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Route-Specific Passage Proportions and Survival Rates for Fish Passing through John Day Dam, The Dalles Dam, and Bonneville Dam in 2010 and 2011

INTERIM REPORT

GR Ploskey
MA Weiland
TJ Carlson

June 2012

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Pacific Northwest National Laboratory
Richland, Washington 99352

Preface

The U.S. Army Corps of Engineers Portland District (USACE) received a request for estimates of route-specific fish-passage proportions and survival rates of yearling Chinook salmon and juvenile steelhead passing through lower Columbia River dams from 2010 and 2011 to update the Compass Model for the Columbia River Treaty and the new Biological Opinion. Route-specific estimates were not part of the published summary or compliance reports for 2010 or 2011, although single-release, route-specific estimates were published in 2010 technical reports and will appear in technical reports scheduled for completion in September 2012. In the interim, there was a need for a citable report that presents the estimated fish passage proportions and survival rates for steelhead and Chinook salmon smolts passing through various sampled routes at the three lower dams on the Columbia River in 2010 and 2011. This brief report tabulates the estimated proportions and rates to meet the interim need for citable data.

The 2011 studies upon which this summary report is based were conducted by the Pacific Northwest National Laboratory (PNNL) and the University of Washington (UW) for the USACE. The PNNL and UW project managers were Drs. Thomas J. Carlson and John R. Skalski, respectively. The USACE technical lead was Mr. Brad Eppard.

Suggested citation for this report:

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Summary

This report tabulates route-specific fish-passage proportions and survival rates for steelhead and Chinook salmon smolts passing through various sampled routes at John Day Dam, The Dalles Dam, and Bonneville Dam in 2010 and 2011. Results were compiled from analyses of data acquired in spring 2010 and 2011 studies that were specifically designed to estimate dam-passage and forebay-to-tailrace survival rates, travel time metrics, and spill passage efficiency, as stipulated by the 2008 Federal Columbia River Power System Biological Opinion and the Columbia Basin Fish Accords. The study designs allowed for estimation of route-specific fish passage proportions and survival rates as well as estimation of forebay-passage survival, all of which are summarized herein.

Acknowledgments

This compilation of route-specific fish passage proportions and survival rates was based on the results of 2010 and 2011 studies conducted by dedicated scientists from the Pacific Northwest National Laboratory (PNNL), Pacific States Marine Fisheries Commission (PSMFC), the U.S. Army Corps of Engineers, Portland District (USACE), and the University of Washington (UW). Their teamwork and attention to detail, schedule, and budget were essential for the studies to succeed in providing high-quality, timely results to decision-makers.

- PNNL: T Abel, C Arimescu, G Batten, R Brown, J Carter, K Carter, E Choi, K Deters, G Dirkes, J Duncan, D Faber, E Fischer, A Flory, T Fu, G Gaulke, D Geist, M Gay, B Goodman, K Hall, M Halvorsen, K Ham, K Hand, R Harnish, M Hennen, JL Hughes, JS Hughes, G Johnson, F Khan, R Karls, J Kim, K Knox, B Lamarche, K Larson, K Lavender, J Martinez, G McMichael, A Miracle, B Noland, E Oldenburg, A Phillips, G Roesijadi, I Royer, D Saunders, J Smith, G Squeochs, S Southard, N Tavan, A Thronas, S Titzler, N Trimble, D Trott, K Wagner, C Woodley, J Varvinec, and S Zimmerman
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- USACE: B Eppard, M Langeslay, and biologists at John Day (M Zyndol and T Hurd), The Dalles (B Cordie), and Bonneville dams (J Rerecich, B Hausmann, and A Traylor).
- UW: J Skalski, R Townsend, A Seaburg, J Lady, and P Westhagen.

Acronyms and Abbreviations

B1	Bonneville Powerhouse 1
B1SL	Bonneville Powerhouse 1 sluiceway
B1T	Bonneville Powerhouse 1 turbines
B2	Bonneville Powerhouse 2
B2T	Bonneville Powerhouse 2 turbines
B2CC	Bonneville Powerhouse 2 Corner Collector
BON	Bonneville Dam
CH1	yearling Chinook salmon
JDA	John Day Dam
NTSW	non-temporary spillway weir
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory
PSMFC	Pacific States Marine Fisheries Commission
SE	standard error
SL	sluiceway
SP	spillway
VSR	virtual single release
STH	steelhead
T	turbines
TDA	The Dalles Dam
TSW	temporary spillway weir
USACE	U.S. Army Corps of Engineers
UW	University of Washington
VPR	virtual paired release

Contents

Tables

1.0 Introduction

This report presents estimates of fish passage proportions and survival rates for Chinook salmon and steelhead smolts passing through various sampled routes at the three lower dams on the Columbia River in 2010 and 2011. It fulfills an interim need for a citable report of route-specific estimates before final 2011 estimates are published in September 2012. Estimates for 2010, derived from previous publications (Johnson et al. 2011; Ploskey et al. 2011; Weiland et al. In Press), are included for comparative purposes.

In particular, this interim report provides timely estimates of route-specific passage proportions and survival rates for yearling Chinook salmon and juvenile steelhead that passed through John Day Dam (JDA), The Dalles Dam (TDA), and Bonneville Dam (BON) in spring 2011. The studies conducted in spring 2010 and 2011 were specifically designed to estimate dam-passage and forebay-to-tailrace survival rates, travel time metrics, and spill passage efficiency, as stipulated by the 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008) and the Columbia Basin Fish Accords (3 Treaty Tribes-Action Agencies 2008). The study designs also allowed for estimation of route-specific fish passage proportions and survival rates as well as estimation of forebay-passage survival, all of which are summarized herein.

The metrics used to estimate route-specific dam passage proportions, route-specific survival rates, and forebay survival rates are described under Methods, and the actual estimates are tabulated under Results.

2.0 Methods

For each fish stock, the following metrics were estimated and tabulated using Juvenile Salmon Acoustic Telemetry System technology:

- A route-specific passage proportion is defined as the number of fish known to have passed through a specific sampled route divided by the total number of fish number passing the dam.
- A route-specific survival rate is defined as survival of a virtual release of fish known to have passed through a specific sampled route.
- Forebay survival, defined as the ratio of forebay and dam-passage survival to dam-passage survival.

Results provided in this report are tabulated for the two fish stocks by performance measure. Subsequent, comprehensive technical reports scheduled for publication in late 2012 for each dam will present the same estimates and include discussion.

The 2010 study designs are described by Ploskey et al. (2011) for BON, Johnson et al. (2011) for TDA, and Weiland et al. (In Press) for JDA. The 2011 study designs are described by Skalski et al. (2012a, b, and c). Methods described in the sections below deal with how route-specific passage proportions and survival rates were calculated for this report.

2.1 Route-Specific Dam-Passage Proportions

The proportion of fish passing through each major route of passage through each dam is described for each of the lower Columbia River dams in the next three sections.

To ensure timely production of this report, variances associated with fish passage proportions were based on the assumption of high and equal detection probabilities across the dam and a binomial sampling model. Therefore, only the first term in the typical variance estimator (the term after the equal sign and before the first plus sign in this example for spill passage efficiency) was used to estimate the variance.

$$\mathrm{Var}\left(\widehat{\mathrm{SPE}}\right)=\frac{\mathrm{SPE}\left(1-\mathrm{SPE}\right)}{\sum_{i=1}^{6}N_i}+\widehat{\mathrm{SPE}}^{2}\left(1-\widehat{\mathrm{SPE}}\right)^{2}\left[\frac{\mathrm{Var}\left(\hat{N}_{SP}\right)}{\hat{N}_{SP}^{2}}+\frac{\sum_{i=2}^{k}\mathrm{Var}\left(\hat{N}_i\right)}{\left(\sum_{i=2}^{k}\hat{N}_i\right)^{2}}\right] \tag{2.1}$$

The second term after the first plus sign typically is very small and approaches zero when detection probabilities are very high, and probabilities >0.99 are common for double arrays of three-dimensional tracking hydrophones deployed on the upstream face of dams.

2.1.1 Bonneville Dam

The proportion of fish passing BON through the BON Powerhouse 1 (B1) sluiceway was calculated as follows:

$$\widehat{\mathrm{B1SL}} = \frac{\hat{N}_{B1SL}}{\hat{N}_{SP} + \hat{N}_{B1SL} + \hat{N}_{B1T} + \hat{N}_{B2JBS} + \hat{N}_{B2CC} + \hat{N}_{B2T}}, \tag{2.2}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], BON Powerhouse 1 sluiceway [B1SL], BON Powerhouse 1 turbines [B1T], BON Powerhouse 2 juvenile bypass system [B2JBS], BON Powerhouse 2 corner collector [B2CC], and BON Powerhouse 2 turbines [B2T]).

The proportion of fish passing BON through the B1 turbines was calculated as follows:

$$\widehat{\mathrm{B1T}} = \frac{\hat{N}_{B1T}}{\hat{N}_{SP} + \hat{N}_{B1SL} + \hat{N}_{B1T} + \hat{N}_{B2JBS} + \hat{N}_{B2CC} + \hat{N}_{B2T}}, \tag{2.3}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], BON Powerhouse 1 sluiceway [B1SL], BON Powerhouse 1 turbines [B1T], BON Powerhouse 2 juvenile bypass system [B2JBS], BON Powerhouse 2 corner collector [B2CC], and BON Powerhouse 2 turbines [B2T]).

The proportion of fish passing BON through the spillway was calculated as follows:

$$\widehat{\mathrm{SPE}} = \frac{\hat{N}_{SP}}{\hat{N}_{SP} + \hat{N}_{B1SL} + \hat{N}_{B1T} + \hat{N}_{B2JBS} + \hat{N}_{B2CC} + \hat{N}_{B2T}}, \tag{2.4}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], BON Powerhouse 1 sluiceway [B1SL], BON Powerhouse 1 turbines [B1T], BON Powerhouse 2 juvenile bypass system [B2JBS], BON Powerhouse 2 corner collector [B2CC], and BON Powerhouse 2 turbines [B2T]).

The proportion of fish passing BON through the B2CC was calculated as follows:

$$\widehat{\mathrm{B2CC}} = \frac{\hat{N}_{B2CC}}{\hat{N}_{SP} + \hat{N}_{B1SL} + \hat{N}_{B1T} + \hat{N}_{B2JBS} + \hat{N}_{B2CC} + \hat{N}_{B2T}}, \tag{2.5}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], BON Powerhouse 1 sluiceway [B1SL], BON Powerhouse 1 turbines [B1T], BON Powerhouse 2 juvenile bypass system [B2JBS], BON Powerhouse 2 corner collector [B2CC], and BON Powerhouse 2 turbines [B2T]).

The proportion of fish passing BON through the B2JBS was calculated as follows:

$$\widehat{\text{B2JBS}} = \frac{\hat{N}_{B2JBS}}{\hat{N}_{SP} + \hat{N}_{B1SL} + \hat{N}_{B1T} + \hat{N}_{B2JBS} + \hat{N}_{B2CC} + \hat{N}_{B2T}}, \tag{2.6}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], BON Powerhouse 1 sluiceway [B1SL], BON Powerhouse 1 turbines [B1T], BON Powerhouse 2 juvenile bypass system [B2JBS], BON Powerhouse 2 corner collector [B2CC], and BON Powerhouse 2 turbines [B2T]). The variance of $\widehat{\text{B2JBS}}$ was estimated as

$$\text{Var}\left(\widehat{\text{B2JBS}}\right) = \frac{\text{B2JBS}\left(1 - B2JBS\right)}{\sum_{i=1}^{6} N_i} + B2JBS^2\left(1 - B2JBS\right)^2. \tag{2.7}$$

The proportion of fish passing BON through the B2JBS was calculated as follows:

$$\widehat{\text{B2T}} = \frac{\hat{N}_{B2T}}{\hat{N}_{SP} + \hat{N}_{B1SL} + \hat{N}_{B1T} + \hat{N}_{B2JBS} + \hat{N}_{B2CC} + \hat{N}_{B2T}}, \tag{2.8}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], BON Powerhouse 1 sluiceway [B1SL], BON Powerhouse 1 turbines [B1T], BON Powerhouse 2 juvenile bypass system [B2JBS], BON Powerhouse 2 corner collector [B2CC], and BON Powerhouse 2 turbines [B2T]).

2.1.2 The Dalles Dam

The proportion of fish passing TDA through the spillway (spill passage efficiency) was estimated as

$$\widehat{\text{SPE}} = \frac{\hat{N}_{SP}}{\hat{N}_{SP} + \hat{N}_{SL} + \hat{N}_T}, \tag{2.9}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], sluiceway [SL], or turbines [T]).

The proportion of fish passing TDA through the sluiceway (sluiceway passage efficiency) was estimated as

$$\widehat{\text{SLE}} = \frac{\hat{N}_{SL}}{\hat{N}_{SP} + \hat{N}_{SL} + \hat{N}_T}, \tag{2.10}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the ith route (i = spillway [SP], sluiceway [SL], or turbines [T]).

The proportion of fish passing TDA through turbines was estimated as

$$\hat{\mathrm{T}} = \frac{\hat{N}_T}{\hat{N}_{SP} + \hat{N}_{SL} + \hat{N}_T}, \tag{2.11}$$

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

2.1.3 John Day Dam

The proportion of fish passing JDA through spill bays containing temporary spillway weirs (TSWs) was estimated as

$$\widehat{\mathrm{TSW}} = \frac{\hat{N}_{TSW}}{\hat{N}_{TSW} + \hat{N}_{NTSW} + \hat{N}_{JBS} + \hat{N}_T}, \tag{2.12}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the *i*th route (i = TSW spill bays [TSW], non-TSW spill bays [NTSW], the juvenile bypass system [JBS], or turbines [T]).

The proportion of fish passing JDA through the NTSW spill bays was estimated as

$$\widehat{\mathrm{NTSW}} = \frac{\hat{N}_{NTSW}}{\hat{N}_{NTSW} + \hat{N}_{TSW} + \hat{N}_{JBS} + \hat{N}_T}, \tag{2.13}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the *i*th route (i = TSW spill bays [TSW], non-TSW spill bays [NTSW], the juvenile bypass system [JBS], or turbines [T]).

The proportion of fish passing JDA through the JBS was estimated as

$$\widehat{\mathrm{JBS}} = \frac{\hat{N}_{JBS}}{\hat{N}_{NTSW} + \hat{N}_{TSW} + \hat{N}_{JBS} + \hat{N}_T}, \tag{2.14}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the *i*th route (i = TSW spill bays [TSW], non-TSW spill bays [NTSW], the juvenile bypass system [JBS], or turbines [T]).

The proportion of fish passing JDA through turbines was estimated as

$$\hat{\mathrm{T}} = \frac{\hat{N}_T}{\hat{N}_{NTSW} + \hat{N}_{TSW} + \hat{N}_{JBS} + \hat{N}_T}, \tag{2.15}$$

where $\hat{N}_i$ is the estimated abundance of acoustically tagged fish through the *i*th route (i = TSW spill bays [TSW], non-TSW spill bays [NTSW], the juvenile bypass system [JBS], or turbines [T]).

2.2 Route-Specific Survival Estimates

A virtual single release (VSR) model was used to estimate the route-specific survival rates of fish passing through JDA and BON in 2010, whereas the virtual paired release (VPR) model was used to estimate route-specific survival rates for fish passing through TDA in 2010 and through all three dams in 2011. Calculations are similar to those for estimating dam-passage survival, as described in compliance reports based on the VSR (e.g., Ploskey et al. 2011) or based on the VPR model (Skalski et al. 2012a, b, c). The only difference is that the virtual release is formed from fish known to have passed through a specific route through a dam instead of from all fish known to have passed a dam.

2.3 Forebay Survival Estimates

Forebay survival estimates were calculated as the ratio of forebay and dam-passage survival to dam-passage survival, to remove losses of fish that occurred in the common tailrace and tailwater. The variance in forebay passage survival was calculated using the delta method of Seber (1982):

$$Var(\hat{S}_{FB}) = \left(\frac{\hat{S}_{FB\&Dam}}{\hat{S}_{Dam}}\right)^2 \cdot \left[\left(\frac{Var(\hat{S}_{FB\&Dam})}{\hat{S}^2_{FB\&Dam}}\right) + \left(\frac{Var(\hat{S}_{Dam})}{\hat{S}^2_{Dam}}\right)\right] \tag{2.16}$$

where $Var(\hat{S}_{FB})$ = the variance in forebay passage survival

$\hat{S}_{FB\&Dam}$ = the survival of fish passing through the forebay and dam

$\hat{S}_{Dam}$ = the survival of fish passing through the dam only

$Var(\hat{S}_{FB\&Dam})$ = the variance in forebay- and dam-passage survival

Var_{Dam} = the variance in dam-passage survival.

3.0 Results

The results provided in this section are tabulated for the two fish stocks by performance measure. Subsequent, comprehensive technical reports scheduled for publication in late 2012 for each dam will present the same estimates and additional detailed information.

The tables provide of route-specific passage proportions and survival rates for the spring 2010 and 2011 studies (Table 3.1), averages and differences in passage proportions and TDA-passage survival for those years (Table 3.2), and forebay-passage survival estimates for 2010 (Table 3.3) and 2011 (Table 3.4).

Table 3.1. Route-specific passage proportions and survival rates for fish studied in 2010 and 2011. Estimates are presented by dam, species (CH1 = yearling Chinook salmon; STH = juvenile steelhead), and route of passage for each year. Standard errors (SEs) for estimates are presented in the next adjacent column. Other abbreviations include virtual single release (VSR) and virtual paired release (VPR), which describe the type of survival model used to make calculations.

Dam	Species	Route	Passage Proportion	SE	2010 Survival	SE	Passage Proportion	SE	2011 Survival[b]	SE
BON	CH1	B1 Sluiceway	0.019	0.0024	0.980[a]	0.0238	0.066	0.0034	0.969	0.0239
BON	CH1	B1 Turbines	0.039	0.0033	0.987[a]	0.0148	0.211	0.0055	0.968	0.0214
BON	CH1	Spillway	0.528	0.0086	0.935[a]	0.0061	0.566	0.0067	0.957	0.0207
BON	CH1	B2CC	0.190	0.0068	0.991[a]	0.0046	0.030	0.0023	0.994	0.0210
BON	CH1	B2 JBS	0.065	0.0043	0.981[a]	0.0104	0.045	0.0028	0.982	0.0243
BON	CH1	B2 Turbines	0.159	0.0063	0.957[a]	0.0093	0.082	0.0037	0.947	0.0231
TDA	CH1	Sluiceway	0.106	0.0068	0.993[b]	0.015	0.173	0.0058	0.991	0.0078
TDA	CH1	Spillway	0.841	0.0081	0.966[b]	0.0099	0.658	0.0073	0.961	0.0075
TDA	CH1	Turbines	0.053	0.0050	0.876[b]	0.0355	0.169	0.0057	0.930	0.0117
JDA	CH1	TSW	0.568	0.0106	0.952[a]	0.0006	0.238	0.0086	0.958	0.0107
JDA	CH1	Non-TSW	0.331	0.0101	0.950[a]	0.0083	0.399	0.0099	0.974	0.0082
JDA	CH1	JBS	0.063	0.0052	0.901[a]	0.0260	0.248	0.0087	0.993	0.0077
JDA	CH1	Turbines	0.037	0.0041	0.776[a]	0.0470	0.115	0.0065	0.910	0.0185
BON	STH	B1 Sluiceway	0.024	0.0026	0.963[a]	0.0260	0.082	0.0037	0.954	0.0281
BON	STH	B1 Turbines	0.034	0.0031	0.900[a]	0.0284	0.231	0.0056	0.936	0.0258
BON	STH	Spillway	0.406	0.0085	0.939[a]	0.0069	0.544	0.0066	0.957	0.0207
BON	STH	B2CC	0.306	0.0079	0.975[a]	0.0054	0.096	0.0039	0.994	0.0334
BON	STH	B2 JBS	0.059	0.0041	0.978[a]	0.0112	0.018	0.0018	0.940	0.0334
BON	STH	B2 Turbines	0.171	0.0065	0.911[a]	0.0125	0.029	0.0022	0.919	0.0334
TDA	STH	Sluiceway	0.077	0.0059	0.944[b]	0.0204	0.138	0.0053	1.010	0.0092
TDA	STH	Spillway	0.877	0.0073	0.958[b]	0.0098	0.754	0.0066	1.004	0.0083
TDA	STH	Turbines	0.046	0.0046	0.888[b]	0.0339	0.109	0.0047	0.919	0.0165
JDA	STH	TSW	0.719	0.0097	0.972[a]	0.0040	0.323	0.0094	0.989	0.0070
JDA	STH	Non-TSW	0.169	0.0081	0.944[a]	0.0123	0.305	0.0093	0.990	0.0074
JDA	STH	JBS	0.094	0.0063	0.943[a]	0.0170	0.332	0.0095	1.003	0.0064
JDA	STH	Turbines	0.018	0.0029	0.694[a]	0.0740	0.040	0.0039	0.797	0.0418

(a) A VSR model was used to estimate route-specific survival rates of fish passing through JDA and BON in 2010.
(b) A VPR model was used to estimate route-specific survival rates of fish passing through TDA in 2010 and all three dam in 2011.

Table 3.2. Average route-specific passage proportions and virtual single or virtual paired release survival estimates for 2010 and 2011 studies by dam, species, and route of passage. Survival rates were only averaged for The Dalles Dam (TDA) where the virtual paired release model was used in both years. Different survival models were used for 2010 and 2011 at Bonneville Dam (BON) and John Day Dam (JDA) so estimates for those dams were not averaged.

Dam	Species	Route	Average Passage Proportion	|Difference| Passage Proportion	Average Survival	|Difference| Survival
BON	CH1	B1 Sluiceway	0.043	0.0472		
BON	CH1	B1 Turbines	0.125	0.1728		
BON	CH1	Spillway	0.547	0.0380		
BON	CH1	B2CC	0.110	0.1596		
BON	CH1	B2 JBS	0.055	0.0204		
BON	CH1	B2 Turbines	0.120	0.0778		
TDA	CH1	Sluiceway	0.139	0.0671	0.992	0.0014
TDA	CH1	Spillway	0.749	0.1824	0.963	0.0054
TDA	CH1	Turbines	0.111	0.1153	0.903	0.0238
JDA	CH1	TSW	0.403	0.3306		
JDA	CH1	Non-TSW	0.365	0.0676		
JDA	CH1	JBS	0.156	0.1847		
JDA	CH1	Turbines	0.076	0.0783		
BON	STH	B1 Sluiceway	0.053	0.0579		
BON	STH	B1 Turbines	0.133	0.1966		
BON	STH	Spillway	0.475	0.1387		
BON	STH	B2CC	0.201	0.2100		
BON	STH	B2 JBS	0.038	0.0414		
BON	STH	B2 Turbines	0.100	0.1419		
TDA	STH	Sluiceway	0.107	0.0609	0.977	0.0654
TDA	STH	Spillway	0.815	0.1232	0.981	0.0455
TDA	STH	Turbines	0.077	0.0622	0.903	0.0174
JDA	STH	TSW	0.521	0.3965		
JDA	STH	Non-TSW	0.237	0.1360		
JDA	STH	JBS	0.213	0.2388		
JDA	STH	Turbines	0.029	0.0217		

Table 3.3. Estimates of dam-passage survival, forebay- and dam-passage survival, and forebay-passage survival by dam and species in 2010. The standard error (SE) in forebay passage survival is listed in the sixth column and the seventh column indicates the type of survival model used (VSR = virtual single release; VPR = virtual paired release).

Dam	Species	Dam Passage Survival	Forebay & Dam Passage Survival	Forebay Survival	SE	Model
BON	CH1	0.9520	0.9510	0.9989	0.0059	VSR
TDA	CH1	0.9641	0.9620	0.9978	0.0141	VPR
JDA	CH1	0.9370	0.9340	0.9968	0.0081	VSR
BON	STH	0.9450	0.9440	0.9989	0.0064	VSR
TDA	STH	0.9534	0.9526	0.9992	0.0144	VPR
JDA	STH	0.9500	0.9480	0.9979	0.0073	VSR

Table 3.4. Estimates of dam-passage survival, forebay-and-dam-passage survival, and forebay-passage survival by dam and species in 2011. The standard error (SE) in forebay passage survival is listed in the last column. All 2011 estimates were based on the virtual paired release (VPR) survival model.

Dam	Species	Dam Passage Survival	Forebay & Dam Passage Survival	Forebay Survival	SE
BON	CH1	0.9597	0.9528	0.9928	0.0059
TDA	CH1	0.9600	0.9596	0.9996	0.0106
JDA	CH1	0.9676	0.9646	0.9969	0.0092
BON	STH	0.9647	0.9589	0.9940	0.0063
TDA	STH	0.9952	0.9947	0.9995	0.0118
JDA	STH	0.9867	0.9801	0.9933	0.0080

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