

Contents

Preface	iii
Executive Summary	v
Acknowledgments.....	ix
Acronyms and Abbreviations	xi
1.0 Introduction	1.1
1.1 Background	1.1
1.2 Study Objectives	1.2
2.0 Methods	2.1
2.1 Release-Recapture Design.....	2.1
2.2 Handling, Tagging, and Release Procedures.....	2.3
2.2.1 Acoustic Tags.....	2.3
2.2.2 Fish Source.....	2.3
2.2.3 Tagging Procedure	2.3
2.2.4 Release Procedures.....	2.3
2.3 Acoustic Signal Processing.....	2.4
2.4 Statistical Methods.....	2.5
2.4.1 Estimation of Dam Passage Survival	2.5
2.4.2 Tag-Life Analysis.....	2.6
2.4.3 Tests of Assumptions	2.7
2.4.4 Forebay-to-Tailrace Survival	2.8
2.4.5 Estimation of Travel Times.....	2.8
2.4.6 Estimation of Spill Passage Efficiency	2.8
3.0 Results	3.1
3.1 Discharge and Spill Conditions.....	3.1
3.2 Fish Size Distribution.....	3.1
3.3 Handling Mortality and Tag Shedding.....	3.4
3.4 Tag-Life Corrections	3.5
3.5 Arrival Distributions	3.5
3.6 Downstream Mixing.....	3.5
3.7 Examination of Tagger Effects	3.10
3.8 Estimates of Dam Passage Survival.....	3.12
3.8.1 Yearling Chinook Salmon.....	3.13
3.8.2 Steelhead	3.14
3.9 Estimates of Forebay-to-Tailrace Passage Survival.....	3.14
3.10 Forebay Residence Time.....	3.14
3.11 Tailrace Egress Time.....	3.16
3.12 Estimates of Spill Passage Efficiency	3.18

1.2 Study Objectives

The purpose of spring 2010 compliance monitoring at The Dalles Dam was to estimate performance measures for yearling Chinook salmon and steelhead smolts as outlined in the FCRPS BiOp and Fish Accords. For each fish stock, the following metrics were estimated using the Juvenile Salmon Acoustic Telemetry System (JSATS) technology:

- Dam passage survival, defined as survival from the upstream face of the dam to a standardized reference point in the tailrace. Performance¹ should be $\geq 96\%$ survival for spring stocks (i.e., yearling Chinook salmon and steelhead). Survival should be estimated with a standard error (SE) $\leq 1.5\%$.
- SPE, defined in the Fish Accords as the fraction of fish going through the dam via the spillway and surface flow outlets.
- Forebay residence time, defined as the average time smolts take to travel the last 100 m upstream of the dam before passing into the dam, i.e., from the 100-m mark to the dam face.
- Tailrace egress time, defined as the average time smolts take to travel from the dam to the downstream tailrace boundary, i.e., tailrace array 2 km downstream of the dam.
- Forebay-to-tailrace survival, defined as survival from a forebay array 2 km upstream of the dam to a tailrace array 2 km downstream. The forebay-to-tailrace survival estimate satisfies the “BRZ-to-BRZ” survival estimate called for in the Fish Accords.

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

¹ Performance as defined in the 2008 FCRPS BiOp, Section 6.0.

2.0 Methods

Study methods involved fish release and recapture; the associated fish handling, tagging, and release procedures; acoustic signal processing; and statistical and analytical approaches.

2.1 Release-Recapture Design

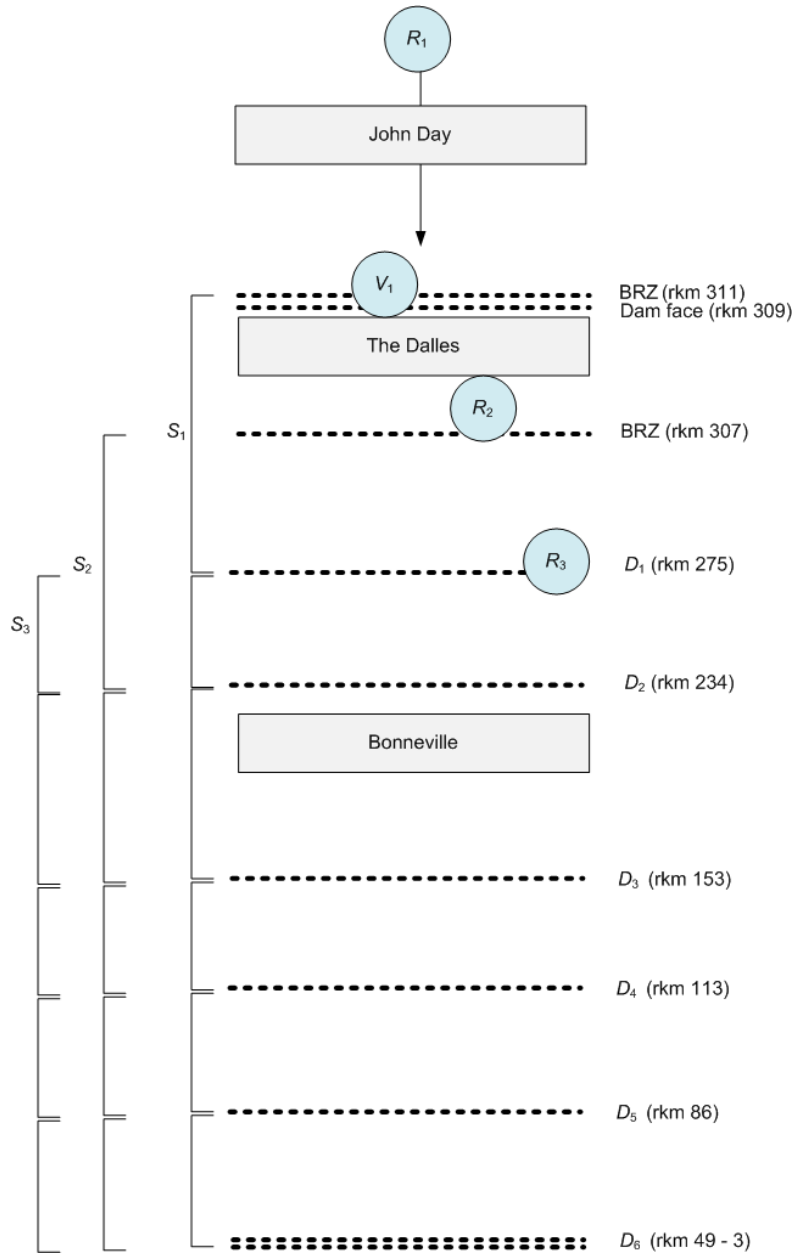
The release-recapture design used to estimate dam passage survival at The Dalles Dam consisted of a novel combination of a virtual release (V_1) of fish at the face of the dam and a paired release below the dam (Figure 2.1) (Skalski et al. 2010). Tagged fish released above John Day Dam were used to supply a source of fish known to have arrived alive at the face of The Dalles Dam. By releasing the fish far enough upstream, they should have arrived at the dam in a spatial pattern typical of run-of-river (ROR) fish. This virtual-release group was then used to estimate survival through the dam and part of the way through the next reservoir (i.e., river kilometer [rkm] 275) (Figure 2.1). To account and adjust for this extra reach mortality, a paired release below The Dalles Dam (i.e., R_2 and R_3) (Figure 2.1) was used to estimate survival in that segment of the reservoir below the dam. Dam passage survival was then estimated as the quotient of the survival estimates for the virtual release to that of the paired release. The sizes of the releases of the acoustic-tagged fish used in the dam passage survival estimates are summarized in Table 2.1.

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

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

The same release-recapture design was also used to estimate forebay-to-tailrace survival, except that the virtual-release group was constructed of fish known to have arrived at the forebay array. The same below-dam paired release was used to adjust for the extra release mortality below the dam as was used to estimate dam passage survival.

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



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

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

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

A total of 49 acoustic tags were randomly sampled from the tags used in the spring season for a tag-life assessment. The tags were activated, held in river water, and monitored continuously until they failed. The information from the tag-life study was used to adjust the perceived survival estimates from the Cormack-Jolly-Seber release-recapture model according to the methods of Townsend et al. (2006).

2.2 Handling, Tagging, and Release Procedures

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

2.2.1 Acoustic Tags

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

2.2.2 Fish Source

The yearling Chinook salmon and steelhead used in the study were all obtained from the John Day Dam juvenile bypass system. The Pacific States Marine Fisheries Commission diverted fish from the juvenile bypass system into an examination trough, as described by Martinson et al. (2006). Fish ≥ 95 mm in length without malformations or excessive descaling ($> 20\%$) were selected for tagging.

2.2.3 Tagging Procedure

The fish to be tagged were anesthetized in an 18.9-L “knockdown” bucket with fresh river water and MS-222 (tricaine methanesulfonate; 80 to 100 mg/L). Anesthesia buckets were refreshed repeatedly to maintain the temperature within $\pm 2^\circ\text{C}$ of current river temperatures. Each fish was weighed and measured before tagging.

During surgery, each fish was placed ventral side up and a gravity-fed anesthesia supply line was placed into its mouth. The dilution of the “maintenance” anesthesia was 40 mg/L. Using a surgical blade, a 6- to 8-mm incision was made in the body cavity between the pelvic girdle and pectoral fin. A passive integrated transponder (PIT) tag was inserted followed by an acoustic tag. Both tags were inserted toward the anterior end of the fish. The incision was closed using 5-0 Monocryl suture.

After closing the incision, the fish were placed in a dark 18.9-L transport bucket filled with aerated river water. Fish were held in these buckets for 18 to 24 h before being transported for release into the river. The loading rate was five fish per bucket.

2.2.4 Release Procedures

All fish were tagged at John Day Dam and transported by truck to the three release locations (Figure 2.1). Transportation routes were adjusted to provide equal travel times to each release location from John Day Dam. Upon arriving at a release site, fish buckets were transferred to a boat for transport to the in-

river release location. There were five release locations at each release cross section (Figure 2.1), and equal numbers of buckets of fish were released at each of the five locations for a given cross-section.

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

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

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

2.3 Acoustic Signal Processing

Transmissions of JSATS tag codes received on cabled and autonomous hydrophones were recorded in raw data files. These files were downloaded periodically and transported to PNNL’s North Bonneville offices for processing. Receptions of tag codes within raw data files were processed to produce a data set of accepted tag-detection events. For cabled arrays, detections from all hydrophones at a dam were combined for processing. The following three filters were used for data from cabled arrays:

- **Multipath filter:** For data from each individual cabled hydrophone, all tag-code receptions that occur within 0.156 seconds after an initial identical tag code reception were deleted under the assumption that closely lagging signals are multipath. Initial code receptions were retained. The delay of 0.156 seconds was the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and was computed as $2(\text{PRI_Window} + 12 \times \text{PRI_Increment})$. Both PRI_Window and PRI_Increment were set at 0.006, which was chosen to be slightly larger than the potential rounding error in estimating PRI to two decimal places.
- **Multi-detection filter:** Receptions were retained only if the same tag code was received at another hydrophone in the same array within 0.3 seconds because receptions on separate hydrophones within 0.3 seconds (about 450 m of range) were likely from a single tag transmission.
- **PRI filter.** Only those series of receptions of a tag code (or “messages”) that were consistent with the pattern of transmissions from a properly functioning JSATS acoustic tag were retained. Filtering rules were evaluated for each tag code individually, and it was assumed that only a single tag would be transmitting that code at any given time. For the cabled system, the PRI filter operated on a message, which included all receptions of the same transmission on multiple hydrophones within 0.3 seconds. Message time was defined as the earliest reception time across all hydrophones for that message. Detection required that at least six messages were received with an appropriate time interval between the leading edges of successive messages.

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

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

The output of the filtering processes for both cabled and autonomous hydrophones was a data set of events that summarized accepted tag detections for all times and locations where hydrophones were operating. Each unique event record included a basic set of fields that indicated the unique identification number of the fish, the first and last detection time for the event, the location of detection, and how many messages were detected within the event. This list was combined with accepted tag detections from the autonomous arrays and PIT-tag detections for additional quality assurance/quality control analysis prior to survival analysis. Additional fields capture specialized information, where available. One such example was route of passage, which was assigned a value for those events that immediately precede passage at a dam based on spatial tracking of tagged fish movements to a location of last detection. Multiple receptions of messages within an event can be used to triangulate successive tag position relative to hydrophone locations.

One of the most important quality control steps was to examine the chronology of detections of every tagged fish on all arrays above and below the dam-face array to identify any detection sequences that deviate from the expected upstream to downstream progression through arrays in the river. Except for possible detections on forebay entrance arrays after detection on a nearby dam-face array 1 to 3 km downstream, apparent upstream movements of tagged fish between arrays that were greater than 5 km apart or separated by one or more dams were very rare ($< 0.015\%$) and probably represented false positive detections on the upstream array. False positive detections usually will have close to the minimum number of messages and were deleted from the event data set before survival analysis.

Three-dimensional tracking of JSATS-tagged fish in the immediate forebay of The Dalles Dam was used to determine routes of passage to estimate spill passage efficiency. Acoustic tracking is a common technique in bioacoustics based on time-of-arrival differences among different hydrophones. Usually, the process requires a three-hydrophone array for 2D tracking and a four-hydrophone array for 3D tracking. For this study, only 3D tracking was performed. The methods were similar to those described by Weiland et al. (2010) for John Day Dam.

2.4 Statistical Methods

2.4.1 Estimation of Dam Passage Survival

Maximum likelihood estimation was used to estimate dam passage survival at The Dalles Dam. The capture histories from all of the replicate releases, both daytime and nighttime, were pooled for the

3.12 Estimates of Spill Passage Efficiency

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

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

and for steelhead smolts

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

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

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

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

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

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

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