13422	14270	15119
69	12549	13334	14118	14903
70	12526	13248	13971	14693

Appendix B

Bonneville Dam Powerhouse 1 and Powerhouse 2 Survival Estimates by Operation Treatment

Appendix B

Bonneville Dam Powerhouse 1 and Powerhouse 2 Survival Estimates by Operation Treatment

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 at various treatment operating ranges at B1 and B2 as described in detail in Sections 3.0 and Section 4.0. Note: Fish that passed at B2 when the STSs were removed are not included in the sample sizes or survival estimates.

Table B.1. BON B1 Survival Estimates by Operation Treatment and Species-Run

	2010–2012						2010, 2012		
	CH1			STH			CH0		
Treatment	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1	0.9971	0.0110	235	0.9740	0.0098	306	0.9362	0.0357	47
Q2	1.0023	0.0147	145	0.9173	0.0267	152	0.9145	0.0376	57
Q3	0.9530	0.0180	215	0.9064	0.0234	204	0.9760	0.0149	116
Q4	0.9534	0.0086	1008	0.9300	0.0083	1199	0.9537	0.0064	1187
BOR	0.9672	0.0147	332	0.9477	0.0143	334	0.9515	0.0112	380
ABOP	0.9640	0.0085	493	0.9328	0.0114	493			
Total			2428			2688			1787

Table B.2. BON B1 Survival Estimates by Pooled Operation Treatment and Species-Run

	2010–2012						2010, 2012		
	CH1			STH			CH0		
Treatment	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1 – Q2	0.9990	0.0088	380	0.9546	0.0110	458	0.9237	0.0262	104
Q3 – Q4	0.9534	0.0077	1223	0.9266	0.0079	1403	0.9557	0.0060	1303
Total			1603			1861			1407

Table B.3. BON B1 Survival Estimates by Operation Conditions and Species-Run

	2010–2012						2010, 2012		
	CH1			STH			CH0		
Group	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
LL - UL	0.9644	0.0063	1603	0.9335	0.0065	1861	0.9534	0.0059	1407
LL - BOP	0.9648	0.0058	1935	0.9357	0.0060	2195	0.9530	0.0052	1787

Table B.4. BON B2 with STS Survival Estimates by Operation Treatment and Species-Run

Treatment	2008–2012						2008–2010, 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1	0.9545	0.0087	759	0.8932	0.0146	541	0.9528	0.0128	298
Q2	0.9575	0.0092	574	0.9427	0.0128	376	0.9314	0.0114	501
Q3	0.9501	0.0163	267	0.9097	0.0259	146	0.9397	0.0124	384
Q4	0.9563	0.0107	469	0.9192	0.0205	202	0.9562	0.0056	1444
Total			2069			1265			2627

Table B.5. BON B2 with STS Survival Estimates by Pooled Operation Treatment and Species-Run

Treatment	2008–2012						2008–2010, 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
Q1 – Q2	0.9556	0.0063	1333	0.9128	0.0101	917	0.9397	0.0086	799
Q3 – Q4	0.9538	0.0090	736	0.9152	0.0161	348	0.9527	0.0052	1828
Total			2069			1265			2627

Appendix C

Bonneville Dam Spillway Passage Survival Estimates by Spillbay and Spillbay Groups

Appendix C

Bonneville Dam Spillway Passage Survival Estimates by Spillbay and Spillbay Groups

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 passing the BON spillway during different years, by spillbay, and across groups of spillbays as described in detail in Section 5.0.

Table C.1. BON Spillway Passage Survival Estimates by Year for Each Species-Run

	CH1			STH			CH0		
Year	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
2008	0.9481	0.0102	1514	0.9362	0.0104	1473	0.9494	0.0050	2279
2009*	*	*	*	*	*	*	*	*	*
2010	0.9309	0.0068	1767	0.9404	0.0079	1363	0.9304	0.0062	1787
2011	0.9402	0.0063	3170	0.9478	0.0054	3111	**	**	**
2012	0.9378	0.0052	2225	0.9359	0.0054	2126	0.9614	0.0029	4532
Total			8676			8073			8598

*No spillway data for 2009
**No study conducted in 2011 summer due to extreme high flow in summer

Table C.2. BON Spillway Survival Estimates Spring 2011 vs. Spring 2008, 2010, and 2012 for Each Species

	CH1			STH		
Year	Estimate	SE	N	Estimate	SE	N
2011	0.9402	0.0063	3170	0.9478	0.0054	3111
2008, 2010, and 2012	0.9343	0.0038	5506	0.9367	0.0042	4962
Total			8676			8073

Table C.3. BON Spillway Passage Survival Estimates by Spillbay for Each Species-Run

	2008, 2010–2012						2008, 2010, 2012		
	CH1			STH			CH0		
Spillbay	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.9326	0.0133	576	0.9451	0.0129	521	0.9575	0.0095	496
2	0.9224	0.0113	791	0.9386	0.0119	623	0.9286	0.0113	548
3	0.9172	0.0110	783	0.9203	0.0122	650	0.9370	0.0097	668
4	0.9377	0.0109	650	0.9558	0.0121	490	0.9596	0.0063	1021
5	0.9553	0.0105	559	0.9232	0.0151	459	0.9445	0.0097	599
6	0.9550	0.0127	385	0.9198	0.0179	301	0.9573	0.0094	503
7	0.9390	0.0156	384	0.9408	0.0172	332	0.9374	0.0123	404
8	0.9527	0.0133	387	0.9438	0.0161	322	0.9494	0.0125	322
9	0.9127	0.0181	310	0.9225	0.0171	327	0.9604	0.0116	293
10	0.9518	0.0163	320	0.9477	0.0157	349	0.9739	0.0093	357
11	0.9156	0.0187	350	0.9510	0.0159	317	0.9595	0.0098	425
12	0.9253	0.0175	317	0.9541	0.0152	333	0.9438	0.0130	326
13	0.9207	0.0191	345	0.9511	0.0152	333	0.9552	0.0112	362
14	0.9612	0.0145	386	0.9405	0.0152	379	0.9560	0.0118	310
15	0.9216	0.0147	454	0.9639	0.0146	449	0.9729	0.0082	437
16	0.9525	0.0131	600	0.9434	0.0124	620	0.9578	0.0088	574
17	0.9225	0.0132	728	0.9382	0.0121	716	0.9450	0.0096	622
18	0.9532	0.0169	351	0.9528	0.0110	552	0.9422	0.0132	331
Total			8676			8073			8598

Table C.4. BON Spillway Survival Estimates by Spillbay Group for Each Species-Run

	2008, 2010–2012						2008, 2010, 2012		
	CH1			STH			CH0		
Spillbays	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–3	0.9229	0.0068	2150	0.9340	0.0071	1794	0.9403	0.0059	1712
4–7	0.9462	0.0061	1978	0.9361	0.0076	1582	0.9520	0.0044	2527
8–12	0.9319	0.0075	1684	0.9440	0.0072	1648	0.9577	0.0050	1723
13–15	0.9338	0.0092	1185	0.9525	0.0087	1161	0.9625	0.0059	1109
16–18	0.9401	0.0082	1679	0.9439	0.0069	1888	0.9492	0.0059	1527
Total			8676			8073			8598

Table C.5. BON Spillway CH1 Estimates by Spillbay for Individual Year

Spillbay	2008			2010			2011			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.9394	0.0298	93	0.9370	0.0240	124	0.9254	0.0235	272	0.9437	0.0250	87
2	0.9650	0.0284	202	0.9017	0.0224	203	0.9444	0.0242	187	0.9045	0.0208	199
3	1.0197	0.0398	76	0.8806	0.0282	152	0.9287	0.0184	317	0.9118	0.0184	238
4	0.9799	0.0270	141	0.9317	0.0266	120	0.9413	0.0232	161	0.9212	0.0179	228
5	0.9128	0.0318	106	0.9961	0.0135	80	0.9613	0.0231	183	0.9642	0.0137	190
6	0.9482	0.0354	59	0.9717	0.0295	75	0.9089	0.0315	115	0.9867	0.0104	136
7	0.8922	0.0891	34	0.9277	0.0287	90	0.9679	0.0271	158	0.9325	0.0251	102
8	1.0008	0.0407	45	0.9710	0.0228	62	0.9478	0.0303	147	0.9560	0.0180	133
9	0.9938	0.0765	27	0.9254	0.0403	62	0.8654	0.0361	123	0.9592	0.0200	98
10	0.9830	0.0551	61	0.9293	0.0313	69	0.9760	0.0399	111	0.9762	0.0178	79
11	0.8306	0.0693	54	0.9406	0.0352	57	0.9423	0.0355	145	0.9370	0.0252	94
12	1.0041	0.0653	55	0.9589	0.0232	73	0.8971	0.0358	116	0.9187	0.0322	73
13	0.9482	0.0659	68	0.8805	0.0431	72	0.9132	0.0362	130	0.9867	0.0132	75
14	0.9772	0.0386	93	0.9494	0.0293	86	0.9805	0.0267	127	0.9388	0.0271	80
15	0.8874	0.0446	82	0.9238	0.0312	103	0.9459	0.0228	166	0.9129	0.0278	103
16	0.9650	0.0382	147	0.9206	0.0268	115	0.9950	0.0231	224	0.9218	0.0253	114
17	0.8834	0.0431	131	0.9515	0.0204	149	0.9346	0.0222	344	0.9429	0.0229	104
18	0.9685	0.0509	40	0.9802	0.0421	75	0.9552	0.0293	144	0.9265	0.0278	92
Total			1514			1767			3170			2225

Table C.6. BON Spillway STH Survival Estimates by Spillbay for Individual Year

Bay	2008			2010			2011			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.8907	0.0411	78	0.9794	0.0232	95	0.9477	0.0193	249	0.9313	0.0259	99
2	0.9390	0.0256	169	0.9388	0.0235	127	0.9239	0.0256	182	0.9465	0.0190	145
3	0.9091	0.0403	88	0.8549	0.0352	122	0.9640	0.0164	246	0.9090	0.0209	194
4	0.9505	0.0398	103	0.9441	0.0371	64	0.9616	0.0224	135	0.9542	0.0156	188
5	0.9018	0.0414	89	0.9606	0.0293	71	0.9659	0.0271	168	0.8792	0.0287	131
6	0.9341	0.0563	63	0.8958	0.0455	52	0.9555	0.0370	82	0.9231	0.0261	104
7	0.9320	0.0433	57	0.9333	0.0426	48	0.9330	0.0309	139	0.9450	0.0248	88
8	0.9449	0.0440	52	0.9007	0.0446	48	0.9624	0.0248	133	0.9246	0.0287	89
9	0.8535	0.0728	37	0.9721	0.0287	64	0.9223	0.0309	128	0.9306	0.0261	98
10	0.9204	0.0525	68	0.9743	0.0271	56	0.9169	0.028	129	0.9718	0.0179	96
11	0.9689	0.0651	46	0.9273	0.0342	64	0.9498	0.0273	126	0.9643	0.0210	81
12	0.9539	0.0502	68	0.9708	0.0296	74	0.9742	0.0228	107	0.9177	0.0302	84
13	0.9843	0.0463	78	0.9431	0.0383	45	0.9317	0.0276	125	0.9681	0.0202	85
14	0.8654	0.0507	63	0.9202	0.0376	83	0.9696	0.0214	134	0.9525	0.0222	99
15	0.9737	0.0399	120	0.9900	0.0443	50	0.9735	0.0236	167	0.9414	0.0231	112
16	0.9667	0.0490	108	0.9058	0.0358	88	0.9588	0.0193	267	0.9442	0.0186	157
17	0.9456	0.0304	157	0.9553	0.0234	128	0.9223	0.0174	331	0.9030	0.0302	100
18	0.8922	0.0707	29	0.9861	0.0279	84	0.9508	0.0168	263	0.9520	0.0167	176
Total			1473			1363			3111			2126

Table C.7. BON Spillway CH0 Survival Estimates by Bay for Individual Year

Spillbay	2008			2010			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.9585	0.0153	206	0.9518	0.0235	83	0.9565	0.0142	207
2	0.9547	0.0175	171	0.9075	0.0231	166	0.9242	0.0182	211
3	0.9316	0.0235	132	0.9199	0.0184	228	0.9520	0.0123	308
4	0.9548	0.0175	171	0.9373	0.0224	123	0.9650	0.0069	727
5	0.9034	0.0255	146	0.9510	0.0212	114	0.9596	0.0108	339
6	0.9204	0.0282	110	0.9332	0.0270	88	0.9783	0.0086	305
7	0.9159	0.0320	86	0.9278	0.0263	97	0.9502	0.0146	221
8	0.9333	0.0312	70	0.9000	0.0387	60	0.9705	0.0126	192
9	0.9935	0.0198	55	0.9265	0.0317	68	0.9650	0.0142	170
10	0.9747	0.0179	115	0.9802	0.0172	83	0.9692	0.0139	159
11	0.9487	0.0182	162	0.9231	0.0370	52	0.9768	0.0105	211
12	0.9590	0.0217	91	0.9383	0.0308	63	0.9365	0.0187	172
13	0.9654	0.0211	95	0.8788	0.0402	66	0.9751	0.0110	201
14	0.9340	0.0293	74	1.0024	0.0026	58	0.9501	0.0164	178
15	0.9636	0.0207	96	0.9424	0.0275	80	0.9852	0.0076	261
16	0.9695	0.0135	196	0.9297	0.0234	124	0.9616	0.0122	254
17	0.9480	0.0164	228	0.9425	0.0203	145	0.9450	0.0146	249
18	0.9549	0.0266	75	0.8835	0.0355	89	0.9701	0.0132	167
Total			2279			1787			4532

Table C.8. BON Spillway CH1 Survival Estimates by Bay Group for Individual Year

Bays	2008			2010			2011			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–3	0.9710	0.0189	371	0.9042	0.0145	479	0.9309	0.0125	776	0.9144	0.0122	524
4–7	0.9420	0.0179	340	0.9522	0.0131	365	0.9469	0.0128	617	0.9490	0.0087	656
8–12	0.9593	0.0279	242	0.9437	0.0136	323	0.9247	0.0156	642	0.9506	0.0100	477
13–15	0.9359	0.0272	243	0.9212	0.0198	261	0.9447	0.0162	423	0.9424	0.0146	258
16–18	0.9327	0.0258	318	0.9427	0.0151	339	0.9591	0.0143	712	0.9303	0.0146	310
Total			1514			1767			3170			2225

Table C.9. BON Spillway STH Survival Estimates by Bay Group for Individual Year

Bays	2008			2010			2011			2012		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–3	0.9206	0.0193	335	0.9197	0.0166	344	0.9474	0.0116	677	0.9267	0.0127	438
4–7	0.9324	0.0225	312	0.9368	0.0190	235	0.9531	0.0143	524	0.9270	0.0116	511
8–12	0.9403	0.0258	271	0.9552	0.0148	306	0.9439	0.0121	623	0.9419	0.0113	448
13–15	0.9502	0.0259	261	0.9428	0.0230	178	0.9598	0.0140	426	0.9530	0.0129	296
16–18	0.9449	0.0243	294	0.9510	0.0167	300	0.9418	0.0103	861	0.9379	0.0119	433
Total			1473			1363			3111			2126

Table C.10. BON Spillway CH0 Survival Estimates by Bay Group for Individual Year

Spillbays	2008			2010			2012		
	Estimate	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
1–3	0.9504	0.0105	509	0.9211	0.0126	477	0.9452	0.0085	726
4–7	0.9263	0.0124	513	0.9377	0.0120	422	0.9643	0.0047	1592
8–12	0.9598	0.0097	493	0.9369	0.0136	326	0.9643	0.0062	904
13–15	0.9564	0.0135	265	0.9385	0.0172	204	0.9722	0.0065	640
16–18	0.9574	0.0100	499	0.9234	0.0146	358	0.9575	0.0079	670
Total			2279			1787			4532

Appendix D

Bonneville Dam Operations and Passage Survival Estimates by Tailwater Elevation and Discharge

Appendix D

Bonneville Dam Operations and Passage Survival Estimates by Tailwater Elevation and Discharge

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 passing 1, B2, and the BON spillway relative to the tailwater elevation as described in detail in Sections 3.0, 4.0, and 5.0.

Table D.1. BON Percent Operation Time for Tailrace Elevation Bins

	2010–2012		2008–2012		2008, 2010–2012	
	B1		B2		Spillway	
	Spring	Summer	Spring	Summer	Spring	Summer
Bins	% Ops	% Ops	% Ops	% Ops	% Ops	% Ops
5 m	4.9%	8.7%	13.9%	22.6%	17.2%	19.8%
6 m	8.7%	13.8%	21.2%	16.1%	16.3%	10.3%
7 m	22.8%	37.0%	20.7%	18.5%	18.3%	32.5%
8 m	31.1%	33.6%	21.4%	33.9%	21.4%	35.4%
9 m	32.5%	6.9%	22.8%	8.9%	26.8%	2.0%

Table D.2. BON B1 Passage Survival Estimates by Tailrace Elevation Bins for Each Species-Run

	2010–2012						2010–2012		
	CH1			STH			CH0		
Bins	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
5 m	0.9868	0.0260	92	0.8605	0.0446	84	0.8939	0.0305	103
6 m	1.0052	0.0152	165	0.9480	0.0161	232	0.9811	0.0132	132
7 m	0.9643	0.0080	623	0.9392	0.0092	700	0.9604	0.0088	568
8 m	0.9635	0.0067	862	0.9462	0.0077	916	0.9517	0.0077	815
9 m	0.9652	0.0134	708	0.9318	0.0129	777	0.9483	0.0170	172
Total			2450			2709			1790

Table D.3. BON B2 Passage Survival Estimates by Tailrace Elevation Bins for Each Species-Run

	2008–2012								
	CH1			STH			CH0		
Bins	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
5 m	0.9515	0.0120	390	0.8960	0.0162	404	0.9102	0.0158	338
6 m	0.9510	0.0106	556	0.8955	0.0170	367	0.9440	0.0139	280
7 m	0.9577	0.0102	490	0.9846	0.0105	243	0.9454	0.0118	398
8 m	0.9598	0.0091	534	0.8953	0.0217	216	0.9522	0.0060	1375
9 m	0.9167	0.0222	264	0.9144	0.0322	106	0.9663	0.0104	315
Total			2234			1336			2706

Table D.4. BON Spillway Survival Estimates by Tailrace Elevation Bins for Each Species-Run

	2008, 2010–2012						2008, 2010, 2012		
	CH1			**STH**			**CH0**		
Bins	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
5 m	0.9328	0.0076	1197	0.9466	0.0086	884	0.9050	0.0094	996
6 m	0.9535	0.0070	1678	0.9538	0.0076	1380	0.9210	0.0106	683
7 m	0.9302	0.0068	1518	0.9311	0.0072	1365	0.9508	0.0046	2478
8 m	0.9351	0.0063	1886	0.9308	0.0064	1954	0.9672	0.0029	4031
9 m	0.9542	0.0094	2397	0.9534	0.0076	2490	0.9709	0.0083	410
Total			8676			8073			8598

Table D.5. BON Spillway Survival Estimates by 10 kcfs Spillway Discharge Bins for Each Species-Run

	2008, 2010–2012						2008, 2010, 2012		
	CH1			**STH**			**CH0**		
10 kcfs Bins	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
≤ 90	0.9404	0.0089	808	0.9361	0.0051	603	0.9141	0.008	1279
100	0.9330	0.0047	3279	0.9317	0.0203	2755	0.9268	0.009	873
110	0.9491	0.0167	175	0.9396	0.0138	158	0.9476	0.0102	536
120	0.9481	0.0119	356	0.9449	0.0147	333	0.9358	0.0113	495
130	0.9643	0.0151	311	0.9159	0.0171	321	0.9538	0.0072	937
140	0.9127	0.0204	193	0.9297	0.0125	269	0.9795	0.0077	457
150	0.9603	0.0091	507	0.9351	0.0233	469	0.9783	0.0045	1192
160	0.9372	0.0221	141	0.9689	0.0220	118	0.9593	0.0069	870
170	0.9685	0.0205	137	0.9390	0.0173	121	0.9539	0.0074	868
180	0.9308	0.0203	218	0.9428	0.0250	283	0.9712	0.0098	303
190	0.9365	0.0212	214	0.9411	0.0243	259	0.9900	0.0099	100
200	0.9588	0.0202	241	0.9269	0.0476	211	0.9684	0.0122	214
210	0.9165	0.0302	154	0.9995	0.0540	134	0.9845	0.0109	129
220	0.9793	0.0218	184	0.9413	0.0373	178	0.9729	0.0102	256
230	0.9515	0.0370	134	1.0006	0.0233	122	0.9775	0.0157	89
240	0.9541	0.0281	235	0.9922	0.0176	245			
250	1.0002	0.0223	286	0.9869	0.0184	273			
260	0.9553	0.0272	269	0.9463	0.0215	310			
270	0.9530	0.0257	261	0.9530	0.0182	303			
280	0.9752	0.0262	363	0.9593	0.0109	418			
≥ 290	0.8563	0.0431	209	0.8448	0.0391	190			
Total			8675			8073			8598

Table D.6. BON Spillway Survival Estimates by 20 kcfs Spillway Discharge Bins for Each Species-Run

20 kcfs Bins	2008, 2010–2012						2008, 2010, 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
≤ 80	0.9404	0.0089	808	0.9593	0.0109	603	0.9141	0.0080	1279
100	0.9336	0.0045	3454	0.9357	0.0049	2913	0.9346	0.0068	1409
120	0.9514	0.0092	667	0.9419	0.0101	654	0.9475	0.0061	1432
140	0.9469	0.0087	700	0.9244	0.0101	738	0.9786	0.0039	1649
160	0.9524	0.0151	278	0.9502	0.0157	239	0.9565	0.0051	1738
180	0.9337	0.0147	432	0.9375	0.0144	542	0.9758	0.0078	403
200	0.9423	0.0171	395	0.9314	0.0222	345	0.9748	0.0087	343
220	0.9679	0.0199	318	0.9658	0.0323	300	0.9741	0.0086	345
240	0.9797	0.0177	521	0.9952	0.0142	518			
260	0.9562	0.0188	530	0.9670	0.0141	613			
≥ 280	0.9324	0.0230	572	0.9193	0.0175	608			
Total			8675			8073			8598

Table D.7. BON Spillway Percent Operation Time for 10 kcfs Spillway Discharge Bins for Each Species-Run

10 kcfs Bins	2008, 2010–2012	2008, 2010, 2012
	Spring % OPS	Summer % OPS
≤ 90	9.15	30.10
100	35.71	15.08
110	2.57	6.51
120	3.66	7.50
130	4.28	10.82
140	3.90	5.56
150	10.28	8.49
160	1.38	5.27
170	2.98	6.17
180	2.69	1.63
190	2.68	0.37
200	4.52	1.03
210	1.38	0.47
220	1.32	0.79
230	0.67	0.20
240	0.98	
250	1.16	
260	1.21	
270	1.10	
280	2.72	
≥ 290	5.66	

Table D.8. BON Spillway Percent Operation Time for Spillway Discharge by 20 kcfs Bins for Each Species-Run

	2008, 2010–2012	2008, 2010, 2012
20 kcfs Bins	Spring % OPS	Summer % OPS
≤ 80	9.15	30.10
100	38.28	21.59
120	7.94	18.32
140	14.17	14.05
160	4.37	11.44
180	5.37	2.01
200	5.89	1.50
220	2.00	0.99
240	2.14	
260	2.31	
≥ 280	8.37	

Appendix E

The Dalles Dam Spillway Survival Estimates by Bay and Spill Discharge

Appendix E

The Dalles Dam Spillway Survival Estimates by Bay and Spill Discharge

The following tables provide the survival estimates, standard errors (SEs) and sample sizes (N) for CH1, STH, and CH0 passing The Dalles Dam spillway during different years, by spillbay, and across groups of spillbays as described in detail in Section 6.0.

Table E.1. TDA CH1 Spillway Passage Survival Estimates by Bay for Individual Years

	2010			2011			2012		
Bay	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
1	0.9494	0.0247	79	0.9529	0.0153	191	0.9396	0.0155	243
2	0.9120	0.0253	125	0.9322	0.0164	236	0.9247	0.0143	343
3	0.9553	0.0201	109	0.9385	0.0154	244	0.9782	0.0078	357
4	0.9518	0.0181	143	0.9366	0.0149	268	0.9655	0.0093	397
5	0.8693	0.0273	153	0.9669	0.0108	272	0.9712	0.0079	467
6	0.9213	0.0192	200	0.9675	0.0107	277	0.9491	0.0104	448
7	0.9340	0.0171	212	0.9639	0.0107	305	0.9527	0.0095	517
8	0.9312	0.0096	694	0.9622	0.0077	608	0.9654	0.0064	848
Total			1715			2401			3620

Table E.2. TDA STH Spillway Passage Survival Estimates by Bay for Individual Years

	2010			2011			2012		
Bay	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**	**Estimate**	**SE**	**N**
1	0.9518	0.0235	83	0.9620	0.0124	237	0.9563	0.0130	261
2	0.9586	0.0165	145	0.9517	0.0131	269	0.9598	0.0113	313
3	0.9403	0.0195	149	0.9846	0.0077	259	0.9617	0.0111	307
4	0.9726	0.0123	180	0.9815	0.0082	270	0.9802	0.0078	337
5	0.9333	0.0204	150	0.9469	0.0143	245	0.9755	0.0084	352
6	0.9461	0.016	202	0.9775	0.0084	311	0.9665	0.0084	467
7	0.9195	0.0177	236	0.9639	0.0102	332	0.9677	0.0077	545
8	0.9280	0.0101	651	0.9678	0.0063	777	0.9715	0.0047	1312
Total			1796			2700			3894

Table E.3. TDA CH0 Spillway Passage Survival Estimates by Bay for Individual Years

Bay	2010			2012		
	Estimate	SE	N	Estimate	SE	N
1	0.9023	0.0250	148	0.9542	0.0129	262
2	0.9316	0.0200	168	0.9590	0.0090	486
3	0.9351	0.0198	179	0.9582	0.0084	571
4	0.9059	0.0235	169	0.9647	0.0075	618
5	0.9123	0.0212	187	0.9567	0.0080	646
6	0.9134	0.0205	199	0.9532	0.0080	702
7	0.9260	0.0186	215	0.9538	0.0082	649
8	0.9120	0.0137	455	0.9469	0.0068	1106
Total			1720			5040

Table E.4. TDA Spillway Passage Survival Estimates by Bay for Combined Years for Each Species-Run

Bay	2010–2012						2010 and 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1	0.9463	0.0100	513	0.9578	0.0084	581	0.9352	0.0123	410
2	0.9251	0.0100	704	0.9568	0.0076	727	0.9519	0.0084	654
3	0.9611	0.0073	710	0.9656	0.0069	715	0.9520	0.0079	750
4	0.9536	0.0075	808	0.9790	0.0052	787	0.9516	0.0078	787
5	0.9526	0.0072	892	0.9578	0.0074	747	0.9465	0.0078	833
6	0.9486	0.0073	925	0.9661	0.0059	980	0.9441	0.0077	901
7	0.9525	0.0067	1034	0.9565	0.0062	1113	0.9464	0.0077	864
8	0.9535	0.0046	2150	0.9603	0.0038	2740	0.9365	0.0062	1561
Total			7736			8390			6760

Table E.5. TDA Spillway Passage Survival Estimates by Bay Group (Inside of Spill Wall vs. Outside of Spill Wall) for Each Species-Run.

Bays	2011–2012						2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
1–8	0.9568	0.0026	6021	0.9683	0.0022	6594	0.9549	0.0029	5040
9–23	0.9486	0.0102	487	0.9802	0.0056	666	0.9650	0.0156	141
Total			6508			7260			5181

Table E.6. TDA Spillway Passage Survival Estimates by Bay Group (Outside of Spill Wall) for Each Species-Run

Bays	2011–2012						2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
9–12	0.9472	0.0133	304	0.9813	0.0069	435	0.9453	0.0270	72
13–23	0.9508	0.0160	183	0.9784	0.0096	231	0.9855	0.0144	69
Total			487			666			141

Table E.7. TDA Spillway Passage Survival Estimates for Spillbays 9–23 by Year for CH1 and STH

Years	CH1			STH		
	Estimate	SE	N	Estimate	SE	N
2011	0.9488	0.0111	391	0.9816	0.0058	544
2012	0.9465	0.0254	96	0.9715	0.0164	122
Total			487			666

Table E.8. TDA Spillway Passage Survival Estimates by 10 kcfs Spill Discharge Bins for Each Species-Run

10 kcfs Bins	2010–2012						2010 and 2012		
	CH1			STH			CH0		
	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
≤ 70	0.9364	0.0086	816	0.9548	0.0075	769	0.8305	0.0225	298
80	0.9448	0.0083	773	0.9485	0.0092	581	0.8933	0.0162	412
90	0.9430	0.0104	502	0.9349	0.0110	507	0.9362	0.0146	314
100	0.9439	0.0060	1488	0.9616	0.0049	1546	0.9429	0.0191	153
110	0.9542	0.0070	890	0.9583	0.0061	1071	0.9598	0.0092	466
120	0.9532	0.0067	996	0.9614	0.0057	1158	0.9505	0.0069	986
130	0.9540	0.0088	563	0.9484	0.0091	599	0.9535	0.0043	2436
140	0.9476	0.0161	191	0.9695	0.0116	224	0.9704	0.0072	562
150	0.9675	0.0097	335	0.9839	0.006	436	0.9671	0.0145	152
≥ 160	0.9634	0.0057	1181	0.9815	0.0038	1497	0.9565	0.0065	981
Total			7735			8388			6760

Table E.9. TDA Spillway Passage Survival Estimates by 24 kcfs Spill Discharge Bins for Each Species-Run

	2010–2012						2010 and 2012		
	CH1			STH			CH0		
24 kcfs Bins	Estimate	SE	N	Estimate	SE	N	Estimate	SE	N
≤ 72	0.9405	0.006	1589	0.9521	0.0058	1350	0.8673	0.0134	710
96	0.9449	0.0047	2360	0.9543	0.0042	2523	0.9460	0.0092	646
120	0.9538	0.0047	1976	0.9589	0.0042	2249	0.9527	0.0035	3600
144	0.9590	0.0073	730	0.9803	0.0046	946	0.9699	0.0057	915
≥ 168	0.9645	0.0059	1080	0.9790	0.0043	1320	0.9531	0.0071	889
Total			7735			8388			6760

Appendix F

Bonneville Dam and The Dalles Dam Tailrace Egress Time

Appendix F

Bonneville Dam and The Dalles Dam Tailrace Egress Time

The following tables provide the median, mean, minimum (min), maximum (max), standard errors (SEs) and sample size (N) tailrace egress time metrics for CH1, STH, and CH0 passing B1, B2, and the BON spillway and TDA spillway during different years, treatments, and discharge volumes as described in detail in Sections 3.0 – 6.0.

Table F.1. BON CH1 Tailrace Egress Time by Operation Condition

2010–2012							
	Treatment	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
B1	Q1	0.27	280.27	6.40	2.10	0.46	234
	Q2	0.28	102.24	3.36	1.15	0.44	136
	Q3	0.23	110.46	2.43	0.82	0.38	189
	Q4	0.24	273.35	3.55	0.57	0.37	860
	BOR	0.24	281.36	5.90	1.67	0.37	286
	ABOP	0.21	200.41	4.23	0.70	0.30	485
	Total						2190
2008–2012							
B2	Q1	0.28	18.53	0.77	0.04	0.65	514
	Q2	0.25	15.53	0.86	0.06	0.65	350
	Q3	0.29	8.61	0.92	0.12	0.61	111
	Q4	0.25	3.41	0.65	0.03	0.55	141
	OG	0.45	5.75	1.12	0.58	0.51	9
	Total						1125

Table F.2. BON STH Tailrace Egress Time by Operation Condition

2010–2012							
	Treatment	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
B1	Q1	0.25	254.90	8.51	1.69	0.60	301
	Q2	0.25	589.93	9.84	4.57	0.57	146
	Q3	0.26	225.21	7.75	2.10	0.63	146
	Q4	0.24	419.08	17.14	1.39	0.52	1013
	BOR	0.25	404.61	23.96	3.49	0.58	282
	ABOP	0.20	415.51	15.11	2.21	0.42	476
	Total						2364
2008–2012							
B2	Q1	0.26	48.20	1.16	0.16	0.72	381
	Q2	0.22	24.13	1.16	0.14	0.71	257
	Q3	0.21	70.55	1.67	0.89	0.68	79
	Q4	0.22	5.19	0.89	0.10	0.71	57
	Total						774

Table F.3. BON CH0 Tailrace Egress Time by Operation Condition

2010 and 2012							
	Treatment	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
B1	Q1	0.29	68.26	2.17	1.45	0.46	47
	Q2	0.32	31.24	1.22	0.56	0.44	56
	Q3	0.25	44.93	1.67	0.53	0.39	116
	Q4	0.24	622.50	3.81	0.68	0.40	1148
	BOR	0.27	127.56	4.33	0.68	0.40	363
	ABOP	*	*	*	*	*	*
	Total						1730
2008–2010, 2012							
B2	Q1	0.29	6.15	0.83	0.06	0.73	111
	Q2	0.22	8.03	0.85	0.05	0.71	272
	Q3	0.21	530.52	2.82	2.01	0.67	263
	Q4	0.19	13.90	0.78	0.03	0.64	911
	Total						1557

Table F.4. BON CH1 Tailrace Egress Time by 10 kcfs Spill Discharge Bins

2008, 2010–2012						
10 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 70	0.38	3.07	0.83	0.16	0.53	18
80	0.33	306.51	1.76	1.13	0.51	271
90	0.32	5.28	0.58	0.02	0.46	418
100	0.19	157.14	0.61	0.07	0.41	2571
110	0.29	26.45	0.63	0.18	0.39	142
120	0.26	1.18	0.40	0.01	0.37	264
130	0.26	1.27	0.37	0.01	0.35	250
140	0.26	0.73	0.36	0.01	0.34	124
150	0.23	1.08	0.33	0.00	0.32	285
160	0.24	0.51	0.32	0.00	0.31	113
170	0.25	68.85	1.71	1.40	0.30	49
180	0.23	0.52	0.30	0.00	0.30	116
190	0.22	3.77	0.42	0.12	0.30	28
200	0.20	1.18	0.32	0.02	0.28	91
210	0.13	0.60	0.28	0.02	0.26	31
220	0.22	11.68	1.51	1.04	0.26	11
230	0.01	0.61	0.30	0.02	0.26	43
240	0.01	4.09	0.40	0.08	0.27	66
250	0.02	11.04	0.41	0.09	0.28	122
260	0.01	0.94	0.29	0.01	0.27	136
270	0.02	2.11	0.29	0.02	0.27	110
280	0.01	1.14	0.29	0.01	0.28	129
290	0.01	0.61	0.26	0.02	0.26	39
≥ 300	0.01	0.70	0.27	0.04	0.28	16
Total						5443

Table F.5. BON STH Tailrace Egress Time by 10 kcfs Spill Discharge Bins

2008, 2010–2012						
10 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 70	0.39	0.65	0.50	0.08	0.47	3
80	0.35	7.76	0.66	0.05	0.47	163
90	0.31	91.65	1.02	0.30	0.43	355
100	0.28	614.65	0.87	0.29	0.41	2179
110	0.29	0.95	0.40	0.01	0.38	118
120	0.27	10.18	0.49	0.05	0.36	227
130	0.26	4.97	0.40	0.02	0.35	245
140	0.25	1.05	0.34	0.01	0.32	170
150	0.23	12.13	0.53	0.07	0.31	266
160	0.25	1.78	0.36	0.02	0.31	103
170	0.22	13.22	0.88	0.35	0.31	38
180	0.11	9.45	0.45	0.08	0.30	131
190	0.22	6.35	0.56	0.18	0.29	34
200	0.05	14.68	0.54	0.21	0.29	70
210	0.19	0.53	0.28	0.02	0.25	21
220	0.19	0.38	0.27	0.03	0.23	7
230	0.10	1.81	0.40	0.07	0.31	26
240	0.11	0.98	0.32	0.02	0.28	56
250	0.01	1.32	0.30	0.02	0.29	111
260	0.02	2.15	0.33	0.02	0.29	133
270	0.03	22.94	0.55	0.22	0.31	103
280	0.01	1.73	0.31	0.02	0.29	142
290	0.03	0.70	0.32	0.03	0.29	39
≥ 300	0.01	0.53	0.30	0.05	0.33	8
Total						4748

Table F.6. BON CH0 Tailrace Egress Time by 10 kcfs Spill Discharge Bins

2008, 2010, 2012						
10 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 80	0.40	1.30	0.69	0.07	0.54	19
90	0.34	4.48	0.60	0.02	0.51	297
100	0.31	5.79	0.53	0.01	0.45	705
110	0.31	2.18	0.43	0.01	0.41	173
120	0.27	4.87	0.42	0.01	0.38	430
130	0.26	15.92	0.40	0.02	0.36	646
140	0.26	0.88	0.35	0.00	0.34	297
150	0.23	50.35	0.39	0.05	0.32	1049
160	0.23	1.02	0.32	0.00	0.31	702
170	0.23	1.07	0.33	0.00	0.30	631
180	0.22	217.95	1.13	0.80	0.30	271
190	0.23	1.34	0.33	0.02	0.28	98
200	0.21	0.82	0.29	0.01	0.28	149
210	0.21	4.13	0.35	0.04	0.28	126
220	0.19	4.40	0.29	0.02	0.26	242
≥ 230	0.19	1.06	0.29	0.02	0.25	78
Total						5913

Table F.7. BON CH1 Tailrace Egress Time by 20 kcfs Spill Discharge Bins

2008, 2010–2012						
20 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 60	0.38	3.07	0.83	0.16	0.53	18
80	0.32	306.51	1.04	0.44	0.48	689
100	0.19	157.14	0.61	0.07	0.41	2713
120	0.26	1.27	0.38	0.00	0.36	514
140	0.23	1.08	0.34	0.00	0.32	409
160	0.24	68.85	0.74	0.42	0.31	162
180	0.22	3.77	0.33	0.02	0.30	144
200	0.13	1.18	0.31	0.01	0.27	122
220	0.01	11.68	0.55	0.22	0.26	54
240	0.01	11.04	0.40	0.07	0.27	188
260	0.01	2.11	0.29	0.01	0.27	246
280	0.01	1.14	0.29	0.01	0.28	168
≥ 300	0.01	0.70	0.27	0.04	0.28	16
Total						5443

Table F.8. BON STH Tailrace Egress Time by 20 kcfs Spill Discharge Bins

2008, 2010–2012						
20 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 60	0.39	0.65	0.50	0.08	0.47	3
80	0.31	91.65	0.91	0.20	0.45	518
100	0.28	614.65	0.84	0.27	0.40	2297
120	0.26	10.18	0.44	0.03	0.36	472
140	0.23	12.13	0.46	0.04	0.32	436
160	0.22	13.22	0.50	0.10	0.31	141
180	0.11	9.45	0.48	0.07	0.30	165
200	0.05	14.68	0.48	0.16	0.29	91
220	0.10	1.81	0.37	0.06	0.29	33
240	0.01	1.32	0.31	0.01	0.29	167
260	0.02	22.94	0.43	0.10	0.30	236
280	0.01	1.73	0.31	0.01	0.29	181
≥ 300	0.01	0.53	0.30	0.05	0.33	8
Total						4748

Table F.9. BON CH0 Tailrace Egress Time by 20 kcfs Spill Discharge Bins

2008, 2010, 2012						
20 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 80	0.34	4.48	0.60	0.02	0.51	316
100	0.31	5.79	0.51	0.01	0.44	878
120	0.26	15.92	0.40	0.02	0.36	1076
140	0.23	50.35	0.38	0.04	0.33	1346
160	0.23	1.07	0.32	0.00	0.30	1333
180	0.22	217.95	0.92	0.59	0.29	369
200	0.21	4.13	0.32	0.02	0.28	275
≥ 220	0.19	4.40	0.29	0.01	0.25	320
Total						5913

Table F.10. TDA CH1 Tailrace Egress Time by 24 kcfs Spill Discharge Bins

2008, 2010–2012						
24 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 48	0.28	153.02	1.69	0.83	0.47	210
72	0	367.24	1.14	0.35	0.36	1233
96	0	475.07	2.14	0.69	0.27	858
120	0.01	156.4	0.9	0.34	0.21	663
144	0.1	120.33	0.49	0.26	0.16	464
≥ 168	0.11	0.44	0.16	0	0.14	227
Total						3655

Table F.11. TDA STH Tailrace Egress Time by 24 kcfs Spill Discharge Bins

2008, 2010–2012						
24 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 48	0.27	201.79	1.63	1.05	0.42	192
72	0	24.1	0.44	0.03	0.33	1060
96	0	52.84	0.43	0.08	0.25	1006
120	0	55.83	0.31	0.07	0.20	838
144	0.1	3.81	0.21	0.01	0.15	610
≥ 168	0.1	0.78	0.16	0	0.14	338
Total						4044

Table F.12. TDA CH0 Tailrace Egress Time by 24 kcfs Spill Discharge Bins

2008, 2010, 2012						
24 kcfs Bins	**Min**	**Max**	**Mean**	**SE**	**Median**	**N**
≤ 48	0.26	194.7	5.98	5.39	0.42	36
72	0.16	65.88	0.73	0.15	0.35	560
96	0.11	145.41	0.8	0.29	0.30	586
120	0.12	324.61	0.57	0.13	0.22	3436
144	0.11	324.19	0.84	0.42	0.19	870
168	0.11	449.89	1.82	0.98	0.17	648
216	0.17	324.49	18.26	12.55	0.24	36
240	0.15	0.48	0.24	0.01	0.23	84
≥ 312	0.12	0.54	0.18	0	0.16	168
Total						6424

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

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