PNNL-16560
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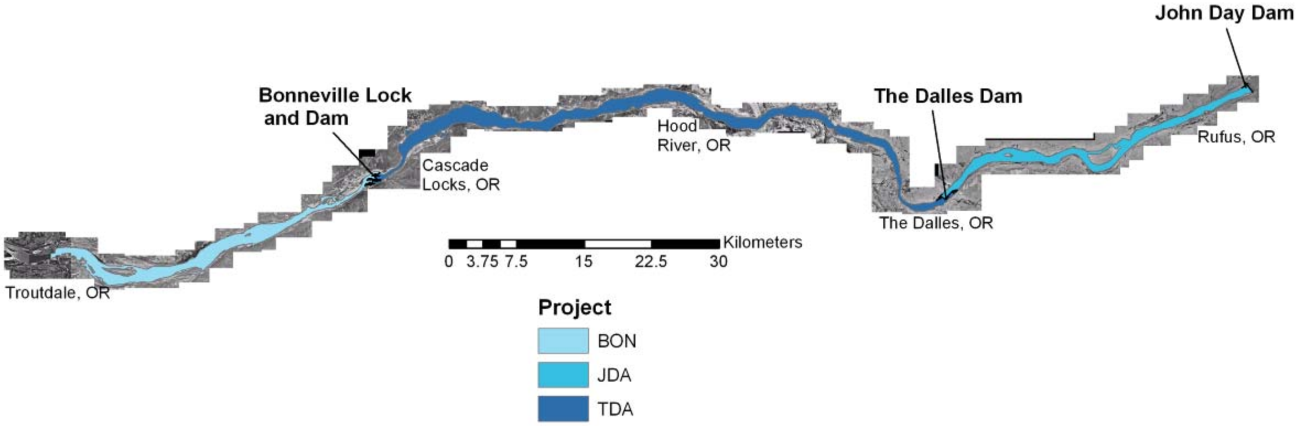
Acoustic Telemetry Studies of Juvenile Chinook Salmon Survival at the Lower Columbia Projects in 2006



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FINAL REPORT
December 2007

Prepared for the
U.S. Army Corps of Engineers
Under a Related Services Agreement
With the U.S. Department of Energy
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Pacific Northwest National Laboratory
Operated by Battelle for the
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Prepared for the U.S. Army Corps of Engineers
Portland District, Portland, Oregon
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Pacific Northwest National Laboratory
Richland, Washington 99352

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(c) National Marine Fisheries Service

Summary

In 2006, the Portland District of the U.S. Army Corps of Engineers (USACE) contracted with the Pacific Northwest National Laboratory (PNNL) to conduct three studies using acoustic telemetry to estimate detection probabilities and survival of juvenile Chinook salmon at three hydropower projects on the lower Columbia River. The primary goals were to estimate detection and survival probabilities based on sampling with Juvenile Salmon Acoustic Telemetry System (JSATS) equipment, assess the feasibility of using JSATS for survival studies, and estimate sample sizes needed to obtain a desired level of precision in future studies.

Tagging

We conducted acoustic-telemetry survival studies on yearling and sub-yearling Chinook salmon at John Day Dam (JDA), The Dalles Dam (TDA), and Bonneville Dam (BON). We surgically implanted 2,501 yearling Chinook salmon in spring and 2,502 sub-yearling Chinook salmon in summer with passive integrated transponder (PIT) and JSATS acoustic tags. Fish were collected and tagged at the John Day Dam Smolt Monitoring Facility (SMF), and unintentional tagging mortality averaged 0.6% in spring and 0.7% in summer.

Tagging seasons encompassed the peaks of the spring and summer runs of juvenile Chinook salmon. The spring tagging season was from May 13 to June 6, 2006, and targeted the yearling Chinook run, which peaked between May 20 and June 1, 2006. A 95-mm minimum length limitation on tagging did not restrict the lengths of fish that could be tagged in the spring, and the length frequencies of tagged and untagged yearling Chinook salmon in the juvenile bypass system (JBS) samples were very similar. The summer tagging season was from June 11 to July 13, 2006, and targeted the subyearling Chinook run, which peaked around July 1. The 95-mm minimum tagging length effectively eliminated about 23% of the run-of-river sub-yearlings from the sample because they were too small to tag without increasing tagging mortality. Tagging must include 80 to 100 mm subyearlings to be fully representative of the run-of-river population at JDA in summer.

All fish tagged in this study and released at or below JDA were implanted with JSATS tags that transmitted a coded signal transmitting once every 5 seconds (5 s tags) that were expected to last about 30 days, and fish that were released into the Snake River by other studies were implanted with tags that transmitted once every 10 s. We conducted a tag-life study using 100 10 s tags and 100 5 s tags randomly sampled from lots allocated to survival studies. The tag-life study verified that most tags lasted about as long as expected. All 10-s tags sampled from lots of tags implanted in Snake River fish lasted at least 57 days relative to an expected 55 days, and all the 5-s tags exceeded the expected 30-day life by about 5 days. No tag-life correction was needed or used for the 2006 survival studies in spring or summer because over 99% of tagged fish exited the study area before tags expired. Tag life and survivorship curves are presented in Appendix A.

Fish Releases and Detection Histories

In spring, we made eight releases each at three JDA locations: JDA Turbine Intake 9C (totaling 497 yearlings), the Front Roll downstream of Turbine 9C (500 yearlings), and the JDA Tailrace (481 yearlings). The Front Roll and Tailrace releases at JDA were designed to serve as controls for turbine-released fish in a paired-release survival model. We also made eight releases totaling 978 yearlings into the TDA Tailrace. In addition to our releases, a separate tag-effects study made two releases totaling 996 yearling Chinook salmon into the Lower Granite Dam (LGR) Tailrace on the Snake River, and an estuary survival study made four releases totaling 972 yearlings into the BON Tailrace.

In summer, we made five releases totaling 299 subyearlings in the JDA Tailrace and 10 releases totaling 2,179 subyearlings into the TDA Tailrace. A Lower Monumental Dam survival study made 10 releases totaling 1,949 subyearlings into the tailrace of Little Goose Dam (LGS) on the Snake River, and the Estuary Survival Study made 10 releases totaling 2,002 subyearlings into the BON Tailrace.

We deployed three arrays of JSATS autonomous hydrophones in the tailwater of each dam and detections of tagged fish were used to develop spatial and temporal detection histories for every released tag to populate various survival models. An array is a group of hydrophones deployed across the entire width of the river to detect live, acoustically tagged fish passing downstream. Rules for classifying a series of properly decoded signals as a tag detection were as follows:

1. Tag codes were detected downstream of the release site.
2. Tag codes were detected after the release date and time.
3. Tag-decode intervals were 8 to 32 seconds for 10-s tags and 3 to 22 seconds for 5-s tags.
4. There were four tag decodes in 120 s for 10-s tags and four decodes in 60 s for 5-s tags.

Downstream survival arrays detected no intentionally tagged and released dead fish out of 23 released below JDA, 45 below TDA, and 30 below BON.

Detection and Survival Results

Results obtained in spring and summer 2006 accomplished the study goals listed above. Based on detection histories, we estimated detection and survival probabilities using a variety of single and paired-release models, and results for preferred array combinations are presented in Table S.1. The JDA Tailrace releases were used to populate single-release survival models for downstream reaches and for post-hoc pairing with TDA Tailrace releases to populate a paired-release model for estimating TDA Project survival. Similarly, our TDA Tailrace releases and BON Tailrace releases by the Estuary Survival Study were used to populate single-release models for downstream reaches and also were paired to create a post-hoc, paired-release model for evaluating BON Project survival. Multi-node detections contributed to high detection probabilities for Columbia River releases in the JDA and TDA tailwaters, in contrast to lower detection probabilities observed at arrays in the BON Tailwater (Table S.2). Part of the low detectability in the BON Tailwater resulted from equipment problems but some of it was undoubtedly related to relatively shallow bathymetry, islands, and extensive sand bars, which limit the range of sound propagation.

Table S.1. Detection and Survival Probability by Season, Release Location, and Reach, with Information on Numbers of Fish, Effect of Interest, Number of Dams Passed, and Survival Models. Numbers in parentheses after probabilities are lower and upper 95% confidence intervals (CIs).

Season	Release Location	Number of Fish	Reach	Effect	Dams Passed	Model	Detection Probability	Survival Probability
Spring	LGR TR	996	To 1J		5	Single	89.6% (86.7, 92.5)	48.7% (45.6, 51.9)
Spring	LGR TR	996	1J to 1T		1 TDA	Single	77.0% (72.9, 81.1)	87.7% (84.5, 91.0)
Spring	JDA FR	497	To 1J			Single	98.9% (98.0, 99.9)	98.3% (97.1, 99.5)
Spring	JDA FR	497	1J to 1T		1 TDA	Single	91.7% (89.2, 94.3)	92.9% (90.6, 95.3)
Spring	JDA IN	500	To 1J		1 JDA	Single	96.1% (94.2, 98.0)	87.7% (84.8, 90.6)
Spring	JDA IN	500	1J to 1T		1 TDA	Single	92.0% (89.3, 94.7)	93.4% (90.9, 95.8)
Spring	JDA TR	481	To 1J			Single	97.8% (96.4, 99.2)	97.5% (96.0, 98.9)
Spring	JDA TR	481	1J to 1T		1 TDA	Single	93.4% (91.0, 95.7)	94.3% (92.1, 96.4)
Spring	JDA TR	481	To 1T		1 TDA	Single	93.4% (91.0, 95.7)	91.8% (89.4, 94.3)
Spring	TDA Virtual	1,079	Forebay to 1T	TDA Dam & Tailwater	1 TDA	Single	93.0% (91.4, 94.6)	94.7% (93.4, 96.1)
Spring	TDA TR	978	To 1T			Single	97.5% (96.5, 98.5)	98.9% (98.3, 99.6)
Spring	TDA TR	978	1T to 2T			Single	99.5% (98.9, 100.1)	99.2% (98.5, 99.9)
Spring	TDA TR	978	To 1B		1 BON	Single	63.3% (59.8, 66.9)	90.0% (87.2, 92.9)
Spring	BON Virtual	957	Forebay to 1B	BON Dam & Tailwater	1 BON	Single	63.6% (60.1, 67.2)	91.9% (89.1, 94.6)
Spring	BON TR	972	To 1B			Single	76.0% (72.8, 79.2)	85.1% (82.4, 87.7)
Spring	BON B2CC*	78	To 1B		1 BON	Single	61.1% (48.6, 73.5)	94.6% (84.6, 104.6)
Spring	BON B2JBS*	42	To 1B		1 BON	Single	53.3% (35.5, 71.2)	89.3% (73.0, 105.6)
Spring	BON Spill*	134	To 1B		1 BON	Single	63.5% (54.3, 72.8)	94.1% (87.1, 101.1)
Spring	JDA FR & JDA TR	497 481	To 1J	FR to TR		Paired	98.4% (97.5, 99.2)	101.0% (99.0, 102.9)
Spring	JDA IN & JDA FR	500 497	To 1J	Intake to FR		Paired	96.1% (94.2, 98.0) 98.9% (98.0, 99.9)	89.2% (86.1, 92.4)
Spring	JDA IN & JDA TR	500 481	To 1J	Intake to TR		Paired	97.0% (95.8, 98.1)	89.9% (86.6, 93.2)
Spring	JDA TR & TDA TR	481 978	To 1T	TDA Project	1 TDA	Paired	93.4% (91.0, 95.7) 97.5% (96.5, 98.5)	92.9% (90.2, 95.4)
Spring	TDA TR & BON TR	978 972	To 1B	BON Project	1 BON	Paired	63.3% (59.8, 66.9) 76.0% (72.8, 79.2)	105.8% (96.6, 115.1)
Spring	BON B2CC & BON TR	78 972	To 1B	BON B2CC to BON TR	1 BON	Paired	61.1% (48.6, 73.5) 76.0% (72.8, 79.2)	111.2% (98.9,123.5)
Spring	BON B2 JBS & BON TR	42 972	To 1B	BON B2 JBS to BON TR	variable	Paired	53.3% (35.5, 71.2) 76.0% (72.8, 79.2)	105.0% (85.5, 124.4)
Spring	BON Spill & BON TR	134 972	To 1B	BON Spill to BON TR	variable	Paired	63.5% (54.3, 72.8) 76.0% (72.8, 79.2)	110.6% (101.7,119.6)
Summer	LGS TR	1,949	To 1J		4	Single	94.8% (92.3, 97.3)	19.6% (8.6, 30.6)
Summer	LGS TR	1,949	1J to 1T		1 TDA	Single	99.4% (97.2, 101.6)	60.3% (40.0, 80.7)
Summer	JDA TR	299	To 1J			Single	82.8% (78.5, 87.1)	99.4% (98.5, 100.4)
Summer	JDA TR	299	1J to 1T		1 TDA	Single	98.8% (97.4, 100.2)	99.6% (98.8, 100.4)
Summer	TDA Virtual	279	Forebay to 1T	TDA Dam & Tailwater	1 TDA	Single	98.8% (97.4, 100.2)	86.1% (82.0, 90.2)
Summer	TDA TR	2,179	To 1T			Single	99.2% (98.7, 99.6)	97.0% (96.2, 97.7)
Summer	TDA TR	2,179	1T to 2T			Single	100% (100, 100)	95.8% (95.0, 96.7)
Summer	BON Virtual	2,022	Forebay to 1B	BON Dam & Tailwater	1 BON	Single	81.3% (79.2, 83.5)	86.9% (85.0, 88.8)
Summer	BON TR	1,957	To 1B			Single	82.4% (80.5, 84.3)	94.7% (93.3, 96.1)
Summer	BON B2CC*	91	To 1B		1 BON	Single	87.7% (79.8, 95.7)	95.3% (89.1, 101.4)
Summer	BON B2 JBS*	189	To 1B		1 BON	Single	82.3% (75.3, 89.4)	90.7% (84.6, 96.8)

Season	Release Location	Number of Fish	Reach	Effect	Dams Passed	Model	Detection Probability	Survival Probability
Summer	BON Spill*	706	To 1B		1 BON	Single	82.3% (78.7, 85.9)	85.8% (82.5, 89.1)
Summer	BON B2CC* & BON TR	91 1,957	To 1B	B2CC to BON TR	variable	Paired	87.7% (79.8, 95.7) 82.4% (80.5, 84.3)	100.6% (94.0, 107.2)
Summer	BON B2 JBS* & BON TR	189 1,957	To 1B	B2 JBS to BON TR	variable	Paired	82.3% (75.3, 89.4) 82.4% (80.5, 84.3)	95.9% (89.3, 102.4)
Summer	BON Spill* & BON TR	706 1,957	To 1B	Spill to BON TR	variable	Paired	93.4% (91.0, 95.7) 82.4% (80.5, 84.3)	90.6% (86.9, 94.4)
Summer	JDA TR & TDA TR	299 2,179	To 1T	TDA Project	1 TDA	Paired	93.4% (91.0, 95.7) 97.5% (96.5, 98.5)	84.9% (76.1, 93.8)
Summer	TDA TR & BON TR	2,179 1,957	To 1B	BON Project	1 BON	Paired	63.3% (59.8, 66.9) 76.0% (72.8, 79.2)	85.2% (80.4, 90.1)
*Pooled releases based upon route-specific detections.								

Table S.2. Means and Standard Errors of Mean Detection Probabilities for Columbia River Releases of Chinook Salmon in Spring and Summer 2006. These estimates were calculated from pooled detection estimates.

Statistic	To 1J	To 1T	To 2T	To 1B	To 2B
Spring					
Mean	96.2	91.3	99.7	67.6	72.5
SE of Mean	3.1	5.3	0.3	5.9	5.9
Mean	97.2	99.0	100.0	80.2	N/A
SE of Mean	2.4	0.2	0.0	11.4	N/A

A Z-test indicated that the single-release survival estimate for Intake-released yearlings was significantly lower than that for yearlings released in the Front Roll (Z=-6.385; P < 0.0001; n = 8), and it was significantly lower than that for yearlings released in the Tailrace (Z=-5.843; P < 0.0001; n = 8). However, single release-survival estimates from the Front Roll and Tailrace releases to the primary array did not differ significantly (Z = 1.131 < 1.645; P = 0.129; n = 8). A paired-release survival estimate for yearlings passing through Intake 9C to the Tailrace was significantly lower than a paired-release estimate for yearlings released in the Front Roll and then traveling to the Tailrace release site (Z = -4.945; P < 0.0001; n = 8.

We compared the probability of fish being detected on any one of three downstream JSATS survival arrays with reported probabilities from some previous radio telemetry studies. The 2006 JSATS arrays usually performed as well as or better than radio telemetry arrays in the JDA and TDA tailwaters, and underperformed radio arrays in the BON Tailwater, particularly in spring. Most of the probabilities of detection on at least one of all arrays in a tailwater exceeded 80% for each method, which was sufficient to provide confidence in survival estimates. The probability of detection on one of three arrays includes survival and detection probabilities because fish may die or pass all three arrays undetected but alive.

Our effort at modeling the required sample sizes for future studies relied on observed detection and survival probabilities to estimate precision as a function of sample size (Appendix G, H, I, and J). This approach assumes that equal effort will be expended to detect fish, e.g., similar numbers of autonomous nodes with similar ranges of detection. These tables should be useful for conducting power analyses for future studies that have a specific study design in mind. However, it does not and cannot account for the potential benefits of increasing detection probabilities by increasing the number of nodes or node performance. Based upon high detection probabilities for the JDA and TDA tailwater arrays, there is little room for improving detection by increasing the number of autonomous receivers at these projects.

However, deploying additional nodes below BON, where detection probabilities averaged 67.6% in spring and 80.2% in summer, has the potential to significantly increase detectability and to reduce the need for large numbers of tags for future studies employing paired-release models. Modeling for BON indicates that high precision can be obtained for single-release models with the existing sampling effort and a reasonable number of tags in either season. However, modeling precision for paired-release models indicated that buying a lot more tags will not improve precision significantly. The density of detection nodes below BON will have to be increased to achieve a one-half 95% CI of 2% on paired-release survival estimates with a reasonable number of tags. The tradeoff between buying tags and buying autonomous nodes can easily be calculated and compared to find an optimum balance between detectability and sample size. Our recommendation is to make certain that arrays are populated fully or even overpopulated with receivers to assure high detection probabilities before buying more tags to increase precision, because the latter usually will be much more costly than the former until a high detection probability is achieved.

The choice of array locations and spacing between arrays can provide savings for future studies seeking to evaluate survival at multiple projects. We deployed nine survival arrays (three per tailwater) to thoroughly assess detection and survival probabilities, but our results indicate that all survival estimates could have been obtained with just six arrays. Those arrays would include

1. One in the JDA Tailwater, serving as a primary survival array (1J) and as a TDA forebay array.
2. Two in the TDA Tailwater (2006 arrays 1T and 3T), where 1T would serve as a secondary for JDA releases or as a primary for TDA virtual and tailrace releases, and 3T would serve as a tertiary for JDA releases, a secondary for TDA virtual and tailrace releases, and as a forebay array for constructing BON virtual releases.
3. Three in the BON Tailwater.

We compared survival estimates calculated from detections on “as planned” arrays in each tailwater (Appendix K) with estimates based on detections on “preferred” arrays in Table S.1 and found no significant differences in any estimates. Therefore, we recommend that future studies maximize return on investment by using the six arrays described above when multiple projects are being studied. Our results also indicate that, if a single study is planned, three survival arrays can be located in a single tailwater and can be relatively close together without detriment, as long as detections cannot be made simultaneously on two successive arrays. However, spreading out three arrays within a pool will provide greater inference about survival in the first two river reaches.

Tests of Model Assumptions

There were no significant trends in detection probabilities or survival through time in spring, so we were able to pool estimates for the season, but in summer there was a significant decline in survival through time. The value of pooled survival estimates for summer is questionable, given apparent decreases in survival or residualization. The decline in survival during summer has been observed before (e.g., Counihan et al. 2006a).

Paired release models assume that treatment and control release groups pass through the common river reach at about the same time of day and under similar conditions. In spring, the paired release models for JDA releases were the only pairs designed and planned before the 2006 study began and, although homogeneity tests were significant because of Chi square test sensitivity to large sample sizes, we know that treatment and control fish mixed and experienced similar tailwater conditions relative to time of day. Survival processes also were stable throughout the spring season.

However, there were significant departures from mixing for pairings of JDA Tailrace and TDA Tailrace Releases and for pairings of TDA and BON tailrace releases, respectively, because these pairings were made post hoc without benefit of planning to synchronize timing. Research at the three projects was originally conceived and proposed as separate pilot studies, and post-hoc pairing was our way of trying to get the most from available data. Nevertheless, spring data from the next reach downstream of the reach from TDA to Array 1T (i.e., from 1T to 2T) suggest that survival processes were stable regardless of differences in the time of arrival. In addition, high river flow throughout spring 2006 resulted in a consistency of discharge among days and among hours that may not occur in an average or low-flow year, and this likely contributed to stability in survival processes. Similarly, survival estimates for TDA and BON tailrace releases from Array 1B to 2B did not differ from each other and had no seasonal trend, which again suggests that survival processes were stable for the two release groups in spring.

In summer, mixing violations for post-hoc pairings of JDA and TDA releases may not have been as detrimental as goodness-of-fit-tests indicated, although we acknowledge that mixing could be improved. The JDA and TDA Tailrace releases used to estimate project survival for TDA showed significant ($P < 0.001$) departures from mixing in summer, primarily because releases after June 27 in the TDA Tailrace had no treatment counterparts. Violations raised concerns about interpreting pair-release project survival models for TDA, so we recomputed estimates using only data acquired during the period of concurrent releases, and the resulting survival estimate of 82.9% (95% CI =78.6, 87.2) did not differ significantly from the estimate based on all releases (85.2%; 95% CI =82.8, 87.7). Hourly time-of-arrival data indicated that the slowest and fastest fish from the JDA or TDA groups could arrive any hour of the day, but there was a 4-h difference in mean arrival time that may have affected survival conditions. A summer paired-release estimate of 83.7% for BON Project survival for concurrent releases is considered reliable because subyearlings in the concurrent summer releases from TDA and BON tailraces traversed the BON Tailwater at about the same time of day, even though all release data indicated significant differences in arrival distributions. However, the point estimate is not particularly meaningful given the significant decrease in survival during summer.

Because of mixing violations observed for some of the post-hoc paired releases, we used time-of-travel estimates as a function of river discharge each season to derive equations for predicting appropriate lag times between upstream and downstream releases as a function of river discharge. In the future, researchers can use derived equations as a starting place to predict appropriate lag times from forecasts of river discharge. Data on travel times from years with a lower range of discharge also should be consulted to increase the appropriateness of lag estimates for normal to low-water years. River discharge was higher than average throughout spring and the first half of summer.

Survival models assume that upstream and downstream detections do not affect estimates of detection or survival, and Burnham et al. (1987) Test 2 and Test 3 are used to evaluate that assumption. There is some question about whether these tests are appropriate for active tag studies that have high detection probabilities and no physical mechanism like recapture or re-handling to cause the effect.

In spring, two out of the three JDA releases had significant ($P < 0.10$ Burnham et al. 1987) Test 2 results, but none of the tests was significant for the JDA, TDA, and BON Tailrace releases. This was not surprising because there was no physical mechanism associated with detections to affect downstream detection performance. For the Intake 9C release, pooled data had a highly significant Test 2 ($P = 0.0001$), but the Chi square test statistic was only significant in one of six tests (16.7%) on releases that could be calculated (83.3% were not significant). The other release with a significant Test 2 for pooled releases was the JDA Tailrace. Only three of eight release could be calculated, and of those, only one of three was significant. None of the Burnham et al. (1987) Test 3 results were significant for any of the release groups tested.

In summer, none of the calculable Burnham et al. (1987) Test 2 results were significant, and only one Test 3 was significant, indicating that the capture history to Array 2T had an effect on detection at Array 1B. Very high detection probability upstream arrays (pooled estimate = 99.1% to 100%) relative to a lower probability of 81.5% for Array 1B may have produced the false-positive result. When we ran the Test 3 on 10 individual releases, only one was significant out of the four that were calculable.

Survival Trends by River Reach and Among Seasons

We made plots of survival from the point of release to each array but the last in the study area, and they showed that most losses occurred in reaches with dams rather than in reaches between dams each season, and losses were higher in summer than in spring. The reach survival between arrays from JDA to TDA and TDA to BON showed high levels of survival. Mortality for non-dam reaches usually was < 5%. Losses of JDA-released subyearlings in the reach including TDA during the summer were three times greater than those observed in spring for yearlings. The loss of subyearlings in the reach including BON (Array 3t to 1B) was nearly double that observed for yearlings in spring.

Temporal Trends in Summer

A significant decline in survival estimates for many releases during summer suggests that many fall subyearling Chinook salmon stopped migrating or died. Examples are shown in Figures S.1 through S.4. The possibility of residualization in upstream areas is supported by results of the Lower Monumental Fall Chinook Salmon Behavioral Study (Cook et al. 2007). Because of the reduction in apparent survival, data from replicate releases should not be pooled but analyzed separately to properly characterize the between-release variability.

The fact that losses for non-dam reaches are much lower than for reaches with dams suggests that residualization is not a dominant factor causing losses in the lower river. Smaller size and lower energy reserves in subyearlings likely makes them more susceptible to stress and death. For fish of the lengths that we tagged in summer (> 95 mm), the tag-effects study showed minimal tagging mortality, although it was slightly higher than that observed for yearlings (Rich Brown, PNNL, Personal Communication).

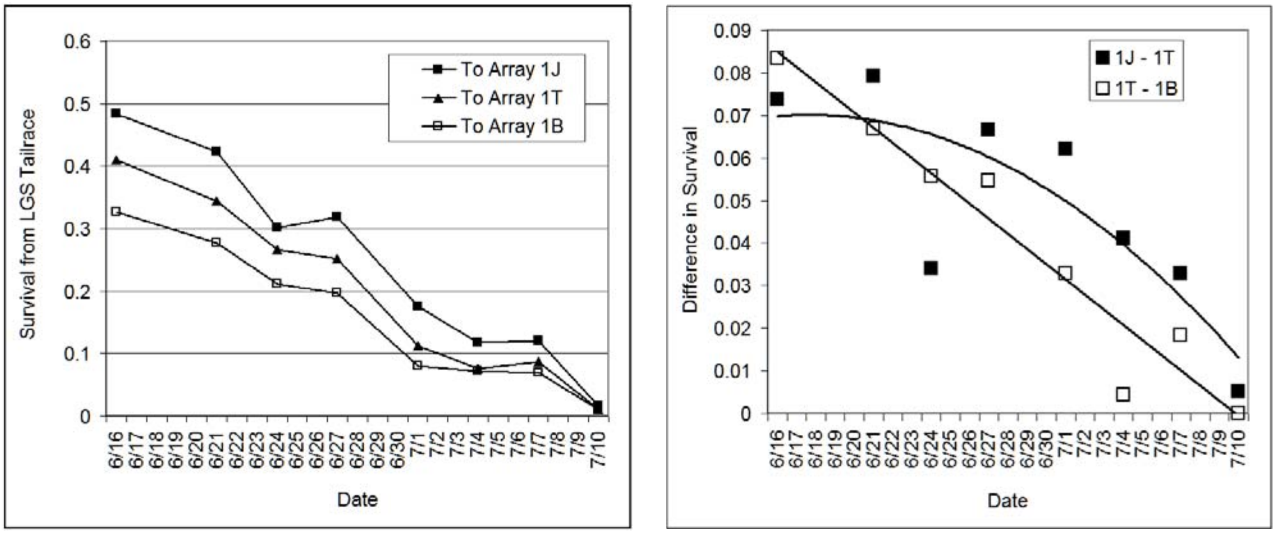

Figure S.1. Apparent Survival of Subyearling Chinook Salmon Released from Lower Goose Tailrace in Summer Down to Primary Arrays in the JDA, TDA, and BON tailwaters (Left) and Differences in Survival Between Successive Primary Arrays (Right).

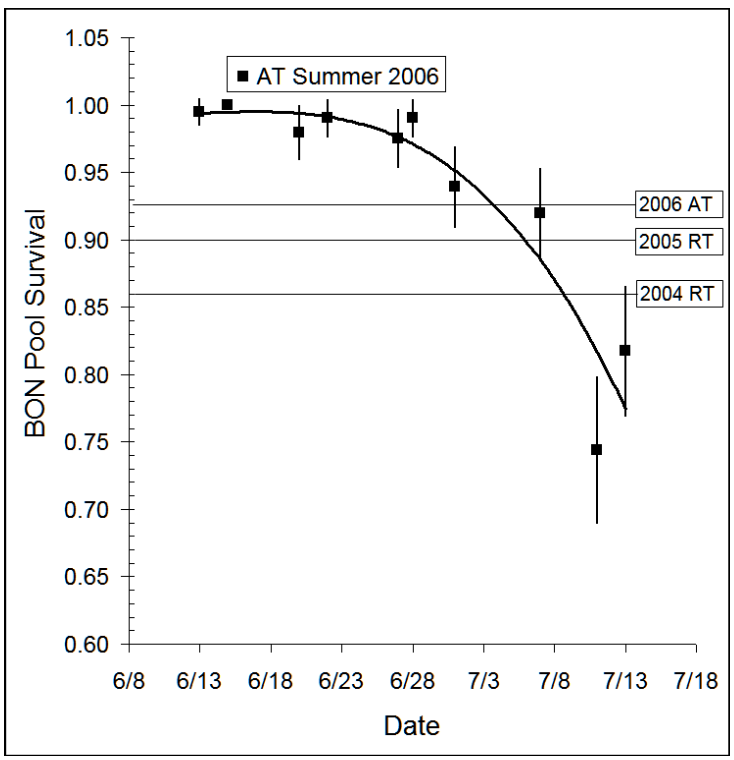

Figure S.2. Apparent Survival of Subyearling Chinook Salmon Released from the TDA Tailrace in Summer Down to Array 3T just above BON. Vertical bars are 95% CIs. Horizontal lines show means for this study (2006 AT) and for the 2004 and 2005 radio telemetry (RT) studies (after Counihan et al. 2006a and b).

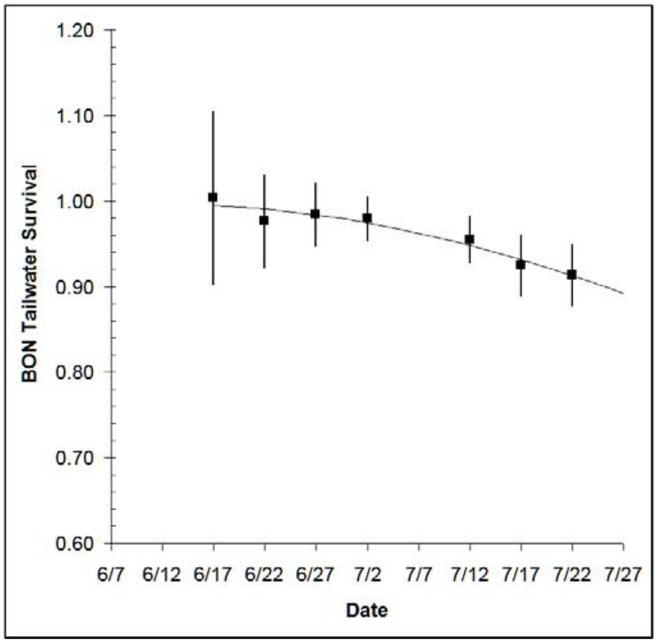

Figure S.3. Apparent Survival of Subyearling Chinook Salmon Released from the BON Tailrace in Summer Down to Array 1B. Vertical bars are 95% CIs.

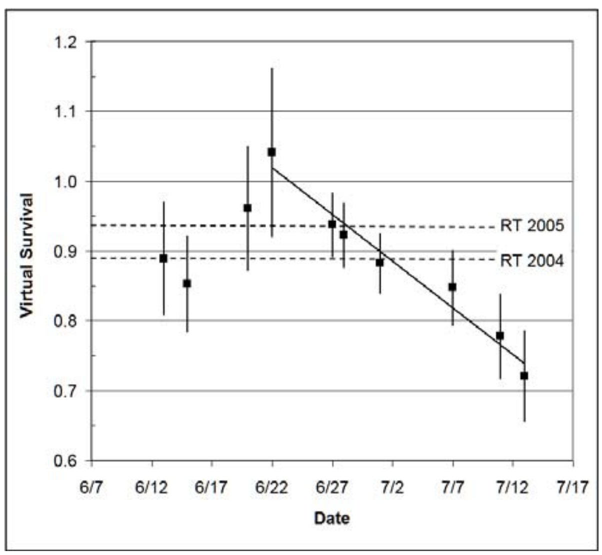

Figure S.4. Apparent Survival of Subyearling Chinook Salmon Regrouped at Array 3T above BON. Vertical bars are 95% CIs. Horizontal lines show means for the 2004 and 2005 radio telemetry (RT) studies (after Counihan et al. 2006f and g).

Bonneville Route-Specific Survival Based on Pooled Releases

In spring, fish were regrouped as they passed through the Bonneville spillway, B2 JBS, and B2CC regardless of release location to obtain enough detections for route-specific survival estimates and even then sample sizes were low. We could not distinguish between survival rates of yearlings passing the B2CC, B2 JBS, and spillway because of the low precision of the estimates due to small sample sizes. The estimate for the B2 JBS of 89.3% did not differ from estimates for the B2CC of 94.6% or from the spillway estimate of 94.1%, according to overlapping 95% CIs. Single-release survival estimates for yearling Chinook salmon passing the BON spillway during the day (96%) was 9% higher than that of fish passing at night (88%), but completely overlapping 95% confidence intervals suggest that this difference was not significant. Daytime was defined as from 0600 through 2100 hours each season, and the remaining hours of the day were assigned as nighttime hours. Spill was consistently high (to gas cap) 24 h per day, so diel shifts in spill would not have been a major driving factor in spring 2006.

In summer, there were few surprises in the single-release estimates of survival for the B2CC, B2 JBS, and spillway. Survival at the spillway decreased almost 15% in summer relative to a 5% drop in spring, but the summer estimates for the B2CC and B2 JBS did not differ from spring estimates. Based upon non-overlap of 95% confidence intervals, the B2CC estimate of 95.2% was significantly different from a 85.8% estimate for the spillway, but the B2CC estimate did not differ from the B2-JBS estimate of 90.7%, and the B2 JBS estimate did not differ from that of the spillway. Poor precision associated with the small number of detected fish (91 at the B2CC, 189 at the B2 JBS, and 706 at the spillway) made it difficult to detect differences of less than about 10%. Paired release estimates of survival for each of the three routes also had overlapping 95% confidence intervals.

Survival by Spill Condition at Bonneville in Summer

Our comparison of subyearling survival during three different spill conditions, which occurred in three successive two-week periods over the course of the summer, was confounded by an independent decline in survival as summer progressed and river discharge decreased. The earliest spill condition from June 14 through June 25 happened to be 24-h spill to the gas cap ranging from 96,000 to 149,000 cfs, and it had the highest single-release survival estimate (96.0%; 95% CI = 88.7, 103.4). The paired release estimate for the 24-h gas cap spill condition was 97.0% (95% CI = 86.3, 107.6). The next condition was 24-h spill ranging from 63,000 to 83,000 cfs, which occurred from June 26 through about July 5, and it was associated with a lower, although not significantly lower, single-release survival estimate (87.8%; 95% CI = 82.6, 93.0) than the high-spill condition. A paired release estimate for the 24-h < 80,000 cfs spill condition was 89.4% (95% CI = 83.4, 95.4). The third condition was a Bi-Op spill of 75,000 cfs during the day and spill to the gas cap at night. It lasted through the end of the summer releases from July 6 through August and not surprisingly was associated with a significantly lower single-release survival estimate of 78.3% (95% CI =73.1, 83.5), which probably would have occurred regardless of spill treatment. A paired-release estimate for the Bi-Op spill condition was 83.6% (95% CI = 77.3, 89.9). Precision was higher for the single-release estimate than it was for the paired-release estimate.

There are several comparisons of results that reinforce our conclusion that survival trends for BON spillway-passed subyearlings were not related to spill condition. First, survival estimates for the 24-h gas-cap spill condition and the 24-h low-spill condition did not differ significantly, probably because both occurred before a summer decline in survival was obvious. Second, survival estimates associated with 75,000 cfs spill during the day and gas-cap spill at night did not differ significantly and were low (75.8-80.02%) because they occurred in mid to late summer when survival was low. In short, subyearlings that migrate in early summer had better survival than those migrating in later summer, regardless of spill condition at BON.

If there is a desire to test different spill conditions in summer, the confounding effect of migration timing must be considered and eliminated from the experimental design. We recommend confining tests of spill conditions to early summer periods or late summer periods to avoid a confounding effect.

Travel Time and Rate

Travel times and rates were primarily a function of river discharge, particularly when discharge was above 250,000 cfs (Figure S.5), as it was in spring and early summer. Relations between travel time and discharge were much weaker when river discharge was < 250,000 cfs, a level that first appeared after June 26 and continued throughout summer 2006. This period coincided with declining survival estimates associated with increased mortality or residualization of subyearlings. Travel times were slower in summer than they were in spring, particularly at downstream locations (Figure S.6). On average, subyearlings released at JDA took 10 hours longer than yearlings to make it from the first array below JDA to the last array below BON. For TDA Tailrace releases, subyearlings took an average of 5 hours longer than yearlings to reach the last array below BON. Longer travel times have the potential to increase exposure to predation.

Travel times were useful for identifying delays at dams when specific routes could be identified. At JDA, egress times were significantly and inversely correlated with river discharge. Egress time was about an hour longer for fish released at minimum discharge (311,000 cfs) than it was for fish released at maximum discharge (387,000 cfs). Egress times did not differ between turbine and front-roll releases. The time it took fish to traverse the BON forebay until they were detected passing the dam was much longer (4.5-21.6 times longer) for fish using the B2 JBS than for fish using other routes, probably because of holding delays in gatewell slots. Delays are not desirable in late summer when survival estimates appear to decline significantly over time.

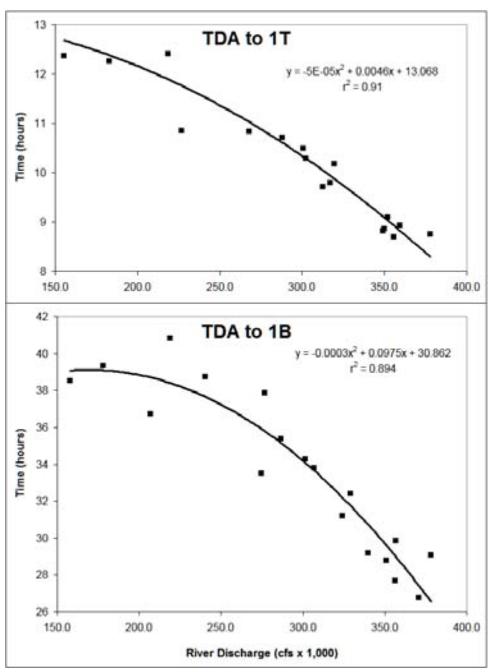

Figure S.5. Travel Time as a Function of River Discharge for the River Reach from TDA to Array 1T near Hood River and from TDA to Array 1B near Rooster Rock State Park below BON

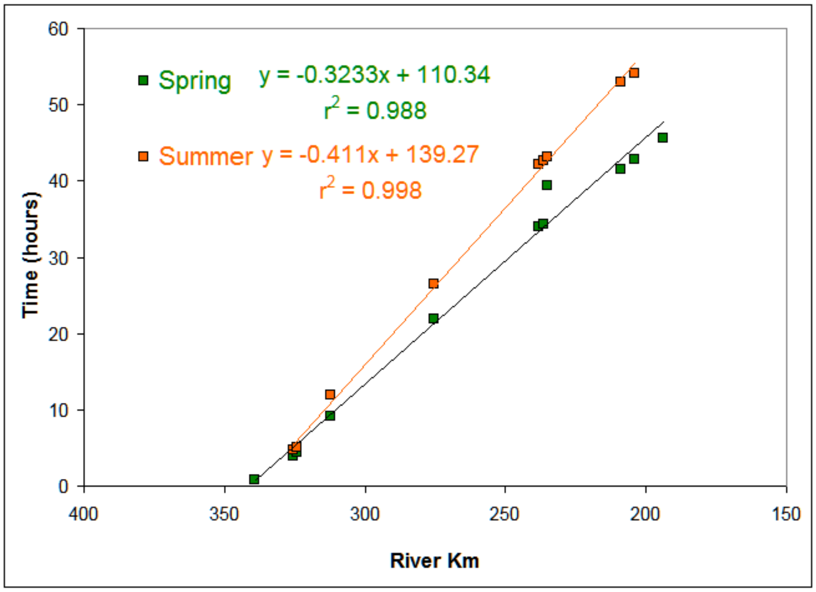

Figure S.6. Travel Time in Spring and Summer as a Function of River Kilometer

Diel Distribution

Fish regrouped at Array 3T in the BON forebay from all upstream releases and passed the dam at all hours of the day, because diel distributions of arrival from TDA and JDA Tailrace release locations complimented one another. Most TDA Tailrace-released fish arrived during hours when arrivals from the JDA Tailrace releases were low.

Cross Channel Distribution

A majority of fish were detected away from shore each season, and there was little evidence that subyearlings preferred to migrate near shore instead of in the middle of the river in summer. Only two of nine lateral distribution plots showed any skew toward shore in summer. The most reliable evidence came from primary arrays in each tailwater (1J, 1T, and 1B) because they each had five or six autonomous nodes. We worried a lot about tagged fish migrating around islands and avoiding detection in the BON Tailwater, but the percentage of detections on nodes sampling side channels was low in two of three locations. High detection percentages on Node 4 of Array 3B located at the upstream opening to Camas Slough formed by Lady Island made it the only exception.

Physical Factors Affecting Array Detection Probabilities

Arrays with very high detection probabilities had a majority of the detections on more than one node (2-5 nodes), and this was the case for five of nine arrays (1J, 3J, 1T, 2T, and 3T). The BON Tailwater arrays, which had the lowest detection probabilities (mean = 67.6% in spring and 80.2% in summer), received 80% or more detections on a single node. Array 1B had 16% multiple node detections, showing that contributing factors of node density and bathymetry played a role in the poor performance of this array. Array 2B and 3B performed similarly in spring with only 9% detections on multiple nodes. Both of these arrays had three nodes covering a 650-m transect across the river and a backwater node separate from the main transect. Separate nodes for sampling side channels would not allow for simultaneous detections on the side channel node and other nodes in the main channel, but multiple node detections should have occurred on the other three nodes.

The 2006 single- and multi-node detection results indicate that the best location for an array is at a cross section that is deep and narrow, and the worst location is one with extensive shallows, uneven bathymetry, and islands to limit sound propagation and maximize multi-path signals. Primary factors affecting array performance include the shape (depth and width) of the river cross section and node density. In 2006, multiple detections were more common at upstream locations that tended to be deeper and narrower than locations below BON, where finding narrow cross sections without bars, islands, and side channels was difficult.

Examination of scatter plots of detection probability regressed on physical variables provided useful observations for making recommendations for deploying acoustic receivers. Our examination of correlations of observed average detection probabilities with several physical factors (Table S.3) led us to recommend the following to provide a reasonable chance of achieving detection probabilities > 80% in future studies.

1. Arrays should be located at the narrowest and deepest (mean depth > 14 m) cross sections available, after allowing enough travel distance to avoid detecting dead fish on an array. There was a significant negative correlation between detection probability and river width and a positive correlation between the probability and mean depth.
2. We recommend deploying enough autonomous nodes to keep inter-nodal distances < 150 m, so that node densities are at least six per km of river width.
3. Offshore distances to the first node on either side of the river should not exceed 100 m.

Limiting offshore distance to 50 m and inter-node distances to 100 m (i.e., node density ≈ 10 / km) would provide completely overlapping coverage so that the loss of any single node would not diminish detection probability and the loss of two adjacent nodes would only leave a small breach in coverage. An example approaching such a deployment was Array 1T in the TDA Tailwater. This array had 82% of detections occurring on multiple nodes because the width of the river at this array location was only 500 m and five nodes were deployed there, so the inter-node spacing with five nodes was 100 m.

Table S.3. Correlations Between Mean Detection Probability and Physical Characteristics of the Survival Arrays.

Variable	r	P
River Width (Km)	-0.78041	0.0002
Mean Offshore Distance (m)	-0.74197	0.0006
Inter-node Distance (m)	-0.58771	0.0131
Node Density (Nodes / Km)	0.58124	0.0144
Mean Depth (m)	0.52399	0.0309
Mean Number of Nodes	-0.17649	0.4980
SE Depth (m)	0.00485	0.9853

Survival and Dam Operations, Rate of Travel, Water Temperature

Significant positive correlations of survival probabilities with travel rates of some releases in spring and with travel rate and discharge in summer made sense but relations were not consistent for all releases. We were reassured by significant positive correlations of survival with rate of travel for all three JDA releases in spring and for the JDA Tailrace release of subyearlings in summer. Explained variation ranged from 21% to 50%. However, we were puzzled that the same correlations were not observed for TDA Tailrace releases in spring or summer.

The strong decline in survival of subyearlings in summer would make correlations with discharge and temperature very likely but is not indicative of cause and effect. Loss of fish to residualization (reverse smoltification) in summer could produce spurious correlations of apparent survival with discharge and water temperatures, simply because there usually is a downward trend in discharge and an upward trend in water temperature during summer. Sorting out cause and effect would require more information than is available from this study.

Preface

The U.S. Army Corps of Engineers (USACE) Portland District (CENWP), contracted with the Pacific Northwest National Laboratory (PNNL), Richland, Washington, to conduct acoustic telemetry survival studies at three Columbia River Projects in 2006. PNNL is operated by Battelle - Pacific Northwest Division for the U.S. Department of Energy. PNNL assembled a study team consisting of staff from PNNL, the Pacific States Marine Fisheries Commission (PSMFC), the University of Washington, and the National Marine Fisheries Service. The Portland District provided all funding and oversight.

Acknowledgments

Many people made valuable contributions to this study and deserve acknowledgment. Mr. Dennis Schwartz served as the USACE Contracting Officers Representative (COTR) for the Bonneville Dam portion of the study and Mr. Brad Eppard was the COTR for the John Day and The Dalles portions. Both provided valuable coordination between researchers and the CE hydropower project personnel, and Brad also contributed valuable recommendations to improve the study design and execution and furnished dam operations data.

Ben Hausman, Tim Darland, Tammy Mackey, and Jonathon Rerecich with the Bonneville Project provided pre-work safety orientations and assistance and coordination whenever needed.

Terry Hurd and Miro Zindol provided similar assistance and coordination for the John Day Project, and Erin Kovalchuk with the Project was helpful in providing information about the Smolt Monitoring Facility (SMF).

Project Biologist Greg Kovalchuk of PSMFC provided smolt-collection training and was very helpful in making fish collection and scheduling of SMF activities run smoothly. Laura Cowger (PSMFC), who often worked processing fish for the SMF, was also very helpful.

Many PNNL staff assisted with various aspects of the study including management (Geoff McMichael), surgery training (Rich Brown), tag-life monitoring (Kathleen Carter), fish tagging (Kate Deters, Ian Welch, Scott Titzler), fish release (Ian, Kate, Chris Eiler, Garrett Mckinney), deployment and retrieval of autonomous nodes or fish-release mechanisms (Kyle Bouchard, Scott Titzler, Fenton Kahn, Chris Eiler), database entry and management (Jessica Vucelick), and development of tracking algorithms (Daniel Deng). Dr. David Geist was the Ecology Group Manager within PNNL and a valuable source of support and information, and Dr. Charlie Brandt was the Program Line Manager.

Terry Goss (PSMFC), helped with fish collection, tagging, and release. Carl Schilt, with LGL Limited, Inc., helped anesthetize fish before surgery in spring. Sonic Concepts in Seattle, Washington, fabricated electronic tags and receiving hydrophones and repaired broken hydrophones when needed. Precision Acoustic Systems, also in Seattle, conducted node acceptance tests for PNNL. Cascade Aquatics, Inc., of Ellensberg, Washington, activated and delivered the acoustic tags. Schlosser Machine Shop fabricated anchors for autonomous nodes and The Dalles Iron Works made aluminum floats for a fish release hose. SDS Lumber Company dropped a 1,000 pound anchor in the John Day Tailrace to anchor the downstream end of a tailrace release hose. Cliff Pereira and Brad Eppard provided detailed reviews that improved the quality of the report.

Acronyms and Abbreviations

AIC	Akaike Information Criterion
B1	Bonneville Powerhouse 1
B2	Bonneville Powerhouse 2
B2CC	Bonneville Powerhouse 2 Corner Collector
B2 JBS	Bonneville Powerhouse 2 Juvenile Bypass System
BKD	Bacterial Kidney Disease
BON	Bonneville Dam
BPA	Bonneville Power Administration
CENWP	U.S. Army Corps of Engineers, Portland District
CF	compact flash
cfs	cubic feet per second
CI	Confidence interval (95% unless specified otherwise)
CJS	Cormack-Jolly-Seber model
COTR	Contracting Officers Representative
csv	comma-separated variables
DART	Data Access in Real Time
FCRPS	Federal Columbia River Power System
g	grams
GB	gigabyte
JBS	juvenile bypass system
JDA	John Day Dam
JSATS	Juvenile Salmon Acoustic Telemetry System
LGR	Lower Granite Dam
LGS	Little Goose Dam
LRT	likelihood ratio tests
mm	millimeter
ml	milliliter
mg/l	milligrams per liter
MS-222	tricaine methanesulfonate
MSL	mean sea level

NOAA	National Oceanic and Atmospheric Administration
PA	pre-anesthetic
PDF	portable document file
PIT	passive integrated transponder tag
PNNL	Pacific Northwest National Laboratory
PSMFC	Pacific States Marine Fisheries Commission
PR	paired release
Rkm	river kilometer
RT	radiotelemetry
s	second
SAS	Statistical Analysis System
SMF	Smolt Monitoring Facility
SR	single release-recapture
SYC	sub-yearling Chinook salmon
TDA	The Dalles Dam
TR	tailrace
USACE	U.S. Army Corps of Engineers
YC	yearling Chinook salmon

Contents

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1.0 Introduction

1.1 Background

Survival of juvenile salmonids passing the three lowermost dams on the Columbia River and associated river reaches has been an ongoing concern of the U.S. Army Corps of Engineers (USACE), Portland District (CENWP), and of the region. The Portland District is committed to increasing survival rates for fish passing its projects, and survival is one of the primary measures of success of management improvements at hydropower projects. The District is currently pursuing a transition from radio telemetry to acoustic telemetry for use in estimating project and dam passage behavior and survival. Acoustic telemetry is an attractive tool for several reasons. First, acoustic tags do not require an external antenna like those needed for radio-telemetry tags, and this makes them less invasive to the host. Second, hydrophones can detect fish throughout the water column, avoiding depth-detection biases sometimes observed with radio telemetry. Third, when deployed appropriately, acoustic telemetry can provide fine-scale two-dimensional (2D) and three-dimensional (3D) movement information to assess fish approach behavior and route of passage, as well as survival. Fourth, acoustic telemetry works in salt water as well as freshwater, so there is the potential to estimate survival out into the ocean. As part of this transition, the Portland District needed to conduct studies to evaluate detection capabilities, survival, and sample sizes required to provide desired levels of precision for future studies.

The Portland District directed and funded the development of the Juvenile Salmon Acoustic Telemetry System (JSATS) used in these studies, and there is hope that someday JSATS will allow researchers to assess survival at multiple hydropower projects and associated river reaches throughout the Snake and lower Columbia rivers. JSATS was first used for Columbia River Estuary survival studies conducted by the National Oceanic and Atmospheric Administration National Marines Fisheries Service (NOAA Fisheries) and PNNL in 2004 (McComas et al. 2004), 2005 (McComas et al. 2005), and 2006 (McComas et al. 2006). Before the study reported here, acoustic telemetry had only been used twice at Portland District projects, once at Bonneville Dam (BON) (Faber et al. 2001) and once at The Dalles Dam (TDA) (Cash et al. 2005) for describing fish passage and approach behavior. While acoustic telemetry studies near projects have been successful (Skalski et al. 2003a, 2003b), multi-project survival studies throughout a river system have not been attempted because of tag-life limitations at commonly used transmission rates.

All previous active tag survival studies on the lower river were conducted with radio telemetry. The use of radio telemetry to estimate survival of tagged fish at John Day Dam (JDA) was evaluated and deemed feasible in 1999 (Counihan et al. 2002a). Survival studies of smolt passage through JDA also were conducted in 2000 (Counihan et al. 2002b), 2002 (Counihan et al. 2006d), and 2003 (Counihan et al. 2006e). Reach survival was conducted from the release point above JDA to the JDA forebay and from JDA to the forebay of TDA (Counihan et al. 2002b and 2006a). Survival studies were conducted at TDA in 2002 (Counihan et al. 2006c), 2004 (Counihan et al. 2006a), and 2005 (Counihan et al. 2006b). Radio telemetry survival studies at BON were conducted in 2000 (Counihan et al. 2002b), 2002 (Counihan et al. 2003), 2004 (Counihan et al. 2006f), and 2005 (Counihan et al. 2006g).

1.2 2006 Studies

In this report, we present acoustic telemetry survival studies for JDA, TDA, and BON as a single study because the primary goals were to estimate detection and survival probabilities based on sampling with JSATS equipment, to assess the feasibility of using JSATS for survival studies, and to estimate sample sizes needed to obtain a desired level of precision in future studies. The three studies were funded separately by the Portland District under the Anadromous Fish Evaluation Program, but they generally were executed as a single study with multiple objectives. Commonalities included surgically implanting yearling Chinook (YC) salmon in spring and sub-yearling Chinook (SYC) salmon in summer with JSATS tags that transmitted once every 5 s and assessing detection probabilities and survival from multiple release points through the study dams and tailwaters. River reach estimates were as important as project-specific estimates for evaluating feasibility. There were elements of each study that were unique, but they were secondary to assessing the overall feasibility of the method and estimating required sample sizes for future survival studies. For example, we evaluated the passage rate, egress rate, and survival of fish passing through a single JDA turbine and the JDA Tailrace in spring. We estimated the survival of fish passing TDA, BON, and the BON spillway each season. Route-specific estimates also were made for the B2CC and the B2 Juvenile Bypass System (JBS) by using PIT tag detections from those routes to confirm the route of passage and to establish the population of tagged fish passing each route.

We released acoustically tagged fish in four locations in spring and two in summer and detected them on autonomous hydrophones deployed in arrays across the river at four locations below JDA and three each below TDA and BON. In spring, we had eight releases of tagged YC salmon into JDA Turbine 9C, the Turbine 9C discharge downstream of JDA, the JDA Tailrace, and the TDA Tailrace. In summer, we had five releases of SYC salmon into the JDA Tailrace and ten releases into the TDA Tailrace.

Other studies released JSATS-tagged YC and SYC salmon, and detections of some of those fish on our hydrophone arrays allowed us to estimate detection and survival probabilities for various reaches between JDA and Camas, Washington. The Tag Effects Study released 996 yearlings with tags that transmitted a coded signal once every 10 s below Lower Granite Dam in spring, and The Lower Monumental Reservoir Study released 1,949 sub-yearlings each with a 10-s tag below Little Goose Dam in summer. The Estuary Survival Study released fish with tags that transmitted once every 5 s into the BON Tailrace each season, and we used these as post-hoc control groups to formulate paired-release survival models for the Bonneville Project. In addition to release-specific estimates, we also made estimates based upon pooled detections above TDA and BON, and these virtual releases were used to estimate dam and tailwater survival.

1.2.1 Objectives

1. Surgically implant YC and SYC salmon with JSATS acoustic tags and PIT tags and release them in specific locations above and below JDA for estimating detection probabilities and survival for turbine-passed fish at JDA, reach survival through the TDA pool, and TDA Dam survival. Locations of the eight release groups of approximately equal numbers of YC salmon in spring included 1) Turbine Intake 9C (500 fish), 2) immediately downstream of Intake 9C discharge (Front Roll; 497 fish), and 3) in the tailwater several km downstream of the front roll discharge (481 fish). In summer, 299 tagged SYC salmon in five release groups of roughly equal size were put in the tailwater several kilometers downstream from the dam.
2. Surgically implant acoustic tags and pit tags in 978 YC salmon in spring and 2,179 SYC salmon in summer and release them along a transect across the river adjacent to the TDA Marina several kilometers below TDA to provide control releases for JDA treatment fish and treatment releases for estimating downstream reach survival and Bonneville Dam Survival. There were nine release groups of approximately equal size on different days in spring, and 10 release groups of approximately equal size on different days in summer.

3. Deploy and maintain autonomous nodes in arrays in the JDA Tailwater, TDA Tailwater, and BON tailwater to detect acoustic tags passing downstream from upstream releases, as described in Objectives 1 and 2. Detections on the three arrays located in each of the three tailwaters were for estimating survival. Detections on the most upstream JDA tailwater array in spring were for estimating egress rates for fish released in a turbine, its front roll, and in the JDA tailwater. Detections on a BON spillway forebay array were for identifying tagged fish that had a high probability of passing the BON spillway.
4. Conduct a tag-life study on 100 5-s tags and 100 10-s tags randomly sampled from lots that will be used in all survival studies in 2006 and evaluate the need for tag-life corrections each season.
5. Estimate detection probabilities and survival by release group and pooled releases in a variety of ways:
    a. By selecting different arrays to use as secondary and tertiary arrays in survival models for JDA and TDA. Compare survival estimates from each approach to see if the choice of secondary and tertiary arrays would have altered conclusions.
    b. Estimate dam and tailwater survival, as described in Peven et al. (2005), for TDA and BON using fish detected on an array just above each project to form “virtual” releases through each dam.
    c. Estimate project survival for TDA and BON from the point of release below the dam upstream to the primary array downstream of the project. This estimate includes survival of fish passing through the upstream pool, the project, and the tailwater. Develop post-hoc, paired-release models in which detections of fish tagged and released below TDA are treated as reference releases for the treatment fish passing through TDA, and detections of fish tagged and released below BON are treated as reference releases for the treatment fish passing through BON. The ratio of these survival estimates provides a survival estimate for the upstream tailwater and the project, but excludes survival through the downstream tailwater.
    d. Estimate route-specific survival estimates by forming virtual releases of fish detected at the B2CC and B2JBS by PIT tags and at the BON spillway by acoustic detections in the forebay. The spillway estimates also were examined by day and night and spill operational condition.
    e. Make Cormack-Jolly-Sever single-release model estimates of survival for pooled release groups from each release point, including Snake River release points, through every reach in the study area using detection histories from successive sets of three arrays or from two arrays for the reach above the last array.
6. Host a workshop on using JSATS to estimate survival.
7. Estimate one-half 95% confidence intervals (CIs) associated with a range of different sample sizes of tagged fish given the detection probabilities and survival estimates from this study.

1.3 Site Descriptions

The study area covered 154 km of the lower Columbia River from JDA at river km (rkm) 347 downstream to Lady Island between Camas, Washington, and Troutdale, Oregon, at rkm 193. It included tailwaters below JDA, TDA, and Bonneville Dam (Figure 1.1).

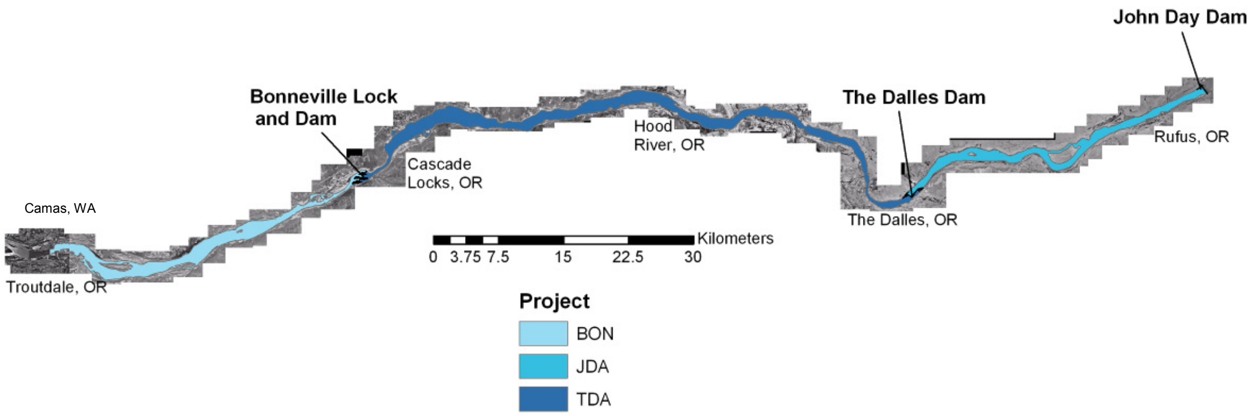


Figure 1.1. Tailwaters Below the Three Dams in this Study

John Day Dam is a single dam structure that consists of a 16 turbine-unit powerhouse on the Oregon side and a 20-bay spillway on the Washington side (Figure 1.2). The Smolt Monitoring Facility (SMF) below JDA served as the site for fish collection and tagging. Fish were released into Turbine Intake 9C, the front roll of Turbine 9 discharge downstream, and in the tailrace about 1.5 km downstream and across from the boat launch at Giles French Park. We deployed an egress detection array about 2.9 km downstream of JDA and survival detection arrays about 21.4, 22.8, and 34.6 km downstream of JDA. Detections of fish on the third survival array just above TDA were used to form virtual releases for estimating dam and tailwater survival for TDA.

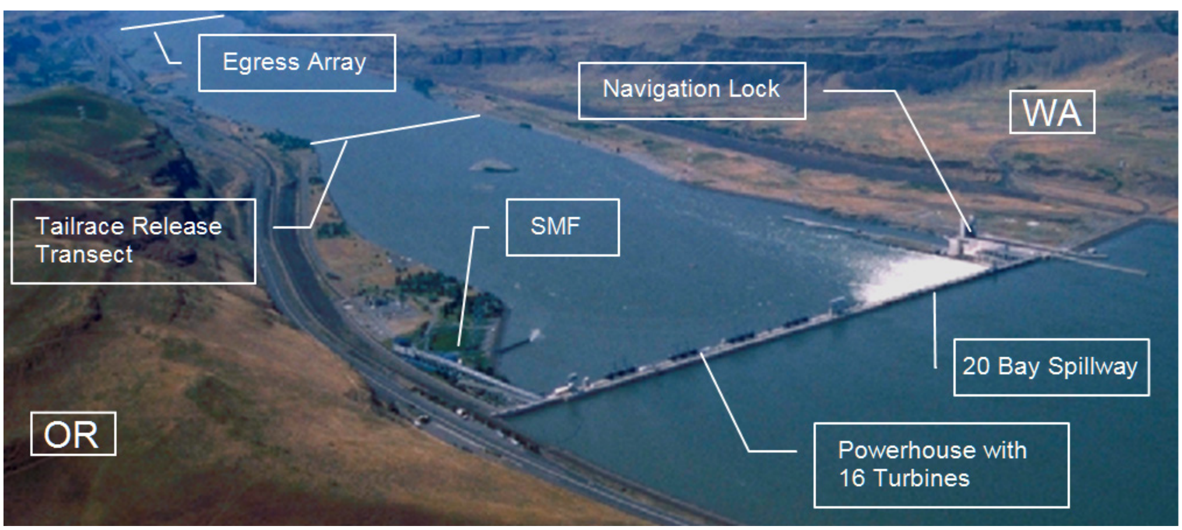


Figure 1.2. Aerial View of John Day Dam. SMF = Smolt Monitoring Facility.

The Dalles Dam is located at rkm 306 and consists of a 22-unit powerhouse, which runs parallel to the river channel, and a 23-bay spillway, which is perpendicular to the river channel and separated from the powerhouse by a non-flow section of dam (Figure 1.3). There was one fish release site located several kilometers below The Dalles Dam adjacent to The Dalles Marina. There were four detection arrays placed in the TDA Tailwater. The first three arrays were used to estimate survival down to Bonneville

Dam, and the fourth array was located in the forebay of the BON spillway to detect fish passing there. The third array just above Boat Rock was used to detect tagged fish for virtual releases at BON.

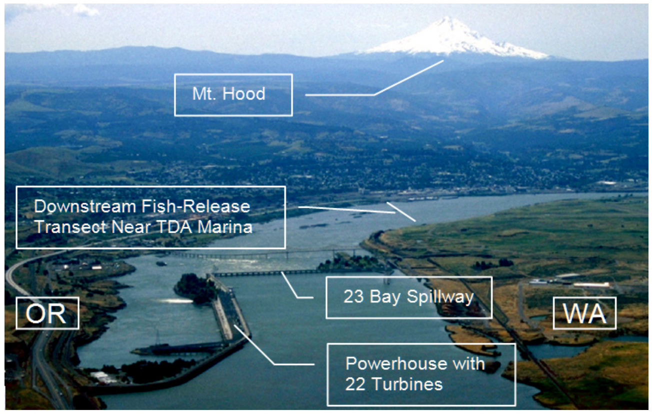


Figure 1.3. Aerial View of The Dalles Dam at rkm 307.8

Bonneville Lock and Dam consists of three dam structures that together complete a span of the Columbia River between Oregon and Washington at River Mile 146.1, about 40 miles east of Portland, Oregon (Figure 1.4). From the Oregon shore north toward Washington, the current project is composed of a navigation lock, a 10-turbine-unit First Powerhouse (B1), Bradford Island, an 18-gate spillway, Cascades Island, and an 8-turbine unit Second Powerhouse (B2). The Estuary Survival Study released fish into the Bonneville Smolt Monitoring Facility (SMF), and those fish entered the river at rkm 232.8. We deployed three detection arrays about 26.2, 31.0, and 41.2 rkm below the SMF outfall.

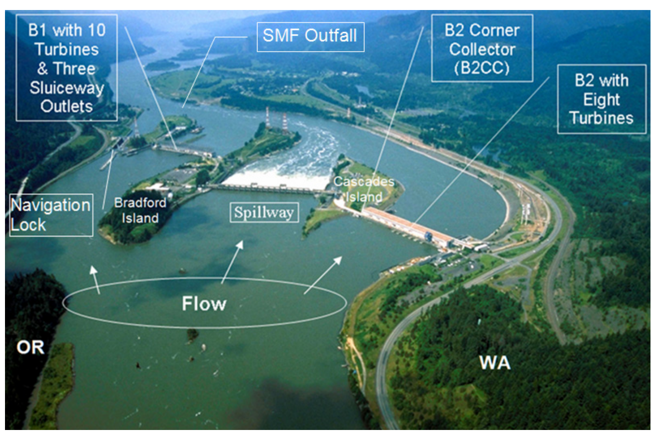


Figure 1.4. Plan View of the Bonneville Dam Project. The B1 sluiceway outlets and the B2 Corner Collector (B2CC) are surface overflow passage routes. Releases of fish from the Estuary Survival Study reentered the river at the SMF Outfall.

Throughout this report, we refer to locations on the river that are varying distances apart, so we created Table 1.1 to provide a quick reference to determine distances between locations.

Table 1.1. Lookup Table for Determining Distances (km) between Locations Referenced in this Study

Location or Array	Study Function	Statute Miles Up-stream of CR Mouth	Km Upstream of CR Mouth	LGR TR	LGS TR	JDA	JDA Intake 9C	JDA FR	JDA TR	0J	1J	2J	3J	TDA	TDA TR	1T	2T	3T	4T*	BON	B2CC	B2 JBS	BON TR	1B	2B	3B
				696.0	636.1	347.0	347.0	346.9	344.4	339.2	325.6	324.2	312.4	308.9	306.0	275.6	238.4	236.4	235.2	234.4	235.0	232.8	232.8	208.8	204.0	193.8
LGR TR	Release - Spr	434.4	696.0	0.0	59.9	349.0	349.0	349.1	351.6	356.8	370.4	371.8	383.6	387.1	390.1	420.4	457.6	459.6	460.8	461.6	462.6	463.2	463.2	487.2	492.0	502.2
LGS TR	Release - Sum	393.1	636.1	59.9	0.0	289.1	289.1	289.2	291.7	296.9	310.5	311.9	323.7	327.2	330.2	360.5	397.7	399.7	400.9	401.7	402.7	403.3	403.3	427.3	432.1	442.3
JDA	Effects	216.9	347.0	349.0	289.1	0.0	0.0	0.1	2.6	7.8	21.4	22.8	34.6	38.1	41.0	71.3	108.6	110.6	111.8	112.6	113.6	114.2	114.2	138.2	143.0	153.2
Intake 9C	Release - Spr	216.9	347.0	349.0	289.1	0.0	0.0	0.1	2.6	7.8	21.4	22.8	34.6	38.1	41.0	71.3	108.6	110.6	111.8	112.6	113.6	114.2	114.2	138.2	143.0	153.2
JDA FR	Release - Spr	216.8	346.9	349.1	289.2	0.1	0.1	0.0	2.5	7.6	21.3	22.6	34.5	38.0	40.9	71.2	108.5	110.5	111.7	112.5	113.5	114.1	114.1	138.1	142.9	153.1
JDA TR	Release - Spr & Sum	215.2	344.4	351.6	291.7	2.6	2.6	2.5	0.0	5.1	18.8	20.1	32.0	35.5	38.4	68.7	106.0	108.0	109.2	110.0	111.0	111.6	111.6	135.6	140.4	150.6
0J	JDA TR Egress	212.0	339.2	356.8	296.9	7.8	7.8	7.6	5.1	0.0	13.6	15.0	26.8	30.3	33.3	63.6	100.8	102.8	104.0	104.8	105.8	106.4	106.4	130.4	135.2	145.4
1J	Survival	203.5	325.6	370.4	310.5	21.4	21.4	21.3	18.8	13.6	0.0	1.4	13.2	16.7	19.6	49.9	87.2	89.2	90.4	91.2	92.2	92.8	92.8	116.8	121.6	131.8
2J	Survival	202.6	324.2	371.8	311.9	22.8	22.8	22.6	20.1	15.0	1.4	0.0	11.8	15.3	18.3	48.6	85.8	87.8	89.0	89.8	90.8	91.4	91.4	115.4	120.2	130.4
3J	Survival	195.2	312.4	383.6	323.7	34.6	34.6	34.5	32.0	26.8	13.2	11.8	0.0	3.5	6.4	36.8	74.0	76.0	77.2	78.0	79.0	79.6	79.6	103.6	108.4	118.6
TDA	Effects	193.1	308.9	387.1	327.2	38.1	38.1	38.0	35.5	30.3	16.7	15.3	3.5	0.0	2.9	33.3	70.5	72.5	73.7	74.5	75.5	76.1	76.1	100.1	104.9	115.1
TDA TR	Release - Spr & Sum	191.2	306.0	390.1	330.2	41.0	41.0	40.9	38.4	33.3	19.6	18.3	6.4	2.9	0.0	30.3	67.6	69.6	70.8	71.6	72.6	73.2	73.2	97.2	102.0	112.2
1T	Survival	172.3	275.6	420.4	360.5	71.3	71.3	71.2	68.7	63.6	49.9	48.6	36.8	33.3	30.3	0.0	37.2	39.2	40.4	41.2	42.2	42.8	42.8	66.8	71.6	81.8
2T	Survival	149.0	238.4	457.6	397.7	108.6	108.6	108.5	106.0	100.8	87.2	85.8	74.0	70.5	67.6	37.2	0.0	2.0	3.2	4.0	5.0	5.6	5.6	29.6	34.4	44.6
3T	Survival	147.8	236.4	459.6	399.7	110.6	110.6	110.5	108.0	102.8	89.2	87.8	76.0	72.5	69.6	39.2	2.0	0.0	1.2	2.0	3.0	3.6	3.6	27.6	32.4	42.6
4T*	Detection	147.0	235.2	460.8	400.9	111.8	111.8	111.7	109.2	104.0	90.4	89.0	77.2	73.7	70.8	40.4	3.2	1.2	0.0	0.8	1.8	2.4	2.4	26.4	31.2	41.4
BON	Effects	146.9	234.4	461.6	401.7	112.6	112.6	112.5	110.0	104.8	91.2	89.8	78.0	74.5	71.6	41.2	4.0	2.0	0.8	0.0	1.0	1.6	1.6	25.6	30.4	40.6
B2CC	Effects	146.8	235.0	462.6	402.7	113.6	113.6	113.5	111.0	105.8	92.2	90.8	79.0	75.5	72.6	42.2	5.0	3.0	1.8	1.0	0.0	0.6	0.6	24.6	29.4	39.6
B2 JBS	Effects	145.5	232.8	463.2	403.3	114.2	114.2	114.1	111.6	106.4	92.8	91.4	79.6	76.1	73.2	42.8	5.6	3.6	2.4	1.6	0.6	0.0	0.0	24.0	28.8	39.0
BON TR	Release - Spr & Sum	145.5	232.8	463.2	403.3	114.2	114.2	114.1	111.6	106.4	92.8	91.4	79.6	76.1	73.2	42.8	5.6	3.6	2.4	1.6	0.6	0.0	0.0	24.0	28.8	39.0
1B	Survival	130.5	208.8	487.2	427.3	138.2	138.2	138.1	135.6	130.4	116.8	115.4	103.6	100.1	97.2	66.8	29.6	27.6	26.4	25.6	24.6	24.0	24.0	0.0	4.8	15.0
2B	Survival	127.5	204.0	492.0	432.1	143.0	143.0	142.9	140.4	135.2	121.6	120.2	108.4	104.9	102.0	71.6	34.4	32.4	31.2	30.4	29.4	28.8	28.8	4.8	0.0	10.2
3B	Survival	121.1	193.8	502.2	442.3	153.2	153.2	153.1	150.6	145.4	131.8	130.4	118.6	115.1	112.2	81.8	44.6	42.6	41.4	40.6	39.6	39.0	39.0	15.0	10.2	0.0

* 4T is an array located in the BON spillway forebay for detecting fish passing at the BON spillway.

2.0 Materials and Methods

2.1 Fish Collection

2.1.1 Site Description

Juvenile Chinook salmon were collected and tagged at the JDA SMF. The SMF is situated on the south side of JDA at the downriver edge of a fish bypass system where out-migrating juvenile salmon and other fishes are routed through a series of flumes and dewatering structures before reentering the Columbia River at an outfall located downstream of the facility.

2.1.2 Federal and State Permitting

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

A federal scientific take permit was authorized for this study by the NOAA Fisheries Hydropower Division's Federal Columbia River Power System (FCRPS) Branch and administered by the National Oceanic and Atmospheric Administration, permit number 10-06 BAT. This permit was authorized under the 2004 FCRPS Biological Opinion.

The Oregon Department of Fish and Wildlife authorized take for this study under permit number OR 2006-3287. This permit was authorized under the 2004 FCRPS Biological Opinion.

All requirements and guidelines of both permits were met. Several amendments were made throughout the season to reflect variances in numbers of in-stream migrants. Reports of collection and release were reported to both agencies.

2.1.3 Sampling Methods

Juvenile fish were diverted from the bypass system and routed into a 1,795-gal holding tank within the SMF. About 250 smolts and other fishes were crowded with a panel net into a 20- by 24-inch pre-anesthetic (PA) chamber. Water levels in the PA chamber were lowered to about 8 inches (48 liters) to obtain the sample size necessary for tagging the following day. Fish were anesthetized with 60 mL of a stock tricaine methanesulfonate (MS-222) solution prepared at a concentration of 50 g L^{-1}. Once induction was achieved, fish were routed into the examination trough. MS-222 was added as needed to maintain induction in the trough and PolyAqua™ was liberally used to reduce fish stress. Water temperatures were monitored between the main holding tank and examination trough and refreshed in the trough before a 2° F temperature difference was reached between the tank and the trough.

Once in the examination trough, smolts targeted for surgical procedures were evaluated under specific acceptance and rejection criteria, as follows.

Accept if:

- adipose-fin clipped
- sized > 95mm.

Reject if:

- non-target species
- more than 20% descaling on any one side
- signs of prior surgery (for instance: radio tags, sutures, or PIT tag scars)
- positive readings when put through a PIT tag reader
- visible elastomer tag(s)
- gross signs of disease (such as Bacterial Kidney Disease [BKD]) or sub-dermal parasites.

Non-target and unacceptable fish were released to the river through the SMF holding system after a 30-min. recovery period. Accepted fish were counted into transfer buckets containing fresh river water and moved to one of three 80-gal pre-surgical holding tanks. Fish were held in the 80-gal circulars for 24 hours before surgery.

2.2 Fish Tagging

2.2.1 JSATS Acoustic Micro-transmitter

The JSATS acoustic micro-transmitter (acoustic tag, Figure 2.1) weighs 0.65 g in air and 0.37 g in water. The acoustic tag is 17 mm long and 5.5 mm wide. The tag must be activated prior to insertion into the fish. The acoustic tags used in this study and in the Estuary Survival Study, which released fish in the BON Tailrace, had a ping rate of 1 pulse every 5 s to provide an expected tag life of about 30 days. Chinook salmon smolts tagged and released into the Snake River all had JSATS tags that transmitted once every 10 s to provide a tag life of about 55 days.

Figure 2.1. JSATS Acoustic Micro-Transmitter with Ruler for Scale

2.2.2 Fish Tagging

A team of six people participated in the tagging process to reduce the handling time from netting to post-surgery recovery. Fish were netted in small groups from the 80-gal holding tanks and placed in a 5-gal "knockdown" bucket with water and a 20-mL solution of 80 mg/L dilution of MS-222. Once a fish lost equilibrium, it was transferred to a processing table in a small container of river water. Each fish was measured (fork length ±1 mm), weighed (±0.1 g), and returned to the small transfer container along with an assigned PIT tag and an activated acoustic tag. Another biologist entered fork length, weight, and tag numbers in PNNL Tag-Tracker software, which added the data to an Access database. The data entry system minimizes errors by reading PIT-tag numbers with a PIT-tag reader and acoustic tag codes with a mobile hydrophone system. The transfer container, fish, and tags were assigned a recovery bucket number and routed to a surgeon for tag implantation.

During surgery, the fish was placed ventral side up and a gravity-fed anesthesia supply line was placed into the fish's mouth. The dilution of this "maintenance" line was 40 mg/L. A 6-8 mm incision, using a #10 or #15 stainless steel surgical blade, was made ventrally, 3 mm from and parallel to the mid-ventral line and equidistant from the pelvic girdle and pectoral fin. The PIT tag was inserted first followed by the acoustic tag. Both tags were inserted toward the anterior portion of the fish. Two interrupted sutures were used to close the incision. For yearling Chinook salmon, 5-0 vicryl sutures were used with a C-3 needle (Figure 2.2). For subyearlings, 5-0 vicryl sutures were also used but with an FS-2 needle. With the incision closed, fish were then taken to an oxygenated recovery bucket containing river water.

Figure 2.2. Closing of Incision Using a 5-0 Vicryl Suture with a C-3 Needle

2.2.3 Recovery and Holding

Tagged fish were placed in 4-gal oxygenated recovery buckets and closely monitored until fish had reestablished equilibrium. Each bucket held 5 to 10 fish depending on the number of fish to be released at each site. The buckets were then carried to a larger holding tank where they were supplied with a continuous feed of river water (Figure 2.3). Fish were held and monitored for 24 hrs prior to release. The large holding tank was insulated to keep the water temperature within acceptable limits. A water level, temperature, and dissolved oxygen monitoring system was installed to automatically call staff if water-quality conditions were undesirable for fish. Alert limits were set to a maximum of 21.7° C and a minimum of 7 mg/L of oxygen.

Figure 2.3. Post-Surgery Holding Tank with Recovery Buckets

2.3 Transportation and Release

2.3.1 Transportation Procedures

A Wells Cargo trailer was outfitted with two 180-gal Bonar insulated totes and one 70-gal Bonar insulated tote. Each 180-gal tote could hold 12 4-gal fish buckets and the 70-gal tote could hold 6 fish buckets. Totes had snug-fitting lids and some extra space inside and behind a wood-frame separator so that ice could be added for cooling on hot days. A network of valves and plastic tubing were attached to O_2 tanks for delivering oxygen to individual fish buckets from 2,200 psi O_2 tanks in the trailer during transport.

Fish buckets were removed from the post-surgery holding tank and topped off with river water. They were then moved into the totes and an oxygen line was inserted into a hole in the top of the fish bucket. After all the buckets were loaded in the totes, each bucket was checked to make sure it was receiving O_2.

2.3.2 Fish Releases

Other studies released yearling and subyearling Chinook salmon that were detected on receivers deployed in this study (Table 2.1). Numbers of fish tagged are listed in Table 2.2 (spring) and Table 2.3 (summer).

Table 2.1. Dates and Numbers of Yearling and Subyearling Chinook Salmon Tagged with JSATS Tags and Released in Other 2006 Studies

Age Class	Release Location	Release Date	Number Released	Total
Yearling	LGR Tailrace	05/06/2006	238	
Yearling	LGR Tailrace	05/13/2006	758	996
Sub-Yearling	LGS Tailrace	06/16/2006	195	
Sub-Yearling	LGS Tailrace	06/21/2006	195	
Sub-Yearling	LGS Tailrace	06/24/2006	195	
Sub-Yearling	LGS Tailrace	06/27/2006	195	
Sub-Yearling	LGS Tailrace	07/01/2006	195	
Sub-Yearling	LGS Tailrace	07/04/2006	195	
Sub-Yearling	LGS Tailrace	07/07/2006	194	
Sub-Yearling	LGS Tailrace	07/10/2006	192	
Sub-Yearling	LGS Tailrace	07/14/2006	198	
Sub-Yearling	LGS Tailrace	07/18/2006	195	1,949

Table 2.2. Numbers of Tagged and Released Yearling Chinook Salmon in Spring 2006

Date	Age Class	Number Tagged	Release Date	Release Location	Number Released	Mortalities
5/15/2006	Yearling	262	5/16/2006	JDA Intake 9C	55	0
				JDA Front Roll	55	1
				JDA Tailrace	55	1
				TDA Tailrace	97	1
5/18/2006	Yearling	303	5/19/2006	JDA Intake 9C	63	0
				JDA Front Roll	60	1
				JDA Tailrace	60	0
				TDA Tailrace	120	0
5/20/2006	Yearling	298	5/21/2006	JDA Intake 9C	58	0
				JDA Front Roll	60	1
				JDA Tailrace	60	0
				TDA Tailrace	120	0
5/22/2006	Yearling	298	5/23/2006	JDA Intake 9C	68	0
				JDA Front Roll	70	0
				JDA Tailrace	70	0
				TDA Tailrace	90	0
5/24/2006	Yearling	212	5/25/2006	JDA Intake 9C	60	0
				JDA Front Roll	60	0
				JDA Tailrace	42	1
				TDA Tailrace	50	2
5/26/2006	Yearling	328	5/27/2006	JDA Intake 9C	80	0
				JDA Front Roll	80	0
				JDA Tailrace	79	2
				TDA Tailrace	89	4
5/31/2006	Yearling	267	6/1/2006	JDA Intake 9C	60	0
				JDA Front Roll	60	0
				JDA Tailrace	80	1
				TDA Tailrace	67	0
6/2/2006	Yearling	320	6/3/2006	JDA Intake 9C	56	0
				JDA Front Roll	55	0
				JDA Tailrace	54	14[a]
				TDA Tailrace	153	0
6/4/2006	Yearling	212	6/5/2006	JDA Intake 9C	0	0
				JDA Front Roll	0	0
				JDA Tailrace	0	0
				TDA Tailrace	214	0
Totals	Yearling	2500	Totals	JDA Intake 9C	500	0
				JDA Front Roll	500	3
				JDA Tailrace	500	19[b]
				TDA Tailrace	1000	7

[a] 12 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 20 dead fish in spring.
[b] 14 of these fish were intentionally sacrificed to reach a goal of tagging and releasing 20 dead fish in spring.

Table 2.3. Numbers of Tagged and Released Sub-Yearling Chinook Salmon in Summer 2006

Date	Age Class	Number Tagged	Release Date	Release Location	Number Released	Mortalities
6/12/2006	Sub-Yearling	250	6/13/2006	JDA Tailrace	50	0
				TDA Tailrace	200	4
6/14/2006	Sub-Yearling	250	6/15/2006	JDA Tailrace	50	0
				TDA Tailrace	200	0
6/19/2006	Sub-Yearling	250	6/20/2006	JDA Tailrace	50	0
				TDA Tailrace	200	4
6/21/2006	Sub-Yearling	250	6/22/2006	JDA Tailrace	50	1
				TDA Tailrace	200	0
6/26/2006	Sub-Yearling	300	6/27/2006	JDA Tailrace	100	0
				TDA Tailrace	200	0
6/27/2006	Sub-Yearling	200	6/28/2006	TDA Tailrace	200	0
6/30/2006	Sub-Yearling	250	7/1/2006	TDA Tailrace	250	5
7/6/2006	Sub-Yearling	250	7/7/2006	TDA Tailrace	250	2
7/10/2006	Sub-Yearling	250	7/11/2006	TDA Tailrace	250	4
7/12/2006	Sub-Yearling	252	7/13/2006	TDA Tailrace	252	6
Totals	Sub-Yearling	2502	Totals	JDA Tailrace	300	1
				TDA Tailrace	2202	25[a]

[a] Two of 25 fish were intentionally sacrificed to meet a dead-fish quota for summer.

A Multiquip 270-gpm dewatering pump was used to pump water from the forebay up to an induction tank on deck (Figure 2.4) through a 4” suction hose and back into the gatewell slot of Turbine Intake 9C. The release hose was mounted to a scintillation frame at mid-depth (131.5 ft msl). When the induction tank and downstream hose were full of water, we poured a bucket of fish into the tank and pulled the standpipe in the center of the tank. The suction created by the downstream hose pulled the water and fish from the tank down into the intake slot. All releases occurred after 2100 hours.

Figure 2.4. Release Apparatus for Turbine Intake 9C Releases at JDA in Spring

For boat releases, we moved the fish buckets from the transport totes into the stern of a boat. The boat operator maneuvered the boat to the release location and put the motor in neutral. Fish buckets were opened and checked for mortalities (“morts”). We scanned all dead fish with a BioMark portable transceiver PIT tag scanner so that identities could be established and recorded. We also recorded the release site, a number from 1 to 5 indicating relative distance from the Oregon shore and the time each bucket of tagged fish was emptied into the river.

2.4 Steps Taken to Minimize Handling Impacts

Numerous steps were taken to minimize the handling impacts of collection and surgical procedures. The collection of all tagged fish was done in conjunction with the JDA Smolt Monitoring Collection Facilities normal collection. The use of these already collected fish allowed us to minimize the impact of having to collect further fish to meet our quota for the day.

The number of personnel on hand was the biggest contributor to ensuring that all tagged fish were handled in a manner that was least intrusive on their survivability. Overall handling time was a consideration that was met with enough personnel to tag effectively and in a timely manner. Six people participated. One individual was responsible for anesthetizing fish and delivering them to be weighed and measured. Two people were responsible for weighing, measuring, and recording tagging data, and three did surgeries to implant fish with tags.

Several steps used in the actual tagging process also helped to minimize the handling impact on tagged fish. Sterilization of all surgical instruments was a continuous and emphasized protocol. Each surgeon used 3-4 complete sets of instruments. When a set was not being used it was placed in a 70% ethanol solution for approximately 10 minutes. All instruments would be rotated before each use and for a duration of 10 minutes, to a solution of distilled water to “wash” all residual ethanol off before the instruments would be used for surgery. This allowed bacteria and other harmful particulates to not be introduced into the incision or suture areas. To counteract the disruption of the mucus membrane from the incision, Poly-Aqua was used to help replace the membrane that was removed from the fish’s epidermal layers (Table 2.4). Local anesthetic was not used on the incision site due to its characteristic of further disrupting the mucus membrane.

Table 2.4. Dilution of Poly-Aqua Used in Surgical Procedures

Volume of Water	Poly-Aqua
1L	0.15
2L	0.30
3L	0.45
4L	0.60
5L	0.75
6L	0.90
10L	1.50
20L	3.00
50L	7.50
1 gallon	0.60
5 gallons	2.80
10 gallons	5.70
50 gallons	28.40

The actual surgical procedure was also designed in such a way as to minimize handling. The proximity of the incision to the midline was closely monitored to ensure that neither incisions nor sutures went through the midline.

Monitoring of all buckets containing anesthesia solution was a vital part of minimizing handling affects. Anesthesia buckets were kept to ±2 degrees of current river temperatures. Anesthesia solutions were either replaced or cooled with ice when temperatures exceeded protocols. Recovery buckets were also monitored in the same manner. Transportation of fish from the JDA Smolt Monitoring Facility to the TDA release site also warranted close monitoring of water temperatures and oxygen delivery to buckets.

2.5 Detection of Tagged Fish

2.5.1 Nodes and Arrays, Defined

Sonic Concepts' autonomous acoustic telemetry receiver (referred to hereafter as a node) consisted of two coupled parts. The top was made from Schedule 40 4-inch-diameter PVC pipe that was capped at the top and had a fitting with male threading at the bottom (Figure 2.5). The cap was modified for water-tight seating of a hydrophone, and the body below the cap housed the analog and digital boards for processing detected tag signals. A lubricated 4-inch-diameter rubber o ring was fitted over the lower threaded end so it would form a water-tight seal when the node top was screwed together with the bottom. The node bottom was made from about 3 ft of 4-inch-diameter PVC pipe and the upper end had a fitting with female threads for coupling it with the node top. The lower end of the node bottom was capped and a stainless steel harness was located just below the upper fitting so the node could be attached to an anchor system, which is described later. A 4x-power 15-second acoustic beacon was attached to the outside of the battery housing just below the threaded end of the housing. This beacon was used to determine the location of a node if it didn't surface after it was acoustically released from an anchor. Beacons also could be used to determine when an adjacent node disappeared.

Immediately before deployment, two 30-day lithium ion batteries were gently lowered into the node bottom with battery leads and secured in place with a battery retention device. Wire leads from the batteries were attached to connectors from the analog board in the node top. One end of a serial cable was connected to a plug from the board set in the node top and the other end was plugged into a laptop computer so that staff could communicate with the node, set its date and time, and verify detection of a beacon tag. Next, a 1-GB compact flash (CF) card was mounted in a slot on the board set, and the node top and bottom were screwed together until beveled edges of each piece compressed the o ring to form a watertight seal. The air space within the battery housing provided positive buoyancy, while the batteries provided ballast to help keep the node upright.

All autonomous hydroacoustic nodes were received from Sonic Concepts with either version 2005 or 2006 software and thoroughly tested by Precision Acoustic Systems (PAS) to ensure that nodes met acceptance-testing criteria. Functionality also was verified just before each deployment in the river.

An array is defined as a group of nodes deployed within 1 to 2 km of a specific river cross section to detect passing fish with acoustic tags. Most arrays had nodes that were deployed within 600 ft of each other and within 300 ft of the shore in a line across the river. However, additional nodes sometimes had to be deployed in entrances to or exits from side channels formed by islands downstream of BON.

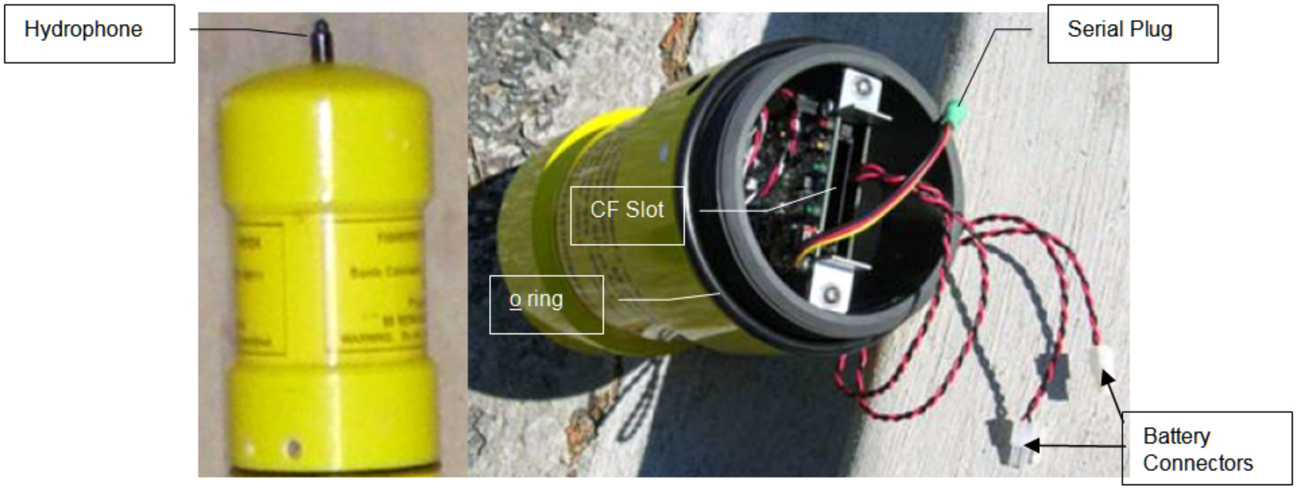


Figure 2.5. Side (left) and Bottom (right) View of a Node Top

2.5.2 Arrays and Release Locations

2.5.2.1 John Day Dam and Tailwater

The three release locations at JDA included the Turbine Intake 9C (rkm 347.0), the Front Roll (rkm 346.9) located 100 to 200 ft off the downstream face of the dam at Unit 9, and the JDA Tailrace at rkm 344.4. An egress-detection array was deployed about 7.8 km below JDA near Giles French Landing (Figure 2.6) during the spring. It was used to estimate the time required for fish released in the turbine, front roll, and tailrace to leave the immediate tailrace area and not to estimate survival. The first array was located at about rkm 325.6, the second at rkm 324.2, and the third at rkm 312.4 (Figure 2.6). This was about 21.4, 22.8, and 34.6 rkm below JDA, respectively. The third array just above TDA was used to detect fish and establish virtual releases for TDA. Array locations were selected based upon bathymetric conditions favorable for acoustic detection of passing transmitters, and criteria included narrow river cross sections without islands or shallow bars.

2.5.2.2 The Dalles Tailwater

The TDA Tailrace release transect was located at rkm 306.0, about 1.7 rkm downstream from TDA. The first TDA array was located at about rkm 275.6 (near the Bingen Marina), the second at rkm 238.4, and the third array at rkm 236.4 (Figure 2.7). These were about 33.3, 70.5, and 72.5 km below TDA, respectively. The third array just above Boat Rock was used to detect fish and establish virtual releases for BON. A fourth array was installed at the BON spillway forebay at rkm 235.0, which is about 73.9 rkm downstream from TDA The first three arrays were for estimating detection and survival probabilities, and the fourth was for detecting fish passing through the BON spillway.

2.5.2.3 Bonneville Dam and Tailwater

The primary BON array was located at about rkm 208.8 near Rooster Rock State Park, Oregon; the secondary at rkm 204.0 near Washougal, Washington; and the tertiary at rkm 193.8 near Lady Island (Figure 2.8). The primary, secondary, and tertiary arrays were located about 26.2, 31.0, and 41.2 rkm below the outfall of the SMF release site in the BON Tailrace at rkm 232.8.

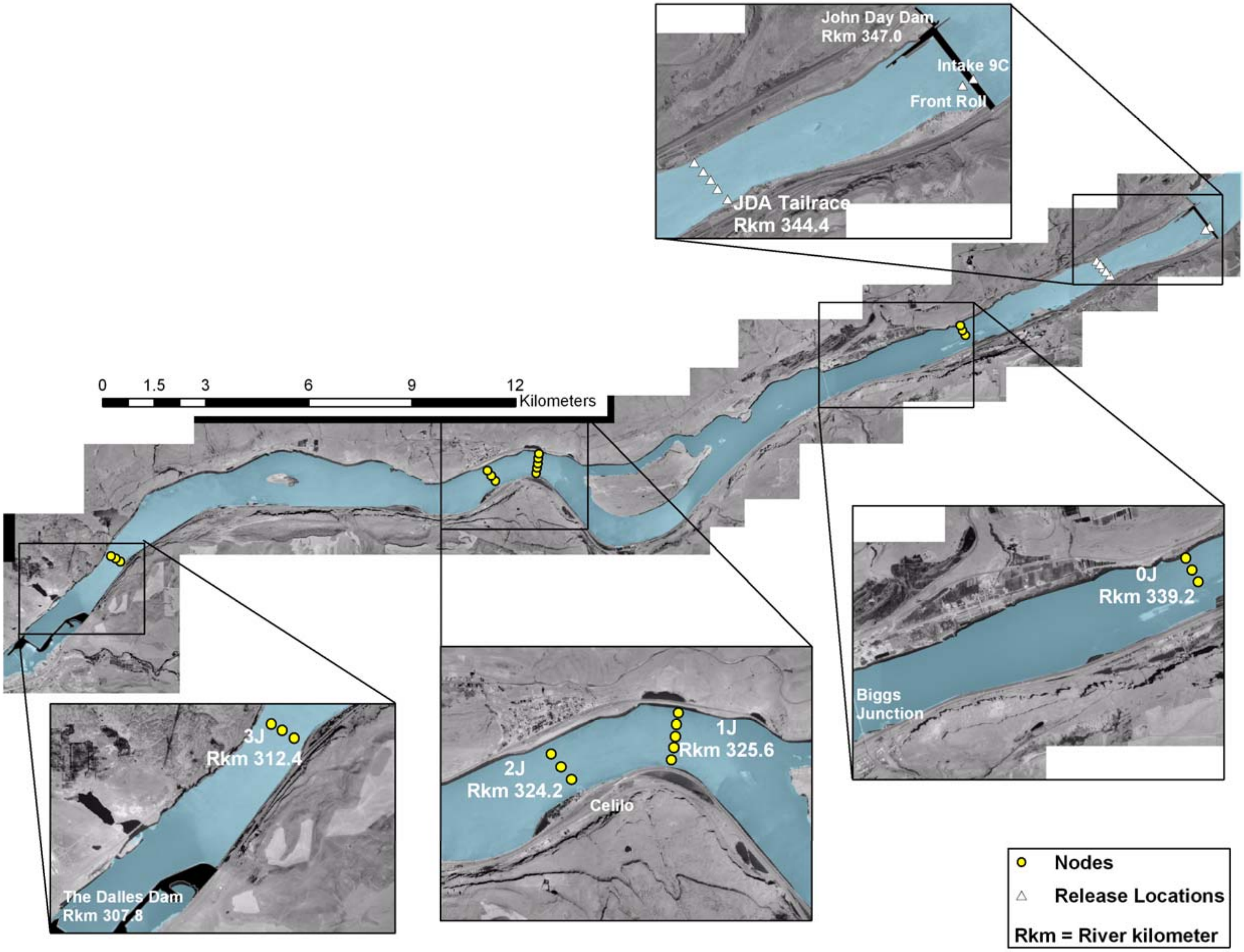


Figure 2.6. Columbia River with Yellow Circles Indicating Waypoints at Autonomous Node Locations for the Four JDA Tailwater Arrays. From right to left the arrays were JDA Egress (0J), and the JDA Primary (1J), 2J, and 3J. The Dalles Dam is located on the far left. In the upper right, white triangles mark the three JDA fish release locations: Intake 9c, Front roll, and JDA Tailrace.

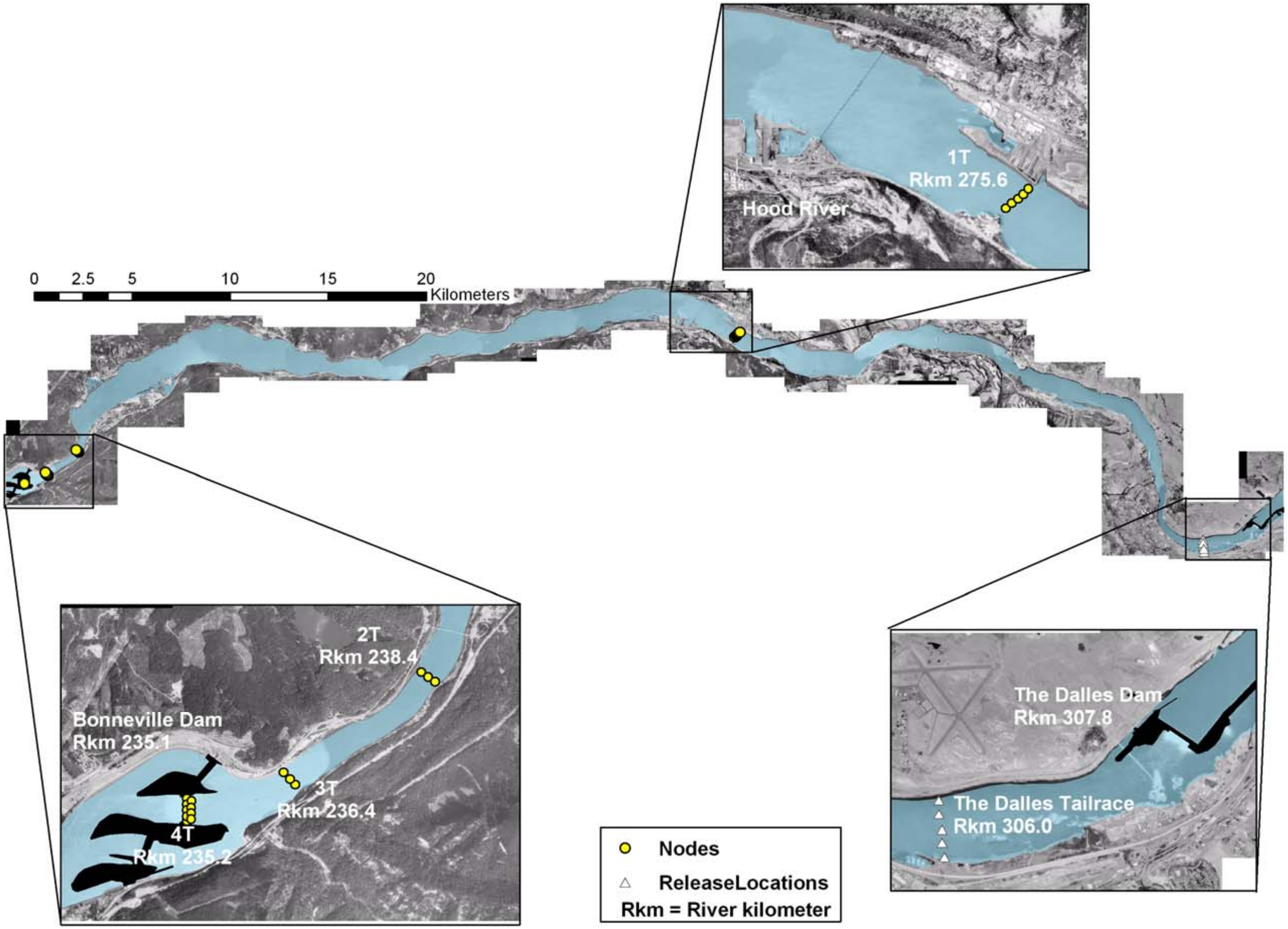


Figure 2.7. Columbia River with White Triangles Marking a Tailrace Release Location Below TDA and Yellow Circles Marking Waypoints of Autonomous Node Locations in Four TDA Tailrace Arrays. From right to left, the diagram shows The Dalles Dam, the tailrace release site, survival arrays 1T, 2T, 3T, and the BON Spillway detection array (4T).

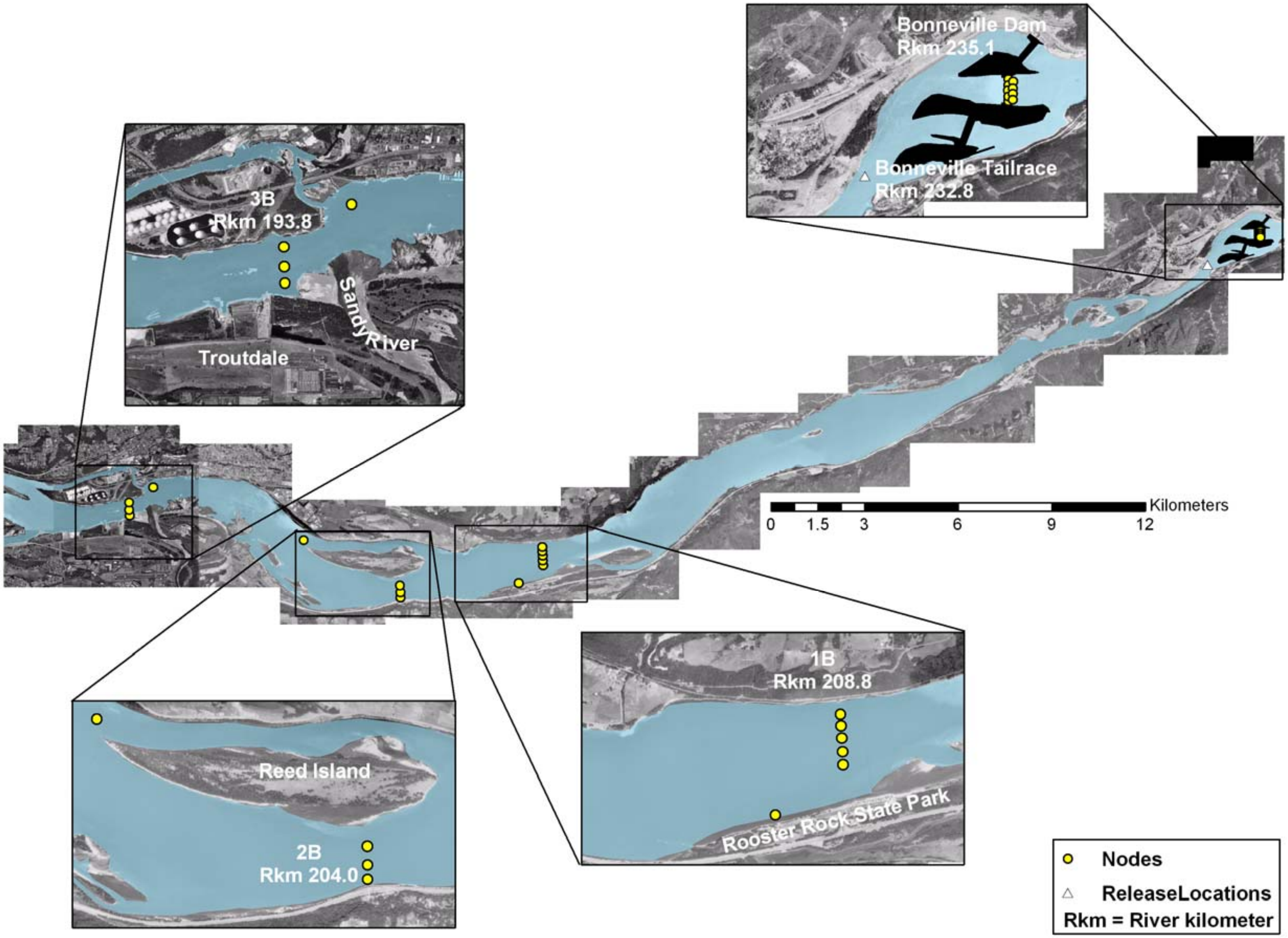


Figure 2.8. Columbia River with Yellow Circles Marking Waypoints of Autonomous Node Locations for BON Survival Arrays 1B, 2B, and 3B in the Tailwater (Left) and White Triangles Marking the BON Tailrace Release Location (Upper Right). Array 4T in the BON Spillway Forebay also is visible in the upper right.

For both the spring and summer season, fish that were tagged and released for the acoustic telemetry project in the estuary were also used to supplement sample size for survival calculations throughout the BON arrays. These released fish were also used to estimate survival through the BON project using a paired release model. These fish were released from the JBS outfall at rkm 232.8 (Figure 2.8).

2.5.3 Node Deployment

After initial deployments, all autonomous nodes were rigged with the configuration shown in Figure 2.9. A 5-foot section of line with three 6-pound buoyancy floats was attached to a strap half way between the node tip and the battery housing bottom. An InterOcean Systems Model 11 acoustic release was attached to the other end of the 5-foot line. Either 6 or 12 ft of cable was attached to the bottom of the acoustic release, depending on water depth and the other end of the cable was attached to a 120-lb anchor. The shorter 6-ft length was used in water <40 ft deep and the 12-ft length was used in water >40 ft deep.

During the initial deployments, a tag-line canister was attached to the acoustic release and filled with 250 ft of nylon line that connected the release to the anchor. When the release was triggered, the node, floats, and release surfaced while line played out of the canister, and if retrieved quickly, the anchor could be recovered and reused. However, given high river flow in spring, the assembly usually only surfaced briefly before re-submerging, and then crews had to drag for nodes to retrieve them. Dragging can be a time consuming process, so the tag-line canister and anchor line were not used in subsequent deployments.

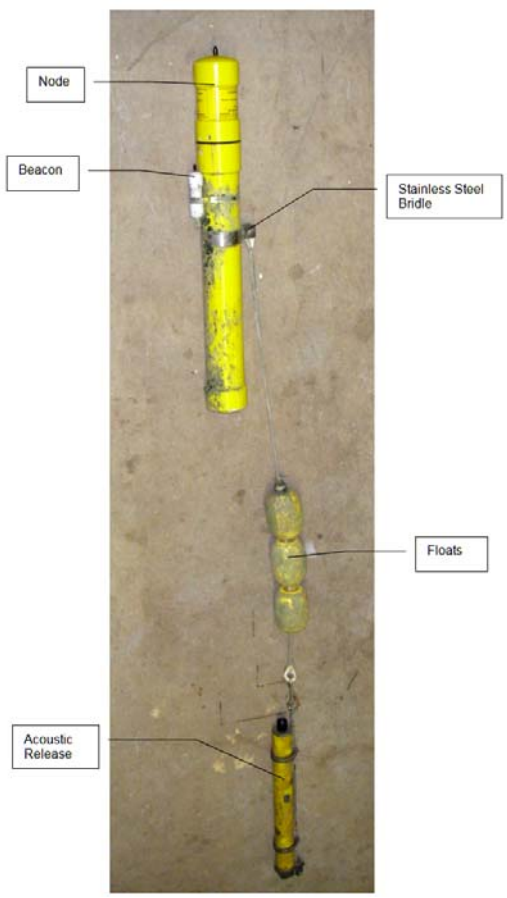


Figure 2.9. Node Rigging without the 120-Pound Anchor Shown 6 to 12 ft below the Acoustic Release

2.5.4 Node Retrieval, Servicing, and Redeployment

We tried to retrieve data from all nodes every week, but high river flows precluded this during some of the spring. Nodes were serviced to replenish the batteries every 4 weeks. The first step in servicing a node was to trigger its acoustic release by entering a release-specific code into a transceiver that transmitted an electrical signal to a underwater transducer, which in turn converted the electrical signal into code-specific acoustic transmissions to activate the release mechanism. Once the node, floats, and acoustic release surfaced, they were retrieved by boat (Figure 2.10). The next step was to dry the node with a towel, open it, dismount the compact flash (CF) card, and download data from the card to a laptop. We checked the data file to verify that the node collected data throughout its last deployment, records were continuous, and records included time stamps and tag detections. We replaced the CF card and batteries and redeployed the node. If the data were corrupt, the node top was replaced with a new one and the faulty top was sent to Sonic Concepts for repair. The most common problem was damage to the hydrophone tip. Nodes were serviced and redeployed until September 30, 2006, to provide maximum opportunity to detect late migrating subyearling Chinook salmon released on the Snake River.

Figure 2.10. Autonomous Node Retrieval

2.6 Project Discharge and Water Temperature

Project discharge data from automated data-acquisition systems for all three dams, including discharge by spill bay and turbine unit, were provided by the Portland District, USACE, in 5-minute increments. The 10-year (1996 to 2005) average discharge and forebay water temperature data were downloaded from the DART (Data Access in Real Time) website (http://www.cbr.washington.edu/dart). Five-minute discharge data were averaged by location and day and by location and hour and merged with temperature data and later with release-specific survival estimates for correlation analysis.

2.7 Data Processing and Validation

Tag detection data were processed in two ways as a quality-control measure, and we found no significant difference in detection and survival estimates based upon detection histories generated by the two methods. One method involved using TagViz software, and the other involved processing data with programs written in Statistical Analysis System (SAS) code. Regardless of the method, tag, release, and detection data were merged into a single dataset, and the same rules were applied to detection data to identify array detection and generate detection histories for every tag. Those rules included the following:

1. Tags codes were detected downstream of the release site.
2. Tags codes were detected after the release date and time.
3. Decode intervals were 8 to 32 s for tags transmitting once every 10 seconds and from 3 to 22 s for tags transmitting once every 5 seconds.
4. Detection rates were four in 120 s for 10-s tags and four in 60 s for 5-s tags.

Unless otherwise noted, straight lines and curves on graphs are linear and quadratic fits using ordinary least squares after first establishing that there was little evidence of lack of fit using higher order polynomials.

2.8 Tag Life Study

Ninety-nine subyearling Chinook salmon from Priest Rapids Hatchery were surgically implanted with JSATS acoustic tags that transmitted once every 10 seconds (10 s tags) and another 100 were implanted with tags transmitting once every 5 seconds (5 s tags). The surgical implantation procedure followed the procedures outlined in Section 2.2.2 above. The fish were held in tanks at PNNL's on-site wetlab in Richland, WA. When a tagged fish died, the tag was re-implanted in another fish until the tag died. A JSATS mobile node was used to listen for tags daily and tag-life history data were compiled to produce tag-life curves, which indicate the percent of each tag type transmitting as a function of days since activation.

2.9 Release-Recapture Designs

2.9.1 Overview

Various release and recapture studies with yearling and subyearling Chinook salmon smolts were conducted in 2006.

2.9.1.1 Definition of Metrics

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

Forebay is the segment of river immediately upstream of a dam where operations at the dam are the primary contributing factor to velocity and direction of water flow. The upstream boundary of a forebay is where a significant alteration in water-flow allocation through dam operational changes affects water velocity or direction. The downstream boundary is the upstream face of the dam. Locations of forebay arrays for TDA and BON in this study were not selected based upon measurable hydraulic criteria, and in both cases probably were 1 to 3 km upstream of the hydraulic influence of each dam most of the time. There is no single location that would meet this definition all of the time.

Tailrace is the segment of river immediately downstream of the dam where dam operations are the primary factor affecting velocity and direction of flow. The upstream boundary of the tailrace is the downstream face of the dam and the downstream boundary is where operational changes at the dam no longer effect the direction of water flow and mixing from the spillway and powerhouse is complete. Our tailrace release locations below JDA and TDA were pretty close or slightly downstream of the downstream hydraulic influence of those dams most of the time, whereas the outfall release point below BON likely was still within the influence of that dam most of the time. There is no single location that would meet this definition all of the time.

Reservoir or Pool is the segment of river downstream of the tailrace of an upstream dam down to the forebay of the next dam downstream.

Tailwater is the segment of river downstream of the tailrace of an upstream dam down to the forebay of the next dam downstream or to the point where salt-water mixing occurs for the last dam in a series (e.g., BON). Tailwater is synonymous with reservoir or pool when it lies between two dams.

Project survival is the probability of survival from the upstream boundary of the reservoir or pool of a dam to the downstream boundary of the tailrace of the dam. Studies utilizing active tags typically use paired release survival models to estimate this parameter whereas studies utilizing PIT tags have typically used single-release survival models.

Dam survival is the probability of survival from the upstream boundary of the forebay to the downstream boundary of the tailrace and includes the forebay, all routes of passage, and the tailrace of a given dam. In this study, dam survival is loosely defined as being from a forebay detection line to the tailrace release location for reference release groups of fish.

Passage-route survival is the probability of survival for fish passing through any individual route (i.e., spillway, turbine, bypass, etc.) to the downstream boundary of the tailrace (release location of a tailrace reference group). In this study passage-route survival was estimated for fish passing Turbine Intake 9C at John Day Dam and those passing the spillway, B2 JBS, and B2 Corner Collector at Bonneville Dam.

2.9.1.2 Yearling Detection and Survival Metrics

For yearling Chinook salmon, we estimated detection probabilities and survival statistics for

1. LGR releases to Array 1J and from Array 1J to 1T from detections at 1J, 1T, and 2T (single release model)
2. JDA Turbine Intake 9C, the 9C Front Roll, and Tailrace releases to 1J and from 1J to 1T from detections at 1J, 1T, and 2T (single release model)
3. Paired release estimates for the JDA Intake 9C and Front Roll relative to each other and to the Tailrace release using detections at 1J, 1T, and 2T. The paired-release estimate to the JDA Tailrace is a passage-route survival estimate, as defined above.
4. TDA Tailrace releases to 1T and from 1T to 2T from detections at 1T, 2T, and 1B (single release model)
5. BON Tailrace releases to 1B and from 1B to 2B from detections on 1B, 2B, and 3B (single release model)

6. Virtual Releases from the TDA Forebay (Array 3J) to 1T and from 1T to 2T using 1T, 2T, and 1B detections (single release model)
7. Dam survival for TDA by post-hoc pairing of the pooled estimate for virtual releases from the TDA Forebay (Item 6 above) with the pooled estimate for TDA Tailrace releases (Item 4 above) in a paired release model
8. Virtual Releases from BON Forebay (4T) to 1B and from 1B to 2B using 1B, 2B, and 3B detections (single release model)
9. Dam survival for BON by post-hoc pairing of the pooled estimate for virtual releases from the BON Forebay (Item 8 above) with the pooled estimate for BON Tailrace releases (Item 5 above) in a paired release model
10. TDA Project survival, as defined above, by post-hoc pairing of JDA Tailrace and TDA Tailrace releases in a paired-release model using detections at Arrays 1T, 2T, and 1B
11. The BON Project, as defined above, by post-hoc pairing of TDA Tailrace and BON Tailrace releases in a paired release model using detections at Arrays 1B, 2B, and 3B
12. Every study reach from release point to each successive array except the last array below Bonneville Dam (single release models)
13. BON spillway, B2 JBS, and B2CC survival based upon populations defined by acoustic detections at the spillway and PIT detections elsewhere and using acoustic detections at Arrays 1B, 2B, and 3B. These are passage-route survivals, as defined above.

2.9.1.3 Subyearling Detection and Survival Metrics

For subyearling Chinook salmon, we estimated detection probabilities and survival statistics for:

1. LGS releases to Array 1J and from 1J to 1T from detections at 1J, 1T, and 2T (single release model)
2. JDA Tailrace releases to 1J and from 1J to 1T from detections at 1J, 1T, and 2T (single release model)
3. TDA Tailrace releases to 1T and from 1T to 2T from detections at 1T, 2T, and 1B (single release model)
4. BON Tailrace releases to 1B from detections on 1B and 2B (single release model)
5. Virtual Releases from the TDA Forebay (Array 3J) to 1T and from 1T to 2T using 1T, 2T, and 1B detections (single release model)
6. Dam survival for TDA by post-hoc pairing of the pooled estimate for virtual releases from the TDA Forebay (Item 5 above) with the pooled estimate for TDA Tailrace releases (Item 3 above) in a paired release model
7. Virtual Releases from the BON Forebay (Array 3T) to 1B using detections at Arrays 1B and 2B (single release model)
8. Dam survival for BON by post-hoc pairing of the pooled estimate for virtual releases from the BON Forebay (Item 7 above) with the pooled estimate for BON Tailrace releases (Item 4 above) in a paired release model
9. After post-hoc pairing with BON Tailrace releases, division of estimates for fish in virtual forebay releases (Item 7 above) by estimates for fish released in the tailrace (Item 4 above) provides a paired-release estimate of dam survival for BON.

10. TDA Project by post-hoc pairing of JDA Tailrace and TDA Tailrace releases in a paired release model using detections at Arrays 1T, 2T, and 1B
11. The BON Project by post-hoc pairing of TDA Tailrace and BON Tailrace releases in a paired release model using detections at Arrays 1B and 2B
12. Every study reach from release point to each successive array except the last array below Bonneville Dam BON in summer (2B)
13. BON spillway, B2 JBS, and B2CC based upon populations defined by acoustic detections at the spillway and PIT detections at the B2 JBS and B2CC and using acoustic detections on Arrays 1B and 2B
14. BON spillway by spill condition or for day and night periods.

Survival estimates of fish passing through TDA and BON were estimated in two ways. First, the estimates were for fish released below the dam upstream (JDA or TDA); these include survival through the upstream pool, dam, and tailwater in a single-release model and through the upstream pool, dam, and tailrace in a paired-release model. The paired-release estimates are referred to as Project survival. Second, the estimates were for fish detected on the array just upstream of the dam; these virtual release estimates do not include survival through the upstream pool but do include the tailrace down to the release point for reference groups of fish. The estimates are for the dam and tailwater in single-release models or, if paired with tailrace release estimates in a post-hoc paired-release model, they represent dam survival.

For the primary arrays deployed below JDA and TDA, we could pick from among several arrays downstream to serve as secondary and tertiary arrays in survival calculations. Therefore, we made those calculations in two ways, first by picking the most independent arrays based upon longer river distances, and second by simply using the next two arrays in the same pool, regardless of distances. We compared the former estimates based on preferred arrays with the latter estimates based upon “as-planned” arrays to broaden choices for future studies. We present detailed methods for the preferred choice of arrays below. Calculations using “as planned” arrays would be similar and are not explicitly described to avoid redundancy.

When examining survival of fish passing the Bonneville Dam spillway, we assigned passage events to day and night categories based upon the time of last detection time in the forebay. Daytime was defined as from 0600 through 2100 hours each season, and the remaining hours of the day were assigned as nighttime hours.

2.9.2 Yearling Chinook Salmon Smolts

Various project-specific, release-recapture studies were performed in 2006. However, these site-specific releases of smolts also provided the opportunity to estimate survival parameters at downstream sites during their outmigration. Therefore, the release groups were often used on more than one occasion to estimate smolt passage survival. A total of nine acoustic arrays located from below JDA to below BON were used to obtain downstream detection data in 2006.

2.9.2.1 Lower Granite Release Group

A total of 996 yearling Chinook salmon smolts were released below Lower Granite Dam on the Snake River (Figure 2.11). Reach survivals were estimated from the release location to the JDA primary array (i.e., 1J) and the TDA primary array, i.e., 1T (Figure 2.11). The terminal detection location was the secondary array below TDA Dam (2T).

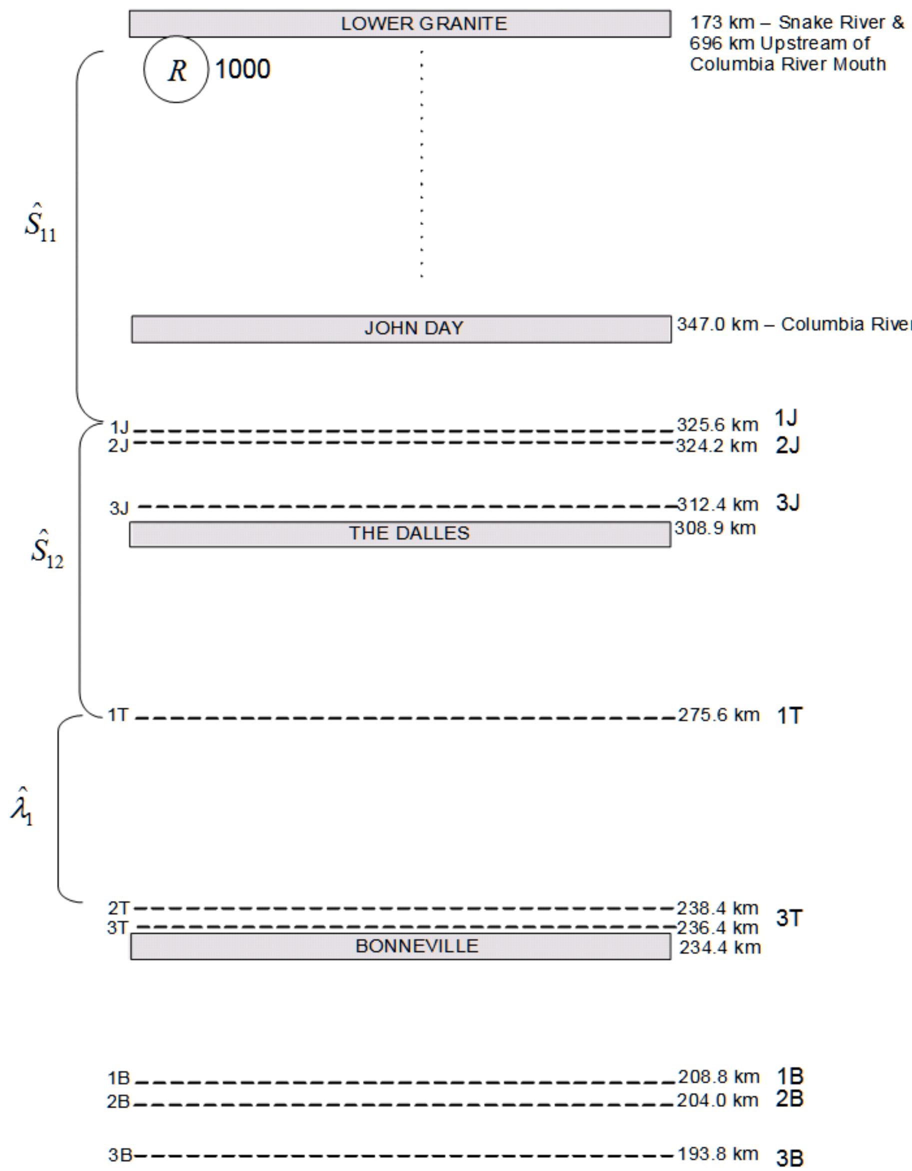
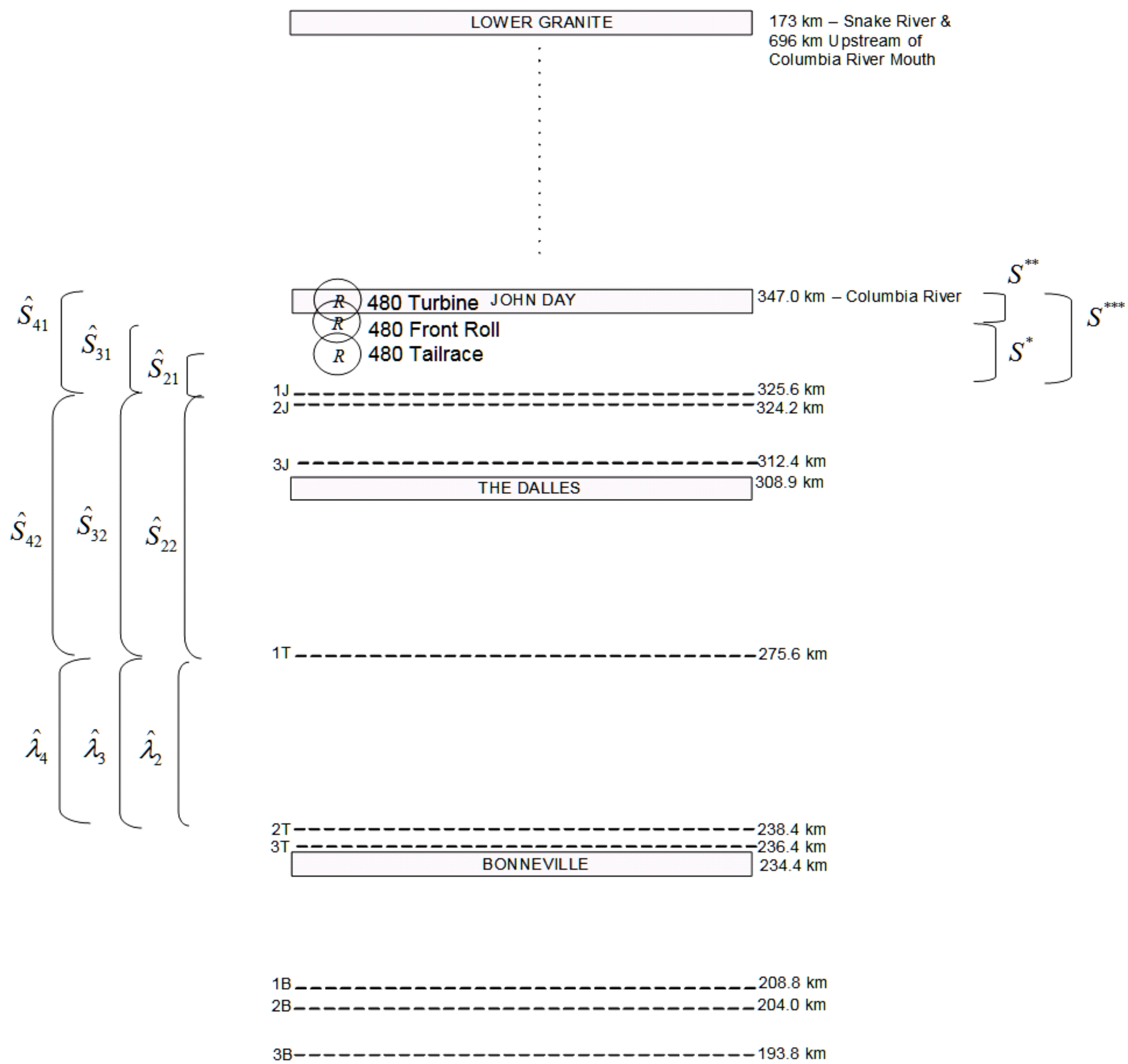


Figure 2.11. Release-Recapture Locations for the Single Release-Recapture (SR) Analyses of the Lower Granite Release Groups of Yearling Chinook Salmon

2.9.2.2 John Day Dam Release Groups

Three different release locations at JDA were used in the 2006 investigation of yearling Chinook salmon. These locations included releases (a) in the turbine, (b) in front of the turbine discharge, and (c) in the tailrace at JDA. At each location, between 481 and 500 yearling Chinook salmon smolts were tagged and released. These three release locations were used to generate three survival estimates based on the paired release-recapture (PR) model and another six survival estimates based on the single release-recapture (SR) model (Figure 2.12). In all cases, the detection locations were at the JDA primary array (1J), and the TDA primary array (1T), and TDA secondary array (2T) (Figure 2.12).



Paired releases used to estimate: $S^{*} = \dfrac{\hat{S}_{31}}{\hat{S}_{21}}, S^{**} = \dfrac{\hat{S}_{41}}{\hat{S}_{31}}, S^{***} = \dfrac{\hat{S}_{41}}{\hat{S}_{21}}$

Figure 2.12. Release-Recapture Locations for the Single-Release (SR) and Paired-Release (PR) Analyses of the JDA Release Groups

2.9.2.3 The Dalles and Bonneville Dams Tailrace Release Groups

At the TDA Tailrace, 978 yearling Chinook salmon smolts were tagged and released, along with 972 below BON (Figure 2.13). These groups were analyzed as single releases. The tailrace releases were used to estimate survival from the release point to the primary and secondary arrays below each project using the single release-recapture model (Figure 2.13).

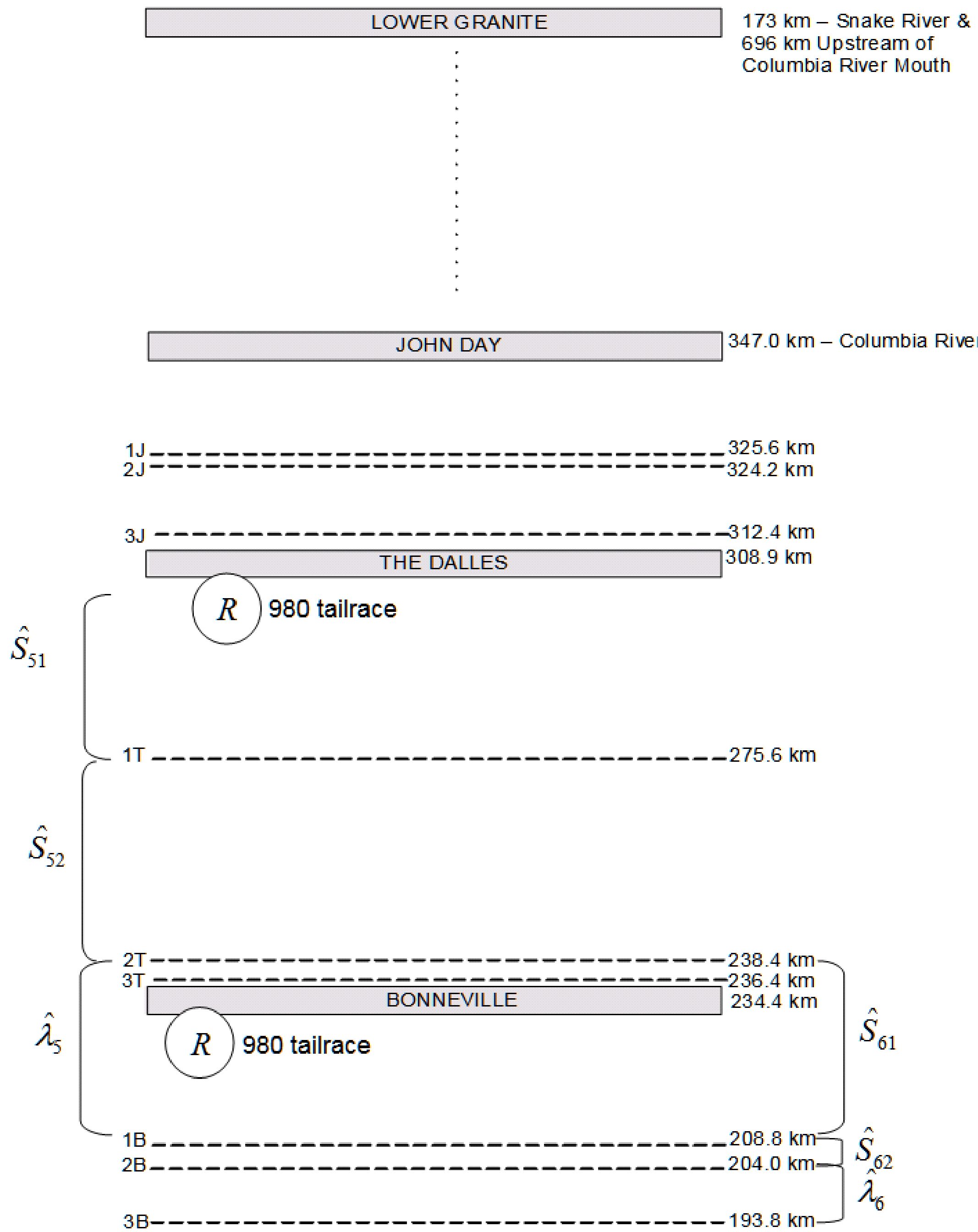


Figure 2.13. Release-Recapture Locations for the Single-Release (SR) Analysis of TDA and BON Tailrace Releases

2.9.2.4 Virtual Releases to Estimate Dam Passage Survival at The Dalles and Bonneville

The tertiary arrays above TDA (3J) and above BON (3T) were used to establish virtual release groups (Figure 2.14) to estimate dam passage survival. Fish released at JDA that were known to have survived to the tertiary array at 3J constituted a virtual release group that was used to estimate passage survival through TDA based on detections at arrays 1T, 2T, and 1B. Fish released at TDA Tailrace that were known to have survived to the tailwater array at 3T constituted another release group that was used to estimate passage survival through BON using detections at 1B, 2B, and 3B. In both cases, the single release-recapture model was used to estimate reach survival.

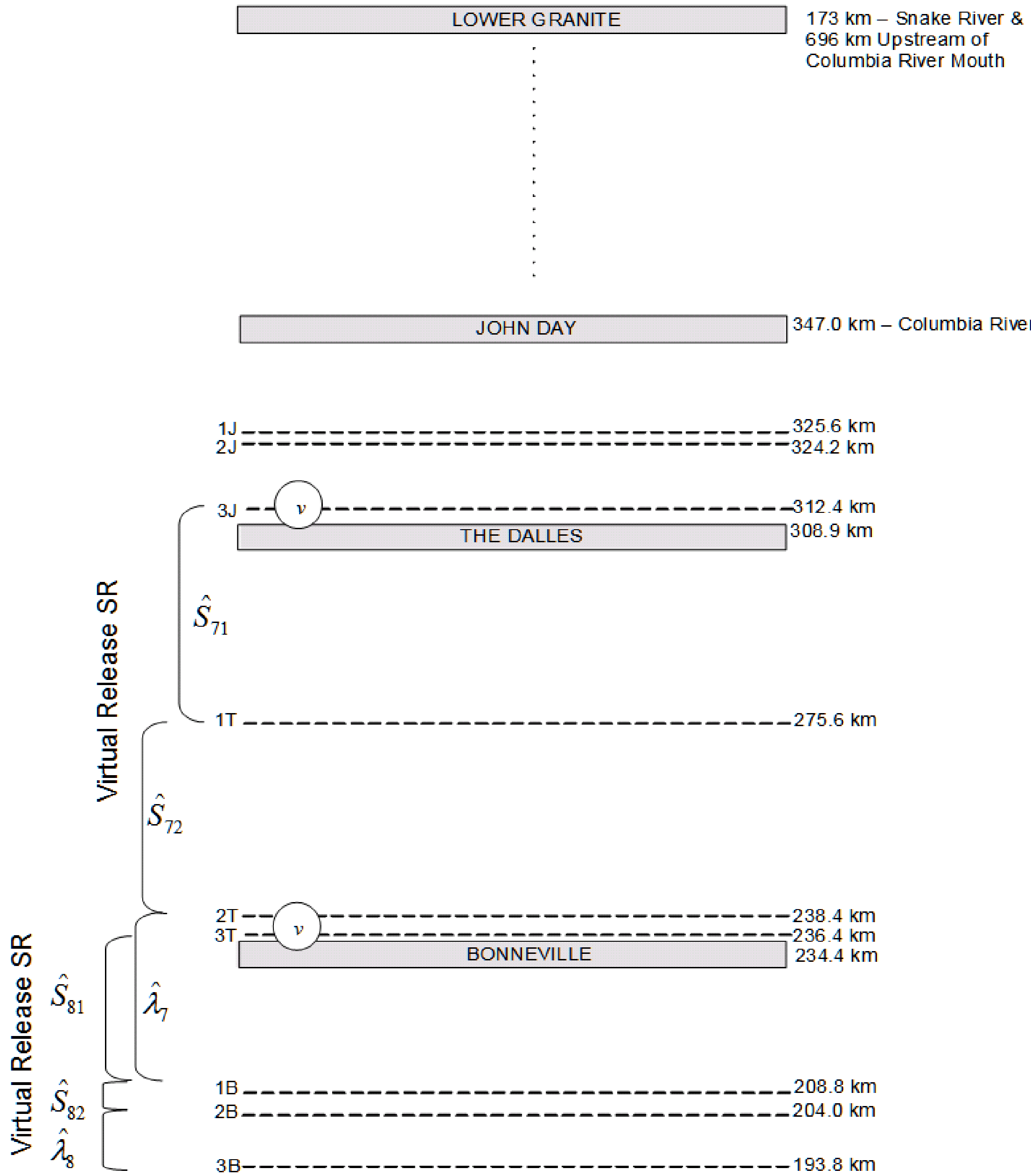
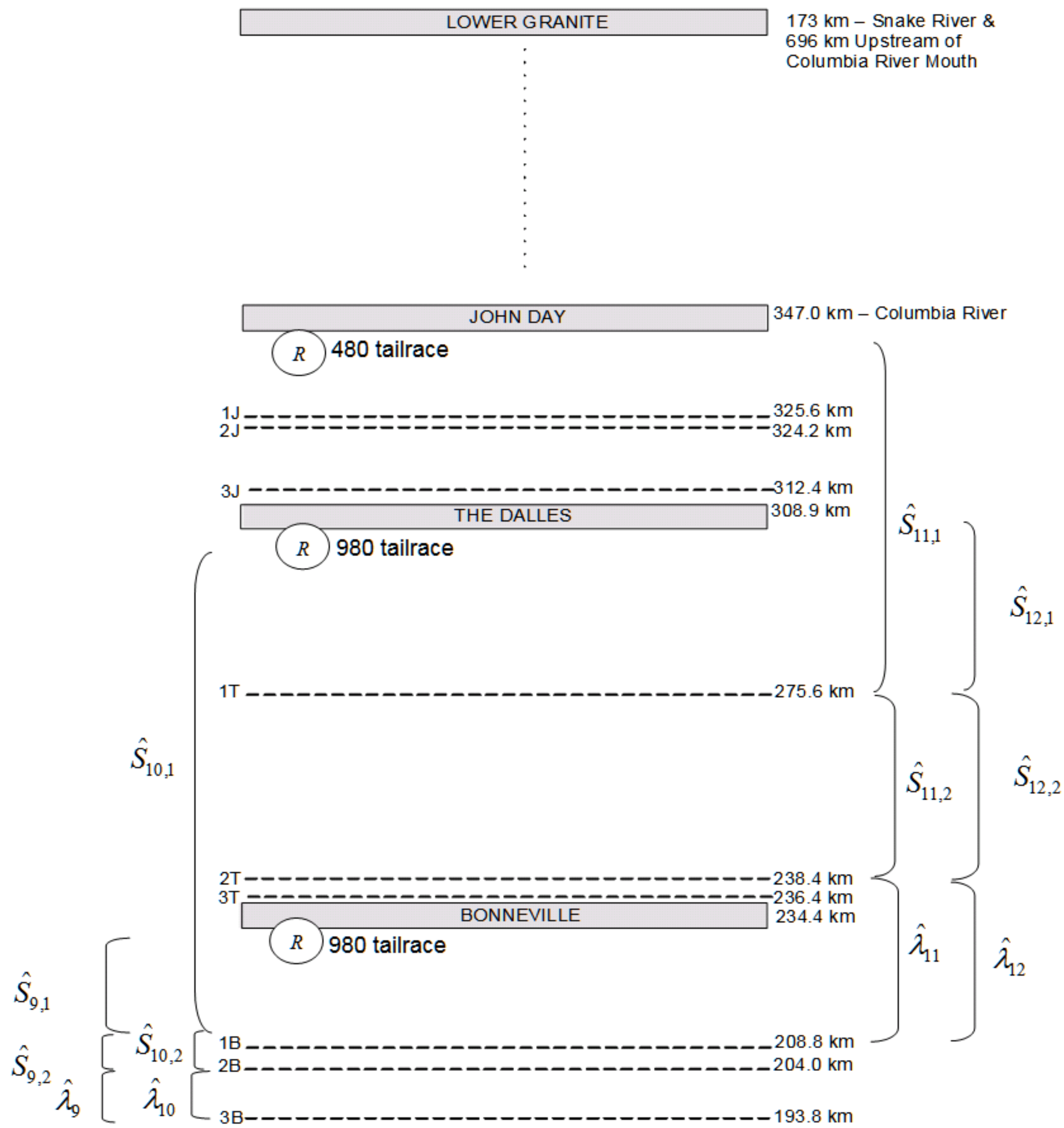


Figure 2.14. Virtual (v) Releases of Fish from 3J and 3T Used to Estimate Dam Passage Survival at TDA and BON Dams

2.9.2.5 Project Survival Estimates at The Dalles and Bonneville

The three tailrace releases below JDA, TDA, and BON dams were used to estimate project passage survival at TDA and BON (Figure 2.15). The paired release-recapture model was used to estimate survival at each project. Using the JDA and TDA Tailrace releases and detections at arrays 1T, 2T, and 1B, TDA project passage survival was estimated (Figure 2.15). Using the tailrace releases from TDA and BON and the detections at 1B, 2B, and 3B, BON project passage survival was estimated.



$$\text{Estimate } \hat{S}_{\text{TDA}} = \frac{\hat{S}_{11,1}}{\hat{S}_{12,1}} \text{ and } \hat{S}_{\text{BON}} = \frac{\hat{S}_{10,1}}{\hat{S}_{9,1}}.$$

Figure 2.15. Release-Recapture Locations for Paired-Release (PR) Studies to Estimate TDA and BON Project Passage Survivals for Yearling Chinook Salmon Smolts

2.9.3 Subyearling Chinook Salmon Smolts

Four release locations—one below Little Goose Dam and the other three at the tailraces of JDA, TDA, and BON dams—were used to investigate reach passage survival for subyearling Chinook salmon smolts. A total of 1,949 subyearling Chinook salmon were released below Little Goose Dam, 299 below JDA, 2,179 below TDA, and 1,957 below BON.

2.9.3.1 Project-Specific Reach Passage Survivals

Tagged fish released below Little Goose Dam were used to estimate reach survivals from the point of release to the JDA primary array (1J), and between primary array 1J and 1T below TDA (Figure 2.16). The tailrace release below JDA was used to estimate reach survivals between the point of release and primary array 1J and between 1J and 1T (Figure 2.17). For the tailrace release below TDA and BON dams, survival was estimated from the point of release to the primary array (i.e., 1T or 1B) and between primary and secondary arrays (1T–2T) for TDA (Figure 2.17).

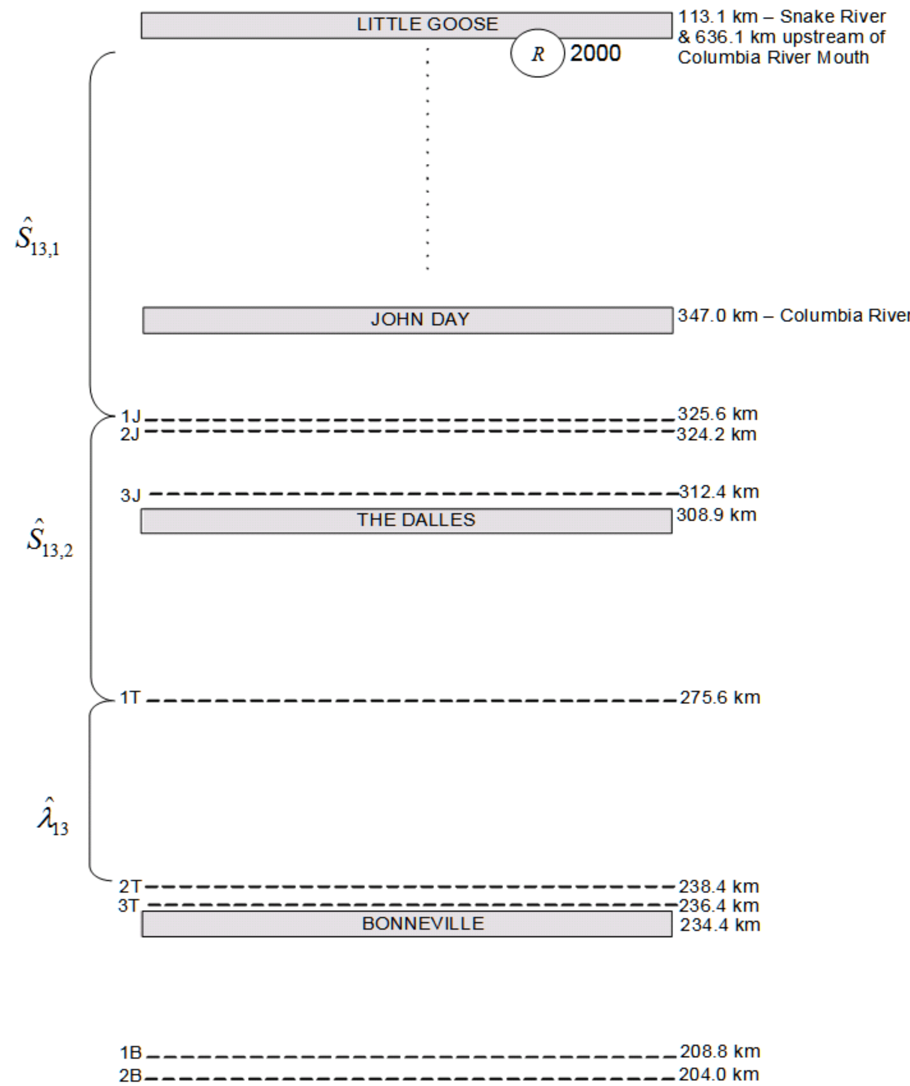


Figure 2.16. Release-Recapture Locations for the Single-Release (SR) Analysis of Reach Survival for Subyearling Chinook Salmon Smolts below Little Goose Dam

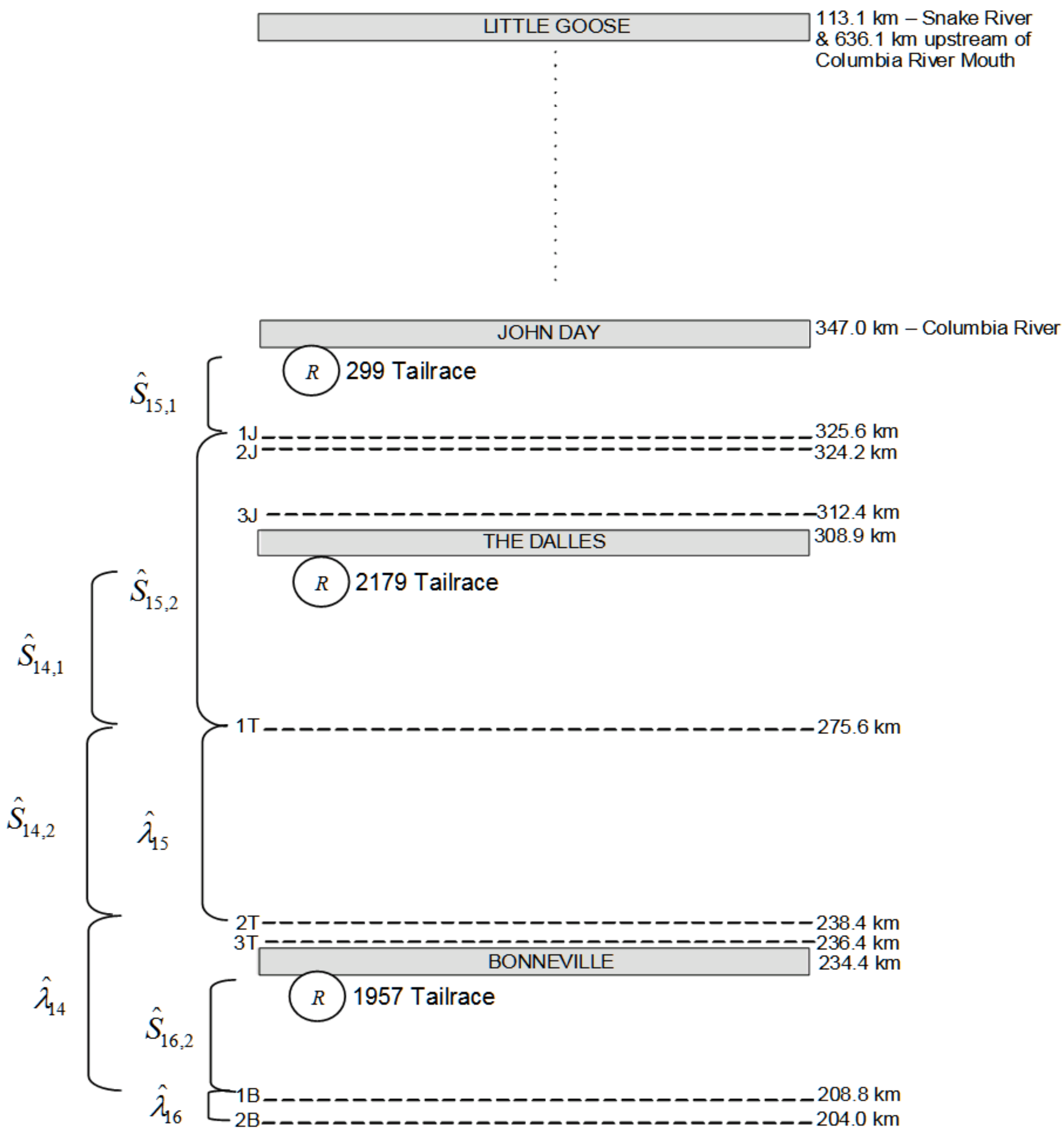


Figure 2.17. Release-Recapture Locations for the Single Release (SR) Analyses of Reach Survival for Subyearling Chinook Salmon Smolts at JDA, TDA, and BON

2.9.3.2 Virtual Releases to Estimate Dam Passage Survival at The Dalles and Bonneville

As with the yearling Chinook salmon, arrays above TDA (3J) and BON (3T) were used to establish virtual release groups (Figure 2.14) to estimate dam passage survival for subyearling Chinook salmon. Fish released at JDA that were known to have survived to the tertiary array 3J (279 fish) constituted a virtual release group that was used to estimate passage survival through TDA using detections at arrays 1T, 2T, and 1B. Fish released at the TDA Tailrace that were known to have survived to the tertiary array at 3T (2,022 fish) constituted another release group that was used to estimate passage survival through BON using detections at 1B, 2B, and 3B. In both cases, the single-release model was used to estimate reach survival.

2.9.3.3 Project Survival Estimates at The Dalles and Bonneville

The three tailrace releases of subyearling Chinook salmon below JDA, TDA, and BON (Figure 2.17) were used to estimate project passage survival at TDA and BON, analogous to the calculation for yearling Chinook salmon shown in Figure 2.15. The paired release-recapture model was used to estimate survival at each project. We used JDA and TDA Tailrace releases and detections at arrays 1T, 2T, and 1B, to estimate The Dalles project passage survival. We used the tailrace releases from TDA and BON and the detections at 1B and 2B to estimate BON project passage survival.

2.9.4 Bonneville Dam Route-Specific Estimates in Spring and Summer

All fish that were released upstream of BON were used to estimate Juvenile Bypass (JBS) and B2 Corner Collector (B2CC) survival estimates using a pooled single release-recapture model. Pit-tagged smolts that were PIT detected at the B2CC and B2 JBS were compiled to produce survival and recapture probabilities based upon detections at Arrays 1B, 2B, and 3B in spring and at Arrays 1B and 2B in summer. The third array below BON was not functional in summer because the nodes there were used to fill in other nodes that were lost from upstream arrays.

Survival estimates at the BON spillway were calculated each season using a pooled-release-recapture model based upon detections of tagged fish from any release on acoustic receivers in the spillway forebay and subsequent detections at Arrays 1B, 2B, and 3B in spring and at Arrays 1B and 2B in summer. Receivers in the spillway forebay could detect tagged fish that were within about 300 ft of spill gates, and those detected fish were assumed to have passed through the spillway, although they were not tracked to a specific final destination. Data on first detection and passage locations in previous radio telemetry studies indicate that that assumption was reasonable. Few fish first detected at the spillway passed at either powerhouse.

2.10 Statistical Analyses

2.10.1 Survival Estimates

The smolt survival estimates were based on two types of models, the single release-recapture (SR) models of Skalski et al. (1998) or the paired release-recapture (PR) models of Burnham et al. (1987). In essence, the paired-release models are a function of two separate single-release models. For this reason, the single-release model will be presented before the paired-release analysis.

For planned comparisons (JDA Intake, Front Roll, and Tailrace effects on survival), we used Z-test to test for significant differences. This test uses the property that maximum likelihood errors are asymptotically normally distributed, and the test has the form:

$$Z = \frac{\hat{S}_1 - \hat{S}_2}{\sqrt{\widehat{\text{Var}}\left(\hat{S}_1\right) + \widehat{\text{Var}}\left(\hat{S}_2\right)}}$$

For the many unplanned comparisons, we simply looked for overlap or non-overlap in ½ 95% confidence limits, because “exact” *P*-values would be unnecessary statistical window dressing in those cases.

2.10.1.1 Single-Release Model

In all cases where the single release-recapture model was used in spring (Figures 2.11-2.14) and below JDA and TDA in summer (Figure 2.16 and 2.17), there is a release location and three downriver detection locations. With the three detection locations, there are $2^3 = 8$ possible detection histories, resulting in the parameterization presented in Table 2.5. Note that there would be just four possible detection histories if two arrays were present, as was the case below, BON in summer.

The parameters in the release-recapture model are defined as follows:

S_1 = probability of surviving the first reach;

p_1 = probability of being detected at the first downstream detection site, given fish survival to that location;

S_2 = conditional probability of surviving the second reach, given fish survive the first reach;

p_2 = probability of being detected at the second downstream detection site, given fish survive to that location;

λ = joint probability of a fish surviving to and being detected at the third downstream detection site, given fish survive to the second detection location.

An eight-celled, multinomial likelihood model with the cell probabilities described in Table 2.5 was used to estimate the five model parameters.

In the case of tag failure, the model parameterization in Table 2.5 was inadequate. A graph of the tag-life survivorship curve, superimposed on a cumulative smolt survival distribution (Figure 2.18), was used to visually check the need for tag-life correction. In other words, if fish arrival times to the last detection array were longer than the time to the first tag failure, survival estimates based on the parameterizations in Table 2.5 would be negatively biased, in which case tag-life corrections of fish survival estimates were necessary (Townsend et al. 2006). In the case of tag failure, additional parameters were needed in the release-recapture model (Table 2.5) based on the method of Townsend et al. (2006). A revised parameterization, taking into account tag failure, is presented in Table 2.6.

Additional tag-life parameters that were estimated from the tag-life survivorship curve included the following:

L_1 = probability a tag survives passage through the first reach;

L_{12} = probability a tag survives passage through the first and second reaches (i.e., second reach);

L_{123} = probability a tag survives passage through all three reaches (i.e., third reach).

The estimates of the survival and capture parameters were calculated using maximum likelihood estimation, treating the estimates of tag-life (i.e., $\hat{L}_1$, $\hat{L}_{12}$, and $\hat{L}_{123}$) as known constants. However, to calculate a realistic variance estimator for the survival parameters, the error in the estimation of the tag-life probabilities was incorporated into an overall variance calculation. The variance of the survival estimates was calculated using the total variance formula

$$\text{Var}\left(\hat{S}\right) = \text{Var}_{\hat{\underset{\sim}{L}}}\left[E\left(\hat{S}\middle|\hat{\underset{\sim}{L}}\right)\right] + E_{\hat{\underset{\sim}{L}}}\left[\text{Var}\left(\hat{S}\middle|\hat{\underset{\sim}{L}}\right)\right] \tag{1}$$

Table 2.5. Cell Probabilities Used in Parameterizing a Single-Release Model for Three River Reaches

History[a]	Probability of Occurrence
111	$S_1 p_1 S_2 p_2 \lambda$
011	$S_1(1-p_1)S_2 p_2 \lambda$
101	$S_1 p_1 S_2 (1-p_2)\lambda$
001	$S_1(1-p_1)S_2(1-p_2)\lambda$
110	$S_1 p_1 S_2 p_2 (1-\lambda)$
010	$S_1(1-p_1)S_2 p_2(1-\lambda)$
100	$S_1 p_1\left[(1-S_2)+S_2(1-p_2)(1-\lambda)\right]$
000	$(1-S_1)+S_1(1-p_1)\left[(1-S_2)+S_2(1-p_2)(1-\lambda)\right]$

(a) 1 denotes detection; 0 denotes no detection at each of three downstream detection locations.

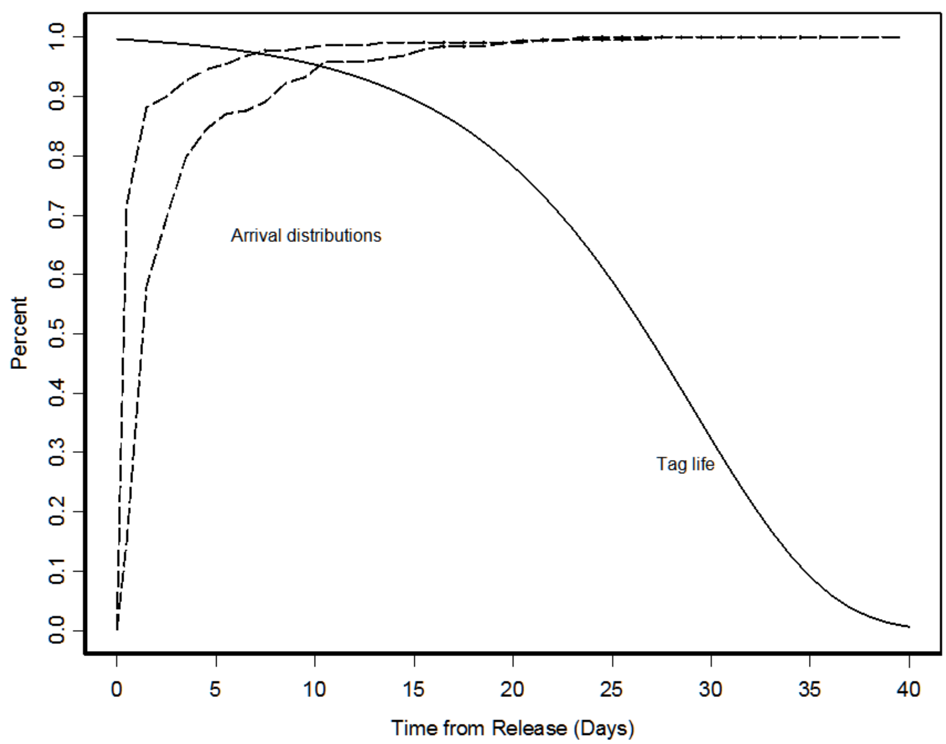


Figure 2.18. Illustration of Tag-Life Survivorship Curves (solid line) versus Cumulative Arrival Distributions (dashed lines) of Smolts to a Detection Site

The above variance was therefore estimated in stages using the expression

$$\widehat{\text{Var}}\left(\hat{S}\right) = s^2_{\hat{S}|\hat{L}} + \text{Var}\left(\hat{S}\middle|\hat{\underset{\sim}{L}}\right) \quad (2)$$

The second term in Equation 2 was derived from the maximum likelihood model (2) conditioning on the tag-life probabilities (i.e., $\hat{\underset{\sim}{L}}$). The first variance component in Equation (2) was calculated using bootstrap resampling techniques (Efron and Tibshirani 1993). Alternative estimates of $\hat{\underset{\sim}{L}}$ were computed by bootstrapping both the observed tag-life data and travel-time data. For each estimated vector of tag-life parameters, survival was estimated using the likelihood model. One thousand bootstrap estimates of the tag-life parameters were calculated, along with the corresponding conditional maximum likelihood estimates of survival. The first variance component in Equation (2) was then estimated by the quantity

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

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

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

Table 2.6. Cell Probabilities Used in Parameterizing a Single-Release Model for Three River Reaches and Tag-Life Correction

History[a]	Probability of Occurrence
111	$S_1 p_1 S_2 p_2 \lambda L_{123}$
011	$S_1(1-p_1)S_2 p_2 \lambda L_{123}$
101	$S_1 p_1 S_2 (1-p_2)\lambda L_{123}$
001	$S_1(1-p_1)S_2(1-p_2)\lambda L_{123}$
110	$S_1 p_1 S_2 p_2 (L_{12} - L_{123}\lambda)$
010	$S_1(1-p_1)S_2 p_2 (L_{12} - L_{123}\lambda)$
100	$S_1 p_1 L_1 - S_1 p_1 S_2 L_{12} + S_1 p_1 S_2 (1-p_2)(L_{12} - L_{123}\lambda)$
000	$1 - S_1 L_1 p_1 - S_1(1-p_1)S_2 L_{12} + S_1(1-p_1)S_2(1-p_2)(L_{12} - L_{123}\lambda)$

(a) 1 denotes detection; 0, not detected at each of three downstream detection locations.

Use of Equations (1) and (2) permitted us to examine the contribution of the sampling error in the tag-life parameters to the overall variance in survival estimates. An asymptotic $(1-\alpha)100\%$ confidence interval for the survival estimate was computed as

$$\hat{S} \pm Z_{1-\frac{\alpha}{1}} \sqrt{\widehat{\text{Var}}\left(\hat{S}\right)} \tag{3}$$

The individual replicate releases over the season were generally inadequate for survival analyses. The intent was to pool the data if feasible. R × C contingency table analyses based on observable capture histories were used to test for homogeneity of survival and detection processes. If significant ($P < 0.10$) heterogeneity were detected, then analyses were performed by release group. An overall survival estimate was computed according to the formula

$$\hat{\hat{S}} = \frac{\sum_{i=1}^{k} W_i \hat{S}_i}{\sum W_i} \tag{4}$$

where k = number of replicate releases;

$\hat{S}_i$ = survival estimates from the *i*th release pair $\left(i = 1, \ldots, k\right)$;

$$w_i = \frac{1}{\left(\frac{\widehat{\text{Var}}\left(\hat{S}_i\right)}{\hat{S}_i^2}\right)} = \frac{1}{\text{CV}\left(\hat{S}_i\right)^2} \tag{5}$$

with variance estimator

$$\widehat{\text{Var}}\left(\hat{\hat{S}}\right) = \frac{\sum_{i=1}^{k} W_i \left(\hat{S}_i - \hat{\hat{S}}\right)^2}{\left(k-1\right)\sum_{i=1}^{k} W_i} \tag{6}$$

It was found that by weighting simply inversely proportional to $\text{Var}\left(\hat{S}_i\right)$, the weights are correlated with the point estimates, resulting in downward bias in the average survival. By using the relative variance, this correlation between the weights and the point estimate was minimized.

The weights (5) are appropriate if replicate survival estimates are estimating the same parameter value. In the case where there may be seasonal trends, it may be more appropriate to weight the replicate estimates by seasonal passage proportions in order to more accurately represent the run-of-river fish.

2.10.1.2 Paired-Release Model

The upstream and downstream releases (e.g., R_1 and R_2) of a paired release-recapture study function as two independent, single release-recapture investigations, which share one or more model parameters.

Define the following parameters:

S_{ij} = survival in the *j*th reach $\left(j = 1, 2\right)$ for the *i*th release group $\left(i = 1, 2\right)$;

p_{ij} = detection probability at the *j*th detection site $\left(j=1,2\right)$ for the *i*th release group $\left(i=1,2\right)$;

λ_i = joint probability of surviving and being detected in the last reach for the *i*th release group $\left(i=1,2\right)$;

$L_{i,1}$ = probability tag is operational to the first detection site for the *i*th release group $\left(i=1,2\right)$;

$L_{i,12}$ = probability tag is operational through the first and second reaches for the *i*th release group $\left(i=1,2\right)$;

L_{123} = probability tag is operational through the full set of three reaches for the *i*th release group $\left(i=1,2\right)$.

The parameterizations of the various capture histories for a three-reach, paired release-recapture study are summarized in Table 2.7. At a minimum, both releases were assumed to experience the same survival for the location of the downstream release to the first detection site, in which case, survival between release locations was estimated by the quotient

$$\hat{S} = \frac{\hat{S}_{11}}{\hat{S}_{21}} \tag{7}$$

with associated variance estimated based on the delta method (Seber 1982:7-9) of

$$\begin{aligned}\widehat{\text{Var}}\left(\hat{S}\right) &\doteq \left(\frac{\hat{S}_{11}}{\hat{S}_{21}}\right)^2 \left[\frac{\text{Var}\left(\hat{S}_{11}\right)}{\hat{S}_{11}^2} + \frac{\text{Var}\left(\hat{S}_{21}\right)}{\hat{S}_{21}^2}\right] \\ &\doteq \hat{S}^2\left[\widehat{\text{CV}}\left(\hat{S}_{11}\right)^2 + \widehat{\text{CV}}\left(\hat{S}_{21}\right)^2\right]\end{aligned} \tag{8}$$

and where $\widehat{\text{CV}}\left(\hat{\theta}\right) = \frac{\sqrt{\text{Var}\left(\hat{\theta}\right)}}{\hat{\theta}}$

Subsequent downstream capture and survival parameters were estimated distinctly for each release. However, precision was enhanced if the parameterization of the joint likelihood model was reduced from the maximum shown in Table 2.7. If the paired releases shared common downstream detection or survival parameters, the joint likelihood model was re-parameterized by equating $p_{11} = p_{12}$, $S_{12} = S_{22}$, $p_{12} = p_{22}$, or $\lambda_1 = \lambda_2$.

The paired release-recapture methods of Burnham et al. (1987) were used to find the most parsimonious models for estimating reach survival. Forward-sequential test procedures were used in model selection based on likelihood ratio tests (LRT) of nested models. The first test in the sequence evaluated whether $p_{11} = p_{21} = p_1$, assuming all other parameters of the paired releases were unique. If the LRT indicated that $p_{11} \neq p_{21}$, the next test in the sequence evaluated whether $S_{12} = S_{22} = S_2$. If the LRT indicated $S_{12} \neq S_{22}$, the next test in the sequence evaluated whether $\lambda_1 = \lambda_2 = \lambda$. At any stage in the testing, if the null hypothesis of homogeneity was not rejected, a reduced model was assumed. All parameters were assumed homogeneous at and below the location of no significance. This reduced model was then compared to the fully parameterized Cormack-Jolly-Seber (CJS) model to assess whether any unexplained heterogeneity between releases still existed. The LRT was performed at $\alpha = .10.$ If the P-value for the LRT was $0.10 \le P \le 0.20,$ the results from the LRT were compared to model selections recommended by the Akaike Information Criterion (AIC). In the case where LRT and AIC did not agree, the more parameterized of the recommended models was selected for the sake of robustness.

The intent was to pool replicate releases within the season prior to survival estimation. Tests of homogeneity were performed and weighted averages were calculated according to the procedures outlined in Section 3.10.1.

Table 2.7. Cell Probabilities Used in Parameterizing the Joint Likelihood for the Paired Release-Recapture Model for Three River Reaches and Tag-Life Correction

Release	History[a]	Probability of Occurrence
Upstream R_1	111	$S_{11} p_{11} S_{12} p_{12} \lambda_1 L_{1,123}$
	011	$S_{11}(1 - p_{11}) S_{12} p_{12} \lambda_1 L_{1,123}$
	101	$S_{11} p_{11} S_{12}(1 - p_{12}) \lambda_1 L_{1,123}$
	001	$S_{11}(1 - p_{11}) S_{12}(1 - p_{12}) \lambda_1 L_{1,123}$
	110	$S_{11} p_{11} S_{12} p_{12}(L_{1,12} - L_{1,123}\lambda_1)$
	010	$S_{11}(1 - p_{11}) S_{12} p_{12}(L_{1,12} - L_{1,123}\lambda_1)$
	100	$S_{11} p_{11} L_{1,1} - S_{11} p_{11} S_{12} L_{1,12} + S_{11} p_{11} S_{12}(1 - p_{12})(L_{1,12} - L_{1,123}\lambda_1)$
	000	$1 - S_{11} L_{1,1} p_{11} - S_{11}(1 - p_{11}) S_{12} L_{1,12} + S_{11}(1 - p_{11}) S_{12}(1 - p_{12})$ $\cdot (L_{1,12} - L_{123}\lambda_1)$
Downstream R_2	111	$S_{21} p_{21} S_{22} p_{22} \lambda_2 L_{2,123}$
	011	$S_{21}(1 - p_{21}) S_{22} p_{22} \lambda_2 L_{2,123}$
	101	$S_{21} p_{21} S_{22}(1 - p_{22}) \lambda_2 L_{2,123}$
	001	$S_{21}(1 - p_{21}) S_{22}(1 - p_{22}) \lambda_2 L_{2,123}$
	110	$S_{21} p_{21} S_{22} p_{22}(L_{2,12} - L_{2,123}\lambda_2)$
	010	$S_{21}(1 - p_{21}) S_{22} p_{22}(L_{2,12} - L_{2,123}\lambda_2)$
	100	$S_{21} p_{21} L_{2,1} 1 - S_{21,} p_{22}, S_{22} L_{2,12} + S_{21} p_{21} S_{22}(1 - p_{22})(L_{2,12} - L_{2,123}\lambda_2)$
	000	$1 - S_{21} L_{2,1} p_{21} - S_{21}(1 - p_{21}) S_{22} L_{2,12} + S_{21}(1 - p_{21}) S_{22}(1 - p_{22})$ $\cdot (L_{2,12} - L_{2,123}\lambda_2)$
(a) 1 denotes detection; 0 denotes no detection at each of three downstream detection locations.		

2.10.2 Tests of Assumptions

2.10.2.1 Single-Release Model

Assumptions associated with the single-release model included the following:

A1. The test fish are representative of the population of inference.
A2. Test conditions are representative of the conditions of interest.
A3. The number of fish released is exactly known.
A4. Tag codes are accurately recorded at the time of tagging and at all detection sites.
A5. For replicated studies, data from different releases are statistically independent.
A6. The fate of each individual fish is independent of the fates of all other fish.
A7. All fish in a release group have equal survival and detection probabilities.
A8. Prior detection history has no effect on subsequent survival and detection probabilities.

Assumptions A1–A5 are pertinent for the validity of statistical inferences to the population of interest and to the proper conduct of the study. These assumptions (i.e., A1–A5) are largely satisfied by the appropriate capture, handling, marking, and release procedures of the study protocol. Post-release handling mortality could violate assumption A1 and tends to underestimate actual survival probabilities. Careful handling is therefore needed to avoid such bias and is the reason fish were held at least 24 hrs prior to release.

The key assumptions in constructing the multinomial likelihood are A6–A8, which imply that the fates (i.e., capture histories) of all tagged fish in a release group are independent, identically distributed, multiple Bernoulli trials. Assumptions A6–A8 are mathematical constraints in the formulation of likelihood [Equation (1)] and investigators have less direct control over them than assumptions A1–A5.

Lack of independence (A6) will not bias the point estimates but will result in the model estimates of variance underestimating the true variability. Conversely, individual heterogeneity (A7) will not bias the point estimates but will result in the model estimate of variance overestimating the true variance. Of more serious concern is whether assumption A8 is violated. However, in acoustic survival studies, the smolts are not recaptured physically; consequently, the process of the detection itself should have little effect on downstream detection or survival.

For the single release-recapture model to be valid, certain data patterns should be evident from the capture histories. For each release group, a series of tests of assumptions was performed to determine the validity of the model (i.e., goodness of fit). The data from a single release is summarized by an m-array matrix of the form below:

Release Site	Detection Site		
	(2)	(3)	(4)
Initial (1)	m_{12}	m_{13}	m_{14}
(2)		m_{23}	m_{24}
(3)			m_{34}
(4)			

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

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

Test 2.2

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

χ_1^2 (9)

Tests were performed at α = 0.10. The multiple releases over the season were used to broaden the seasonal inference and not to add evidence that theoretical variances were reasonable. The individual daily releases also were too small for the purposes of independently estimating survival. At best, they might show some general seasonal trends if the trends are great enough and capture probabilities are high enough.

Burnham et al. (1987:65,74-77) also present a series of tests of assumptions called Test 3, which also examine whether upstream capture histories affect downstream survival and/or capture. For each release, a contingency table was constructed of the form:

Capture History at Third Detection Site		Capture History to Second Downstream Detection Site: 101	111
	1		
	0		

χ_1^2 (10)

This contingency table tests whether detection at the first downstream detection site has a subsequent effect on the capture history at the third detection site.

2.10.2.2 Paired-Release Model

In order to estimate survival components from the paired releases, two additional assumptions beyond those of the single-release model are necessary for valid survival estimation. These assumptions are

A9. Survival in the lower river segments is conditionally independent of survival in the upper river segments.

A10. Releases R_1 and R_2 experience the same survival probabilities in the lower river segments they share in common.

Assumption A9 implies there is no synergistic relationship between survival processes in the two river segments. In other words, smolts that survive the first river segment are no more or less susceptible to mortality in the second river segment than smolts released in the second river segment. Assumption A10 is satisfied by in-river mixing of the release groups but can also be satisfied if the survival processes are stable over the course of smolt passage by the releases. A stable survival process might well be expected for one to a few days under similar flow and spill conditions.

The valid estimation of project survivals using the paired release-recapture data requires fulfilling the assumptions of the single release-recapture model for each release and the paired release-recapture model for each pair of releases. At each downstream detection site, the assumption of mixing among the releases of smolts (e.g., R_1 and R_2) was tested. An R × C contingency table test of homogeneous recoveries over time was performed using a table of the form:

Day of Detections		R_1	R_2
	1		
	2		
	3		
	⋮	⋮	⋮
	D		

(11)

The chi-square test of homogeneous arrival timing was calculated for each of the paired releases (e.g., R_1 and R_2). Each test was performed at α = 0.10. The test of mixing could also have been performed using a two-sample Kolmogorov-Smirnov test (Conover 1980:368-376). The Kolmogorov-Smirnov test and the R × C contingency tests are asymptotically equivalent as shown by several investigators using Monte Carlo simulations. The major distinction is that the Kolmogorov-Smirnov test uses the cumulative distributions, which some people have trouble interpreting, while the R × C contingency tests use the discretized frequency distribution. To test whether releases with a paired-release (e.g., R_1 and R_2) had similar downstream survival and capture histories from the first detection site and below, likelihood ratio tests were performed to compare models. Sequential likelihood-ratio tests were used to help determine the most parsimonious model for the estimation of p_{11}, p_{21}, S_{12}, S_{22}, p_{12}, p_{22}, λ_1, and λ_2.

2.10.2.3 Estimating Tag Life

Two tag-life studies were performed from tags systematically sampled over the course of the tagging operations. One study consisted of 99 tags operating at a transmission rate of one pulse every 10 seconds. The other study consisted of 100 tags operating at a transmission rate of one pulse every 5 seconds. Tags released at JDA and points below used 5-s tags. Tags released in the vicinity of Lower Granite and Little Goose dams used 10-s tags. The tags were surgically implanted and monitored until complete tag failure.

The failure times or tag lives were recorded for each of the tags. A logistic function was used to model the tag-life data for yearling Chinook salmon. The logistic cumulative distribution function can be written as

$$F(t) = \frac{1}{1+e^{\alpha+\beta t}}, \tag{12}$$

with probability density function

$$f(t) = \beta F(t)\left(1-F(t)\right) \tag{13}$$

and survival function

$$S(t) = \frac{1}{1+e^{\beta t-\alpha}} = 1-F(t) \tag{14}$$

The probability (L) a tag was active at a particular detection location was estimated as follows:

$$L = \frac{\sum_{i=1}^{m} S(t_i)}{m},$$

where m = number of tags detected at that location and $S(t_i)$ = the probability tag i with arrival time t_i was active. In some studies a two- or three-parameter Weibull function better fits tag survival curves.

2.10.3 Sample Size Calculations

2.10.3.1 Introduction

There is a one-to-one correspondence between the release-recapture study design, the desired level of precision, and the required sample size to achieve that precision. In fact, sample size calculations can only be performed within the context of a specific study design and a specified level of precision. Precision of survival (S) studies is commonly expressed as the objective function

$$P\left(\left|\hat{S} - S\right| < \varepsilon\right) \geq 1 - \alpha,$$

where the absolute error in estimation $\left(\left|\hat{S} - S\right|\right)$ is to be less than ε, $(1-\alpha)\cdot 100\%$ of the time. For example, if the desired level of precision is to be within ± 0.05 of the value of S, 95% of the time, then

$P\left(\left|\hat{S} - S\right| < 0.05\right) \geq 0.95$.

The error in estimation is approximately equivalent to

$$\varepsilon \approx Z_{1-\frac{\alpha}{2}} \cdot \mathrm{SE}\left(\hat{S}\right),$$

where

$\mathrm{SE}\left(\hat{S}\right)$ = standard error for the estimate $\hat{S}$, i.e., $\mathrm{SE}\left(\hat{S}\right) = \sqrt{\mathrm{Var}\left(\hat{S}\right)}$,

$Z_{1-\frac{\alpha}{2}}$ = standard normal deviate corresponding to the probability $P\left(\left|\hat{Z}\right| < Z\right) = 1 - \alpha$.

For example, if precision is defined as $P\left(\left|\hat{S} - S\right| < \varepsilon\right) = 0.95$, then $\varepsilon = 1.96\ \mathrm{SE}\left(\hat{S}\right)$.

In other words, precision here is approximately equivalent to the half-width of a 95% confidence interval.

Sample size calculations require initial “guesstimates” of the likely values for the survival rates and detection probabilities to be encountered during the study. In other words, you need to “know” the results of the study before you can design the study to obtain the results of the study. This logic has been described as “lifting one’s self up by your bootstraps” (Robson and Regier 1964).

There are two possible solutions to the dilemma of sample size calculations. One approach is to use historical information upon which to base the design of future studies. The more historical information available, the more likely the parameter “guesstimates” will be reliable. The second approach is to bracket the “guesstimates” and subsequent sample size calculations with worse case, most likely, and best case scenarios. This is often the reason sample size curves rather than sample size values are presented.

2.10.3.2 Survival Study Scenarios

There are two common scenarios for smolt survival studies. One approach is the single release-recapture design (Figure 2.19); the other is the paired release-recapture design (Figure 2.20). If the objective is to simply monitor reach passage survival, the single release-recapture design may be adequate. However, any post-release handling mortality that is manifested will downwardly bias the survival estimate in the first one or few reaches. To isolate survival within a well-defined reach and eliminate the bias due to post-release handling mortality, a paired release design is typically used. This design requires a set of releases at the top and bottom of the reach of interest. Often the releases within a pair are staggered in time to facilitate downstream mixing. More fish will be needed for a paired-release than for a single-release design to achieve equal precision. Note there must be at least one detection array below the last reach where survival is to be estimated in either design.

Program SAMPLESIZE (http://www.cbr.washington.edu/paramEst/SampleSize/) can be used to provide sample size calculations for either the single-release or paired-release design.

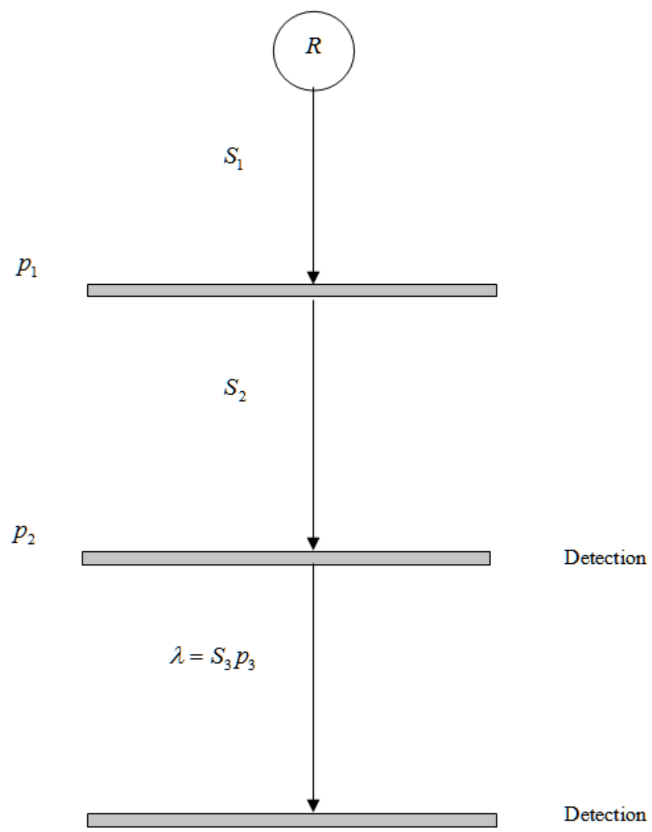


Figure 2.19. Scenario of a Single Release-Recapture Design Used to Estimate Smolt Passage Survival. Survival (S_i) and detection (p_i) parameters can be individually estimated for all but the last reach when only the joint probability of survival and detection (i.e., $\lambda = S_i p_i$) can be estimated.

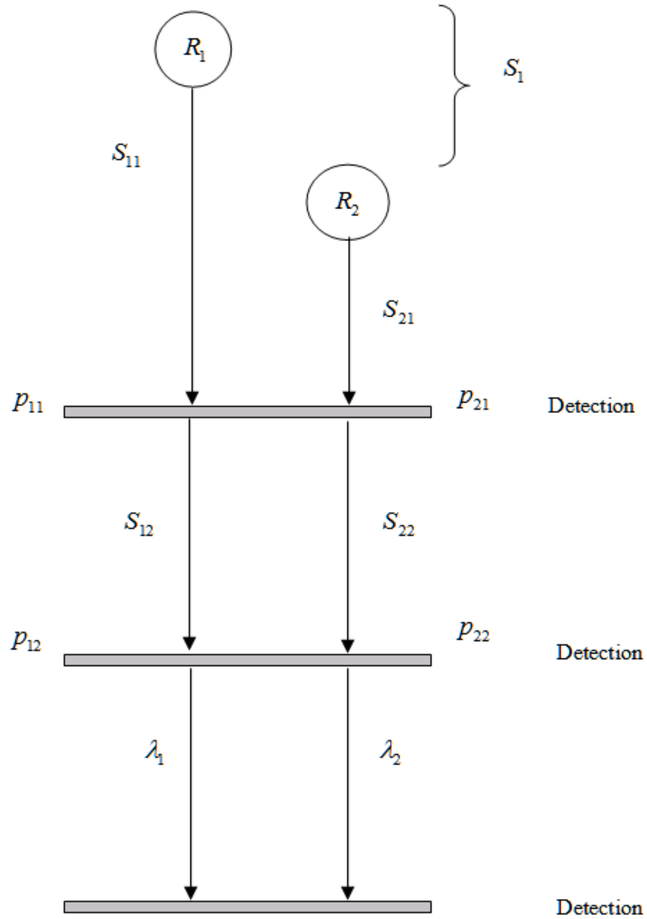


Figure 2.20. Scenario of a Paired Release-Recapture Design Used to Estimate Smolt Passage Survival. Survival (S_{ij}) and detection (p_{ij}) parameters can be estimated uniquely by reach and release group in all but the last reach where only the release-specific estimates of the joint probability of survival and detection (λ_i) can be estimated. Survival in the first reach between release locations is estimated as $\hat{S}_1 = \hat{S}_{11}/\hat{S}_{12}$.

2.10.3.3 Replicate Survival Studies

Often the release-recapture studies are replicated within a season for one or more reasons. One reason is to release tagged smolts throughout the breadth of the outmigration in order to make inferences to the entire migration season. Another reason is to effectively increase sample size while maintaining individual release sizes that are manageable. In both cases, the performance measure is the average survival estimate across k replicates, i.e.,

$$\hat{\bar{S}} = \frac{\sum_{i=1}^{k} \hat{S}_i}{k}. \tag{15}$$

The variance of $\hat{\bar{S}}$ can be expressed as

$$\widehat{\text{Var}}\left(\hat{\bar{S}}\right) = \frac{\sigma_S^2 + \dfrac{\sum_{i=1}^{k} \text{Var}\left(\hat{S}_i \middle| S_i\right)}{k}}{k}, \tag{16}$$

where σ_S^2 = natural variability in survival (S) across time,

$\text{Var}\left(\hat{S}_i \middle| S_i\right)$ = measurement error associated with the *i*th estimate of survival (i.e., $\hat{S}_i$).

If natural variability is negligible (i.e., $\sigma_S^2 = 0$, $S_1 = S_2 = \ldots = S$), then variance formula (16) reduces to

$$\text{Var}\left(\hat{\bar{S}}\right) = \frac{\text{Var}\left(\hat{S} \middle| S\right)}{k} . \tag{17}$$

The implication of variance formula (17) is that sample size calculations for a replicated investigation can be based on the sample size calculations for a single trial and vice versa. Once an overall release size has been determined (R), the release size per replicate (k) is simply R/k. Program SAMPLE SIZE allows the specification of σ_S^2 as either zero or nonzero based on historical evidence. Runs of sample size in this study were based on a single year of estimates, and therefore we did not have an estimate of natural variability to input in the program.

2.10.3.4 General Input to Program SAMPLESIZE

No single set of sample size calculations can describe the entire range of potential survival study designs and scenarios. Program SAMPLESIZE, therefore, has a dynamic structure, allowing the user to specify the scenario(s) of interest. Considerations in the use of Program SAMPLESIZE include the following:

1. Specify the type of study (i.e., single-release, paired-release, balloon-tag).
2. Identify the magnitude of natural variability (i.e., σ_S^2).
3. Specify single trial $(k = 1)$ or multiple replicates $(k > 1)$.
4. Specify the anticipated parameter values:
    a. Survival probabilities
    b. Detection probabilities
    c. Probability a smolt is removed from the river (i.e., fraction going into transportation barges)
5. Specify $(1-\alpha)\cdot 100\%$ confidence interval, either 90% or 95%.

The output of the program is the anticipated half-width of a $(1-\alpha)\cdot 100\%$ confidence interval for the model parameters of interest. By specifying a range of input values for one of the parameters, a precision curve is generated (i.e., precision vs. parameter value).

3.0 Results

3.1 Environmental Conditions

This section contains a description of environmental conditions during the 2006 study, including river discharge temperature relative to a 10-year average, smolt species composition at the JDA SMF, the length frequencies of tagged and run-of-river fish, and results of the tag-life study.

3.1.1 Project Discharge and Temperature

Ten-year (1996 to 2005) average discharges from all three dams were plotted with 2006 discharge from JDA, TDA, and BON by day. During spring, tagged fish were released when most of the discharge was higher than that of the 10-year average, but for summer releases, 2006 discharge was higher than the 10-year average at the beginning but lower towards the end of the releases (Figure 3.1).

Except for June 1, 3, and 5 release dates, the 2006 forebay water temperatures were higher than the 10-year average in spring and during the second half of summer (Figure 3.2). They were similar to a 10-year average in early summer. There were data gaps for temperature between April 14 and 16 for 2006 on all three projects.

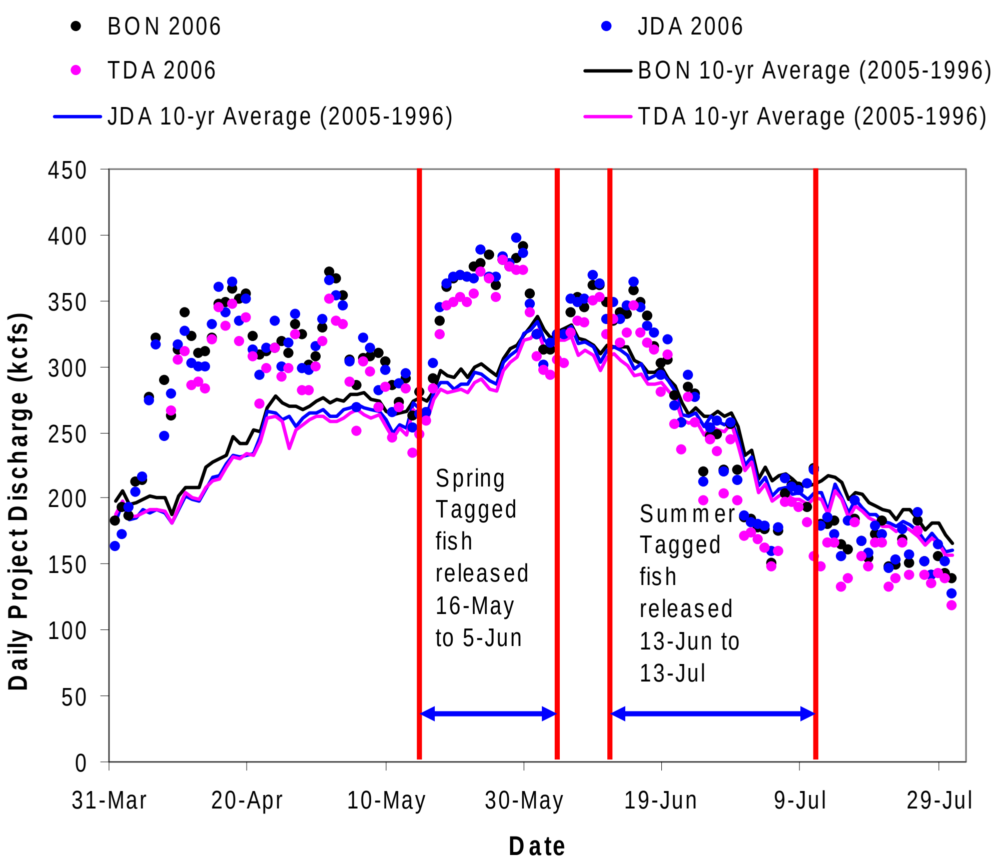


Figure 3.1. Ten-Year Average Daily Project Discharge (kcfs) versus 2006 Daily Project Discharge for JDA, TDA, and BON

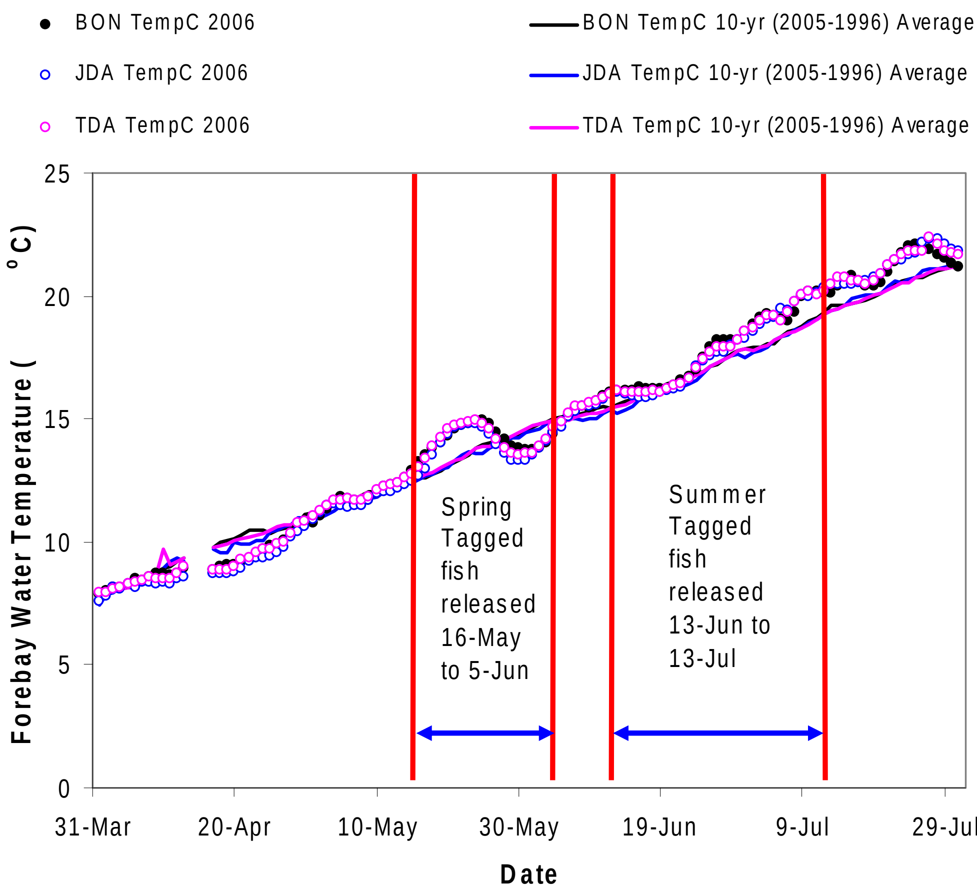


Figure 3.2. Ten-Year Average Forebay Water Temperature (°C) versus 2006 Temperature by Day (April 1 through July 31) at JDA, TDA, and BON

3.1.2 Run Timing of Smolt Species Composition

The species composition of all downstream migrants arriving at JDA was calculated using data obtained from the JDA SMF. Both hatchery and wild stock were combined to display total salmonid run composition for 2006 (Figure 3.3). Spring collection for this study was conducted at the JDA SMF from May 14 to June 6, 2006. The composition of species arriving at the juvenile bypass during our collection period was inclusive of the major migration peak in spring for all downstream migrants. The percent composition of fish arriving at the JDA SMF in spring were yearling Chinook salmon (*Oncorhynchus tshawytscha*) 46%, Coho salmon (*O. kisutch*) 6%, Sockeye salmon (*O. nerka*) 10%, Steelhead (*O. mykiss*) 34%, and subyearling Chinook Salmon 4%. A relatively strong run of Sockeye (10%) was experienced during this year's collection season. Summer collection was from June 11 to July 13, 2006, and also was conducted at the JDA SMF. For summer, subyearling Chinook salmon was the dominant migrant with a total migration composition of 97%. The peak of the subyearling Chinook salmon migration was experienced during the middle of our collection period. Though specific data were not available from DART, a large portion of collected subyearlings were unclipped, comprising both hatchery and wild stock. Unclipped subyearlings dominated the summer migration with a run composition of 86% while our targeted run, clipped subyearlings, made up only 14% of the subyearling run composition.

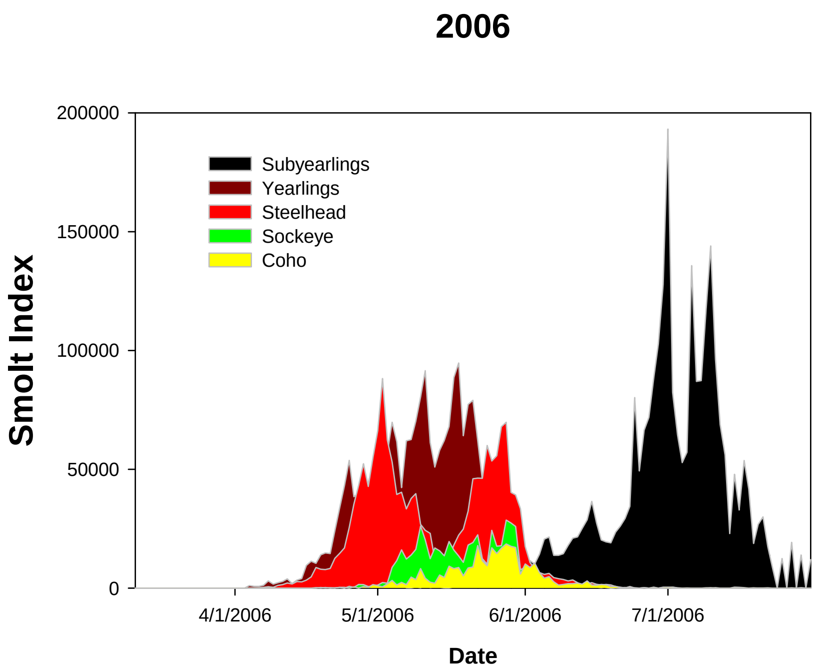


Figure 3.3. Smolt Monitoring Program (SMP) Passage Index for March 1 – July 31, 2006, based on Data from the JDA Smolt Monitoring Facility. Data were obtained from the DART website in December 2006 (http://www.cbr.washington.edu/dart/dart.html).

3.1.3 Length Frequency

We compared length frequencies of 2,498 tagged yearling Chinook salmon with those of run-of-river fish collected at the JDA SMF in spring, and yearlings of all lengths were tagged in proportion to their relative abundance in the run sampled by the juvenile bypass system (Figure 3.4).

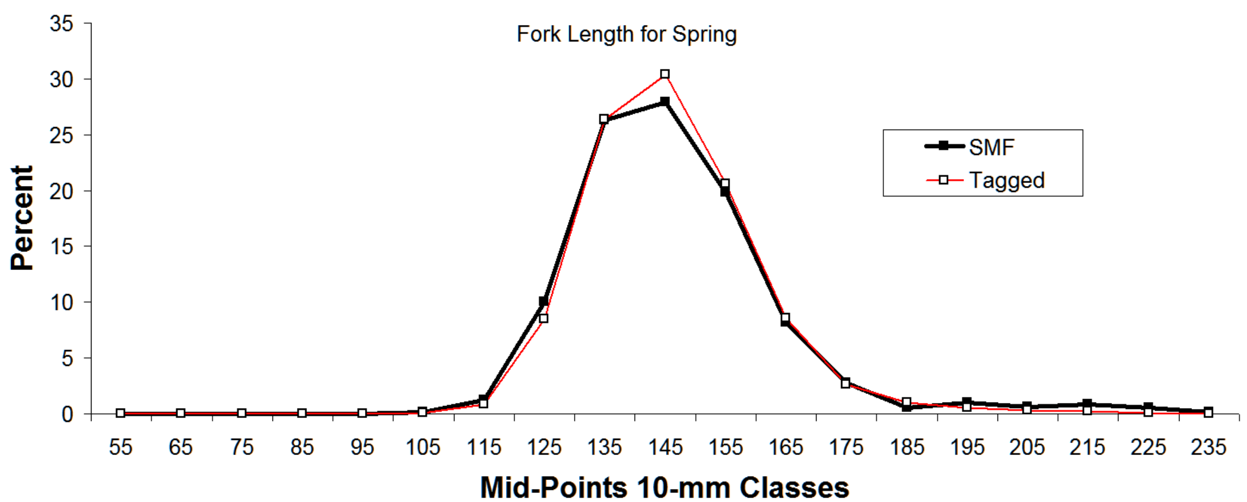


Figure 3.4. Length Frequency of Tagged and Untagged Run-of-River Yearling Chinook Salmon during Spring Tagging (5/16-6/05) at the JDA Smolt-Monitoring Facility in 2006

The lower end of the distribution of length frequencies of 2,532 tagged subyearling Chinook salmon was truncated at 95 mm relative to the length frequency distribution of run-of-river subyearlings handled at the JDA SMF in summer (Figure 3.5). Some 95 to 100 mm subyearlings were tagged (2%), but this was well below the 15% representation of this length class in the general population.

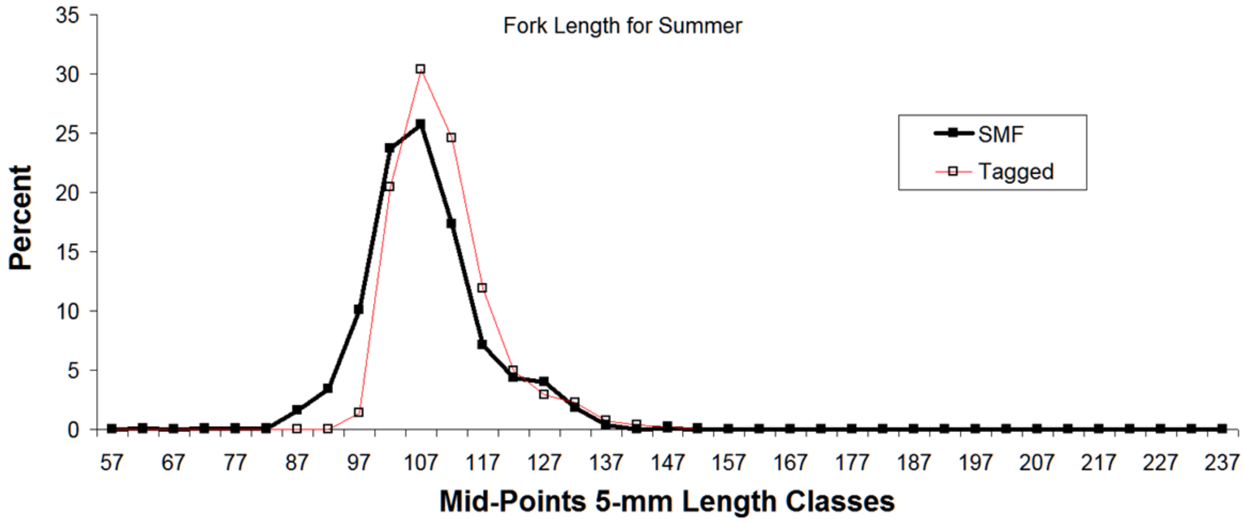


Figure 3.5. Length Frequency of Tagged and Untagged Sub-Yearling Chinook Salmon during Summer Tagging (6/13-7/13) at the JDA Smolt-Monitoring Facility in 2006

Additional information on fish, tag codes, release locations, release times, and dam operations can be found in Appendix A. Tables A1 and A2 include a summary of numbers and percentages of tagged fish released alive and dead (including numbers intentionally sacrificed) by date in spring and summer, respectively. Table A3 includes similar statistics by location and season. Tables A4 and A5 describe comma-separated variable (CSV) files for spring and summer that are on a CD that accompanies printed versions of this report. Those CSV files contain detailed data associated with every fish that was tagged and released at or below JDA including season, release date, release time, PIT tag code, acoustic tag code, acoustic tag activation date, fork length, weight, mortality status, and release location, as well as all dam operations at the time of release.

3.2 Detection of Dead Fish

We detected only one dead fish on survival arrays in 2006, out of releases of 23 at JDA, 46 at TDA, and 30 at BON. The single dead fish tag was detected on TDA survival arrays, but the pattern of movement within and upstream among arrays clearly indicated that this fish had been eaten by a predator. We detected two dead fish on the JDA egress array in spring, but that array was not used for survival calculations.

3.3 Tag-Life Study

A total of 74 tags that transmitted once every 10 seconds were sampled from tag lots used for yearling Chinook salmon on the Snake River and were continuously monitored until their failure to develop a tag-life curve. The failure time data were fit to a logistic curve with the parameterization

$$S(t) = \left(1 + e^{\frac{t-76.8028}{6.0149}}\right)^{-1},$$

with standard errors of 1.1084 and 0.6346 for the numerator and denominator terms, respectively (Figure 3.6). This tag-life curve was used for the yearling Chinook salmon releases from LGR Tailrace.

For all yearlings released from JDA and below, tags transmitting once every 5 seconds were used. A separate tag-life curve was estimated from 100 5-second tags monitored until their failure. Their failure times were fit to a logistic curve with the parameterization

$$S(t) = \left(1 + e^{\frac{t-44.7226}{2.8940}}\right)^{-1}$$

with standard errors of 0.4875 and 0.2485, for the numerator and denominator terms, respectively (Figure 3.7; Appendix B, Figure B.3).

A tag-life survivorship curve was constructed from 99 10-second tags selected from those used to tag subyearling Chinook salmon smolts at Little Goose Dam (Figure 3.8), and there were indications that tags activated on July 15, 2006, had a different survival process (Figure 3.9) than did other tags used (Figure 3.10). Analysis of those 15 July tags shows an unusual survivorship function, with all 25 tags failing within a 2-day period (Figure 3.9).

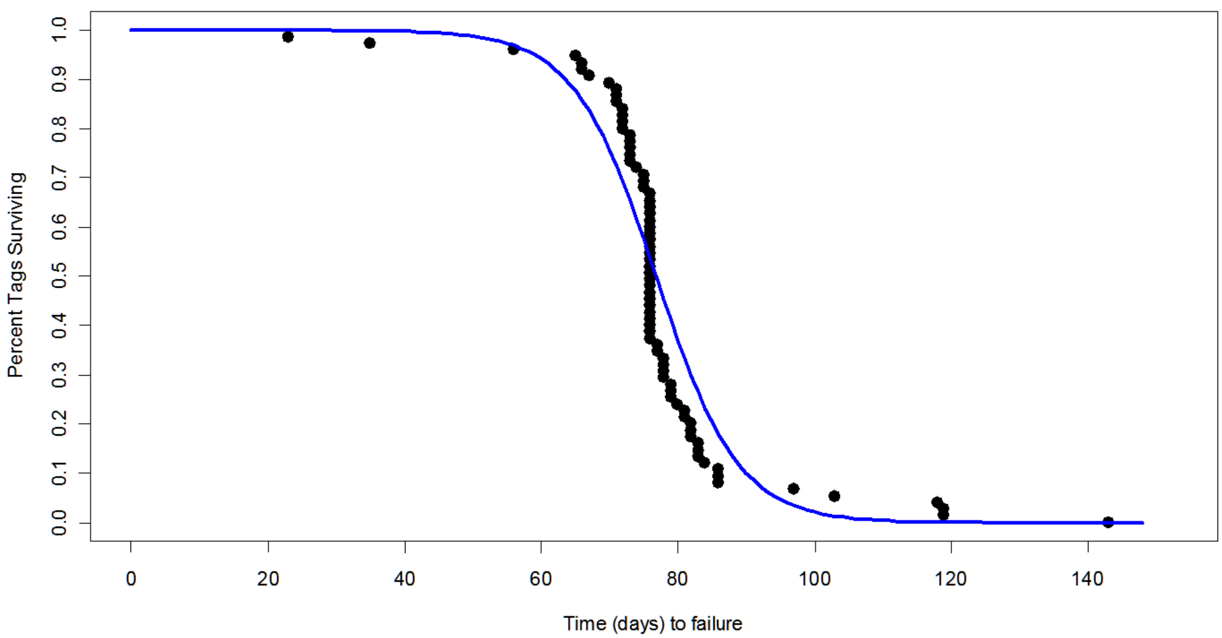


Figure 3.6. Estimated Time to Failure of Tags Transmitting Once Every 10 Seconds Like Those Implanted in Juvenile Chinook Salmon Released below LGR in Spring and below LGS in Summer

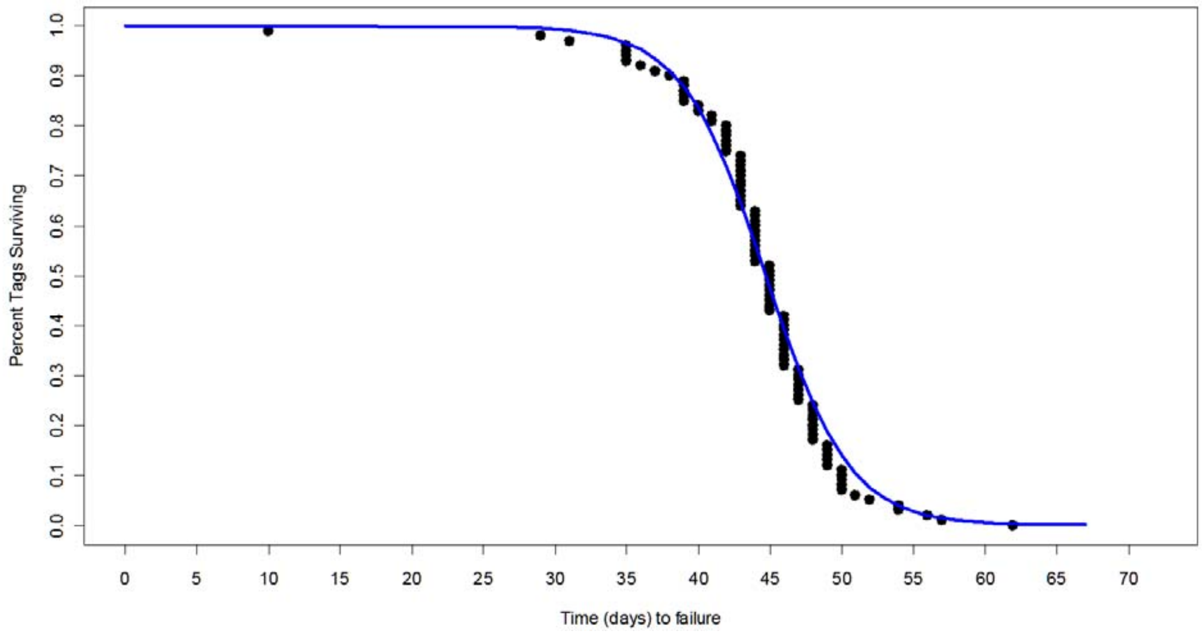


Figure 3.7. Estimated Time to Failure of Tags Transmitting Once Every 5 Seconds Like Those Implanted in Juvenile Chinook Salmon Released at JDA, TDA, and BON in Spring and Summer

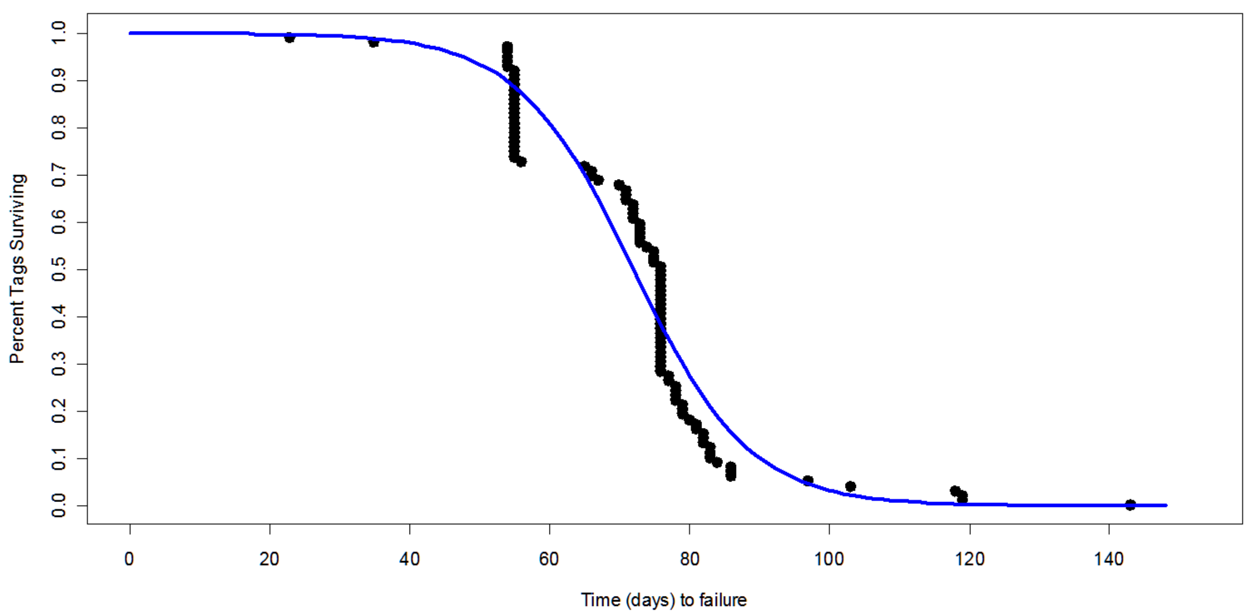


Figure 3.8. Estimated Time to Failure of Tags Transmitting Once every 10 Seconds Like Those Implanted in Chinook Salmon Released at LGR in Spring and LGS in Summer. The solid blue line is a curve fitted to the black points.

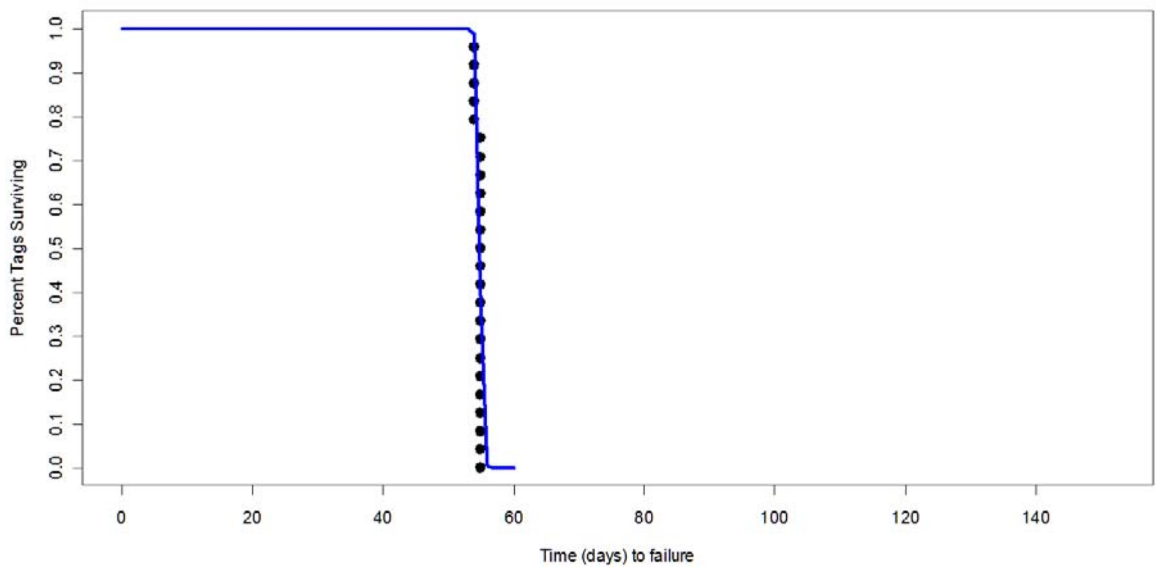


Figure 3.9. Estimated Time to Failure of 24 10-Second Tags Activated on July 15, 2006. The solid blue line is a curve fitted to the black points.

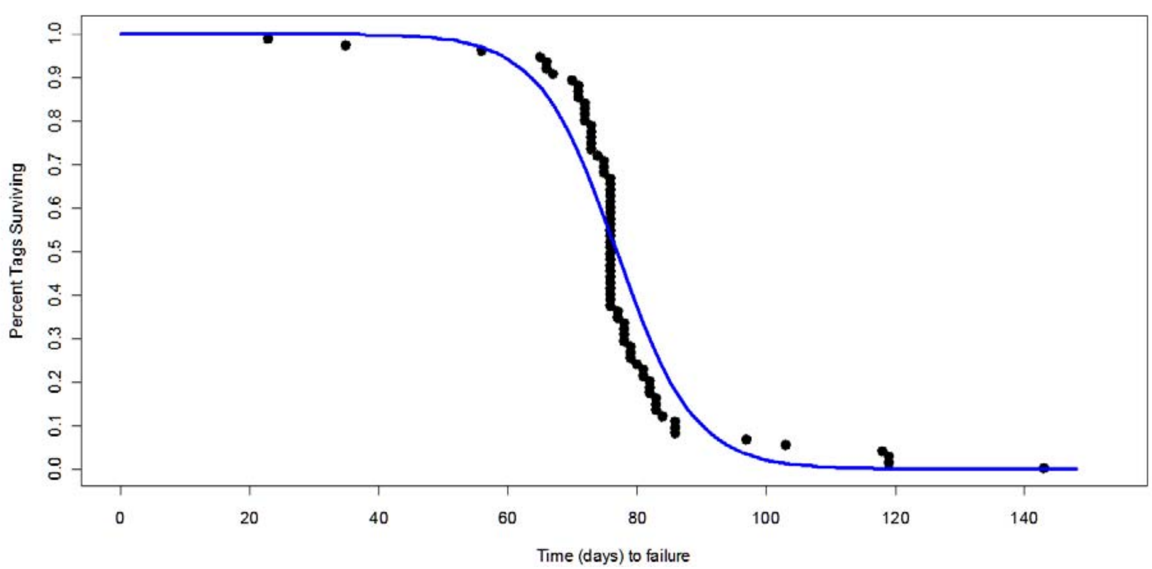


Figure 3.10. Estimated Tag Life of 10-Second Tags, Excluding Those Activated on July 15, 2006. The solid blue line is a curve fitted to the black points.

After the 24 tags that died prematurely were removed, a typical survivorship curve with relatively gradual loss of tag life was realized (Figure 3.10), but because fish tagged from different tag batches could not be differentiated, we used an overall survivorship curve based on all tags (Figure 3.8). The failure time data were fitted to a logistic curve with the parameterization

$$S(t) = \left(1 + e^{\frac{t-71.9645}{8.2595}}\right)^{-1},$$

with standard errors of 1.4104 and 0.7075 for the numerator and denominator terms, respectively. The data did not have to be fit precisely because the arrival time for most tags was >60 days (Appendix D).

3.4 Detection and Survival of Yearling Chinook Salmon in Spring

After presentation of tag-life study results and arrival times for yearling Chinook salmon, we present detection and survival results by release location or type.

3.4.1 Tag-Life Study Correction

Examination of the tag-life curve and arrival distributions of fish to downstream detection arrays (Appendix B) indicated that the vast majority of fish arrived before the time of first tag failure. In these cases, no tag-life correction was necessary. Only fish from the BON Tailrace (Figure B.5), the virtual release above BON (Figure B.7), and the TDA Tailrace release (Figure B.9) showed the potential need for tag-life correction. However, in all three cases, this was only for the last detection array and the expected probability of tag life was $\geq$ 0.999.

3.4.2 Lower Granite Releases

For releases of yearling Chinook from LGR (Table 3.1), we used a single release-recapture model and detection data from the JDA primary (1J), TDA primary (1T), and TDA secondary (2T) arrays to estimate reach survival (Table 3.2). According to the Tag-Effects Study (Hockersmith et al. 2007), LGR releases were scheduled for 14 days partitioned over a 30-day period from 14 April through 15 May, but tag manufacturing and delivery problems permitted only two replicate releases on May 6 and 13, 2006. The replicate survival estimates were not significantly different ($P > 0.10$). From release at the LGR Tailrace (rkm 696) to the JDA primary array at rkm 325.6, survival was estimated to be 0.487 ($\widehat{SE}$ = 0.016). Between the JDA primary array (RKM 325.6) and the TDA primary array (rkm 275.6), survival was estimated to be 0.877 ($\widehat{SE}$ = 0.017). Average detection probability at these two acoustic arrays was 0.896 and 0.770, respectively (Figure 3.11).

Table 3.1. Detection Histories for each Release Group from Lower Granite Dam. In the table heading, a 1 denotes detected and 0 not detected at the JDA primary array and the TDA primary and secondary arrays, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
5/06	75	7	14	4	3	0	17	118	238
5/13	209	23	67	9	9	1	40	400	758
Pooled	284	30	81	13	12	1	57	518	996

Table 3.2. Cormack-Jolly-Seber, Single-Release Estimates of Survival and Detection Probabilities for each Group of Fish Released from LGR Tailrace. The joint probability of survival from the TDA primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 2T
	to 1J	1J to 1T	1J	1T	
5/06	0.513 (0.033)	0.849 (0.035)	0.893 (0.030)	0.820 (0.038)	0.965 (0.020)
5/13	0.478 (0.018)	0.886 (0.019)	0.896 (0.017)	0.753 (0.025)	0.959 (0.013)
Pooled	0.487 (0.016)	0.877 (0.017)	0.896 (0.015)	0.770 (0.021)	0.960 (0.011)

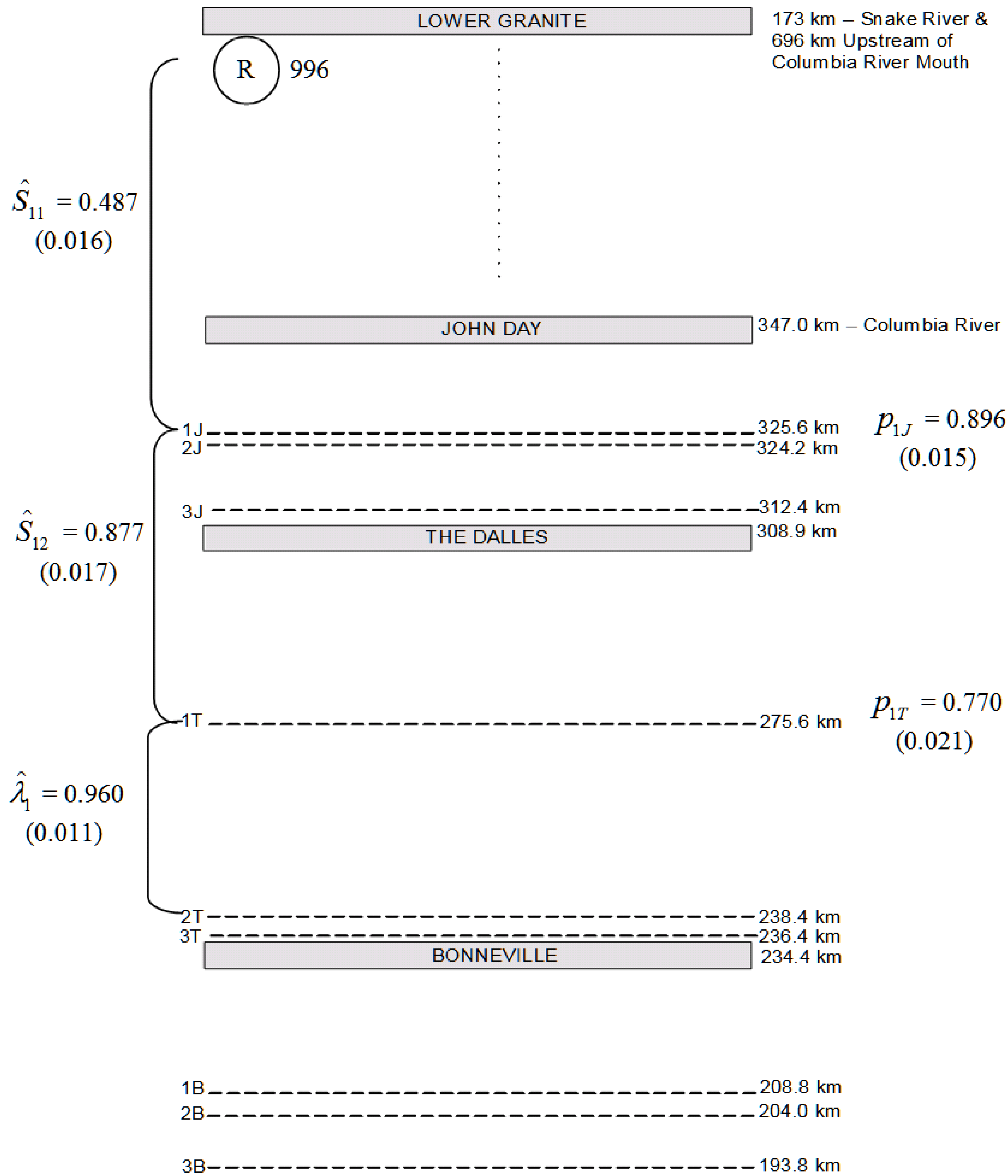


Figure 3.11. Summary of Results for the Single Release-Recapture (SR) Analysis of the LGR Release Groups of Yearling Chinook Salmon. Standard errors are reported in parentheses.

3.4.3 John Day Dam Releases

The three releases at Turbine Intake 9C, its Front Roll, and the JDA Tailrace provided the paired release-recapture data (Table 3.3) to estimate passage survival (Table 3.4) using downstream detection at the JDA primary array (rkm 325.6), TDA primary array (rkm 275.6), and TDA secondary array (rkm 238.4). Ratios of the release survival from the point of release to the TDA primary array were used in the paired release analysis. Detection probabilities and reach survivals below the JDA primary array were found to be homogeneous (Appendix C, Table C1), for the most part, for the paired releases, allowing survival for the paired releases to be estimated by either Model M_{S_1} or M_{S_1,p_1} (Table 3.5).

Table 3.3. Detection Histories for Each Release Group at JDA. In the table heading, a JDA a 1 denotes detected and 0 not detected at the JDA primary and TDA primary and secondary arrays, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
John Day Front Roll									
5/16	44	1	0	0	2	0	5	2	54
5/19	49	0	6	0	1	0	2	1	59
5/21	44	1	6	1	0	0	5	2	59
5/23	51	0	9	0	2	0	6	2	70
5/25	42	0	7	0	2	0	9	0	60
5/27	67	1	7	0	0	0	3	2	80
6/01	56	1	1	0	0	0	2	0	60
6/03	51	0	0	0	1	0	3	0	55
Pooled	404	4	36	1	8	0	35	9	497
John Day Intake 9C									
5/16	37	1	0	0	0	0	8	9	55
5/19	45	0	5	1	1	0	2	9	63
5/21	37	1	5	0	1	0	2	12	58
5/23	44	1	5	2	3	0	3	10	68
5/25	44	1	3	0	1	0	4	7	60
5/27	59	4	5	2	1	0	3	6	80
6/01	47	2	1	1	1	0	3	5	60
6/03	43	0	2	0	2	0	4	5	56
Pooled	356	10	26	6	10	0	29	63	500
John Day Tailrace									
5/16	46	0	0	0	0	0	6	2	54
5/19	48	0	9	0	2	0	0	1	60
5/21	46	0	6	0	2	0	6	0	60
5/23	48	3	4	3	1	0	7	4	70
5/25	33	1	3	0	0	0	2	2	41
5/27	66	2	4	0	1	0	3	1	77
6/01	74	0	0	0	1	0	2	2	79
6/03	37	1	0	0	0	0	1	1	40
Pooled	398	7	26	3	7	0	27	13	481

Table 3.4. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for each Group Released from JDA. The joint probability of survival from the TDA primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 2T
	to 1J	1J to 1T	1J	1T	
John Day Front Roll					
5/16	0.965 (0.026)	0.902 (0.042)	0.979 (0.021)	1.000 (<0.0001)	0.957 (0.029)
5/19	0.983 (0.017)	0.968 (0.024)	1.000(<0.0001)	0.891 (0.042)	0.980 (0.020)
5/21	0.970 (0.024)	0.909 (0.039)	0.962 (0.027)	0.865 (0.047)	1.000 (<0.0001)
5/23	0.971 (0.020)	0.917 (0.035)	1.000(<0.0001)	0.850 (0.046)	0.962 (0.026)
5/25	1.000 (<0.0001)	0.856 (0.047)	1.000 (<0.0001)	0.857 (0.050)	0.955 (0.031)
5/27	0.976 (0.018)	0.961 (0.022)	0.987 (0.013)	0.907 (0.034)	1.000 (<0.0001)
6/01	1.001 (0.001)	0.966 (0.024)	0.983 (0.017)	0.983 (0.017)	1.000 (<0.0001)
6/03	1.000 (<0.0001)	0.946 (0.031)	1.000 (<0.0001)	1.000 (<0.0001)	0.981 (0.019)
Pooled	0.983 (0.006)	0.929 (0.012)	0.989 (0.005)	0.917 (0.013)	0.981 (0.007)
John Day Intake 9C					
5/16	0.840 (0.050)	0.822 (0.057)	0.974 (0.026)	1.0000 (<0.0001)	1.000 (<0.0001)
5/19	0.858 (0.044)	0.965 (0.026)	0.981 (0.019)	0.882 (0.045)	0.978 (0.022)
5/21	0.794 (0.053)	0.958 (0.031)	0.977 (0.023)	0.884 (0.049)	0.974 (0.025)
5/23	0.856 (0.043)	0.954 (0.031)	0.946 (0.030)	0.865 (0.047)	0.938 (0.035)
5/25	0.885 (0.042)	0.924 (0.037)	0.980 (0.020)	0.938 (0.035)	0.978 (0.023)
5/27	0.929 (0.030)	0.957 (0.025)	0.9160 (0.033)	0.900 (0.036)	0.984 (0.016)
6/01	0.920 (0.036)	0.943 (0.032)	0.942 (0.032)	0.961 (0.027)	0.980 (0.020)
6/03	0.911 (0.038)	0.923 (0.038)	1.000 (<0.0001)	0.956 (0.031)	0.956 (0.031)
Pooled	0.8764 (0.0149)	0.9331 (0.0124)	0.9608 (0.0096)	0.9196 (0.0136)	0.9734 (0.0083)
John Day Tailrace					
5/16	0.963 (0.026)	0.885 (0.044)	1.000 (<0.0001)	1.000 (<0.0001)	1.000 (<0.0001)
5/19	0.983 (0.017)	1.006 (0.005)	1.000 (<0.0001)	0.842 (0.048)	0.960 (0.028)
5/21	1.000 (<0.0001)	0.904 (0.039)	1.000 (<0.0001)	0.885 (0.044)	0.958 (0.029)
5/23	0.954 (0.029)	0.885 (0.042)	0.898 (0.039)	0.879 (0.043)	0.981 (0.019)
5/25	0.957 (0.034)	0.947 (0.036)	0.973 (0.027)	0.919 (0.045)	1.000 (<0.0001)
5/27	0.988 (0.013)	0.960 (0.023)	0.973 (0.019)	0.944 (0.027)	0.986 (0.014)
6/01	0.975 (0.018)	0.974 (0.018)	1.000 (<0.0001)	1.000 (<0.0001)	0.987 (0.0132)
6/03	0.976 (0.025)	0.974 (0.026)	0.974 (0.026)	1.000 (<0.0001)	1.000 (<0.0001)
Pooled	0.974 (0.007)	0.942 (0.011)	0.977 (0.007)	0.933 (0.012)	0.983 (0.006)

Table 3.5. Modeled Estimates of Single-Release Survival and Detection Probabilities for each Paired-Release Group from John Day Dam. Estimates were from pooled data from both single-releases when differences in single-release estimates did not differ significantly. The joint probability of survival from the TDA primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses.

John Day Release Site	Survival Probability		Detection Probability		Detection and Survival (λ) to 2T
	to 1J	1J to 1T	1J	1T	
Front roll	0.983 (0.006)	0.935 (0.008)	0.983 (0.004)	0.925 (0.009)	0.982 (0.005)
Tailrace	0.974 (0.007)				
Intake 9C	0.876 (0.015)	0.938 (0.008)	0.969 (0.006)	0.927 (0.009)	0.978 (0.005)
Tailrace	0.975 (0.007)				
Intake 9C	0.876 (0.015)	0.931 (0.009)	0.961 (0.010)	0.918 (0.009)	0.977 (0.005)
Front roll	0.983 (0.006)		0.989 (0.005)		

Survival from the Front Roll to the JDA Tailrace was estimated to be $\hat{S}$ = 1.009 ($\widehat{SE}$ = 0.010). Survival through Turbine Intake 9C to the JDA Tailrace was estimated to be $\hat{S}$ = 0.898 ($\widehat{SE}$ = 0.017). From Turbine Intake 9C to the Front Roll, survival was estimated to be $\hat{S}$ = 0.892 ($\widehat{SE}$ = 0.016). Figure 3.12 summarizes the results of the three acoustic-tag releases at JDA.

A Z-test indicated that the single-release survival estimate for Intake-released yearlings was significantly lower than that for yearlings released in the Front Roll (Z=-6.385; P < 0.0001; n = 8), and it was significantly lower than that for yearlings released in the Tailrace (Z=-5.843; P < 0.0001; n = 8). However, single release survival estimates from the Front Roll and Tailrace releases to the primary array did not differ significantly (Z = 1.131 < 1.645; P = 0.129; n = 8). A paired-release survival estimate for yearlings passing through Intake 9C to the Tailrace was significantly lower than a paired-release estimate for yearlings released in the Front Roll and passing to the Tailrace (Z = -4.945; P < 0.0001; n = 8).

3.4.4 The Dalles and Bonneville Tailrace Releases

Releases from the TDA Tailrace were performed from May 16– June 5, 2006 (Table 3.6). Survival from the tailrace release (rkm 306) to the TDA primary array (rkm 275.6) ranged from 0.959 ($\widehat{SE}$ = 0.018) to 1.001 ($\widehat{SE}$ 0.001) with a pooled estimate across the season of 0.989 ($\widehat{SE}$ = 0.003). From the primary (rkm 275.6) to the secondary (rkm 238.4) array, survival ranged from 0.979 ($\widehat{SE}$ = 0.015) to 1.004 ($\widehat{SE}$ = 0.004), with a pooled estimate across the season of 0.992 ($\widehat{SE}$ = 0.004) (Table 3.7). Joint survival through the BON reservoir is therefore estimated to be 0.989 × 0.992 = 0.981 ($\widehat{SE}$ = 0.005). Results are summarized in Figure 3.13.

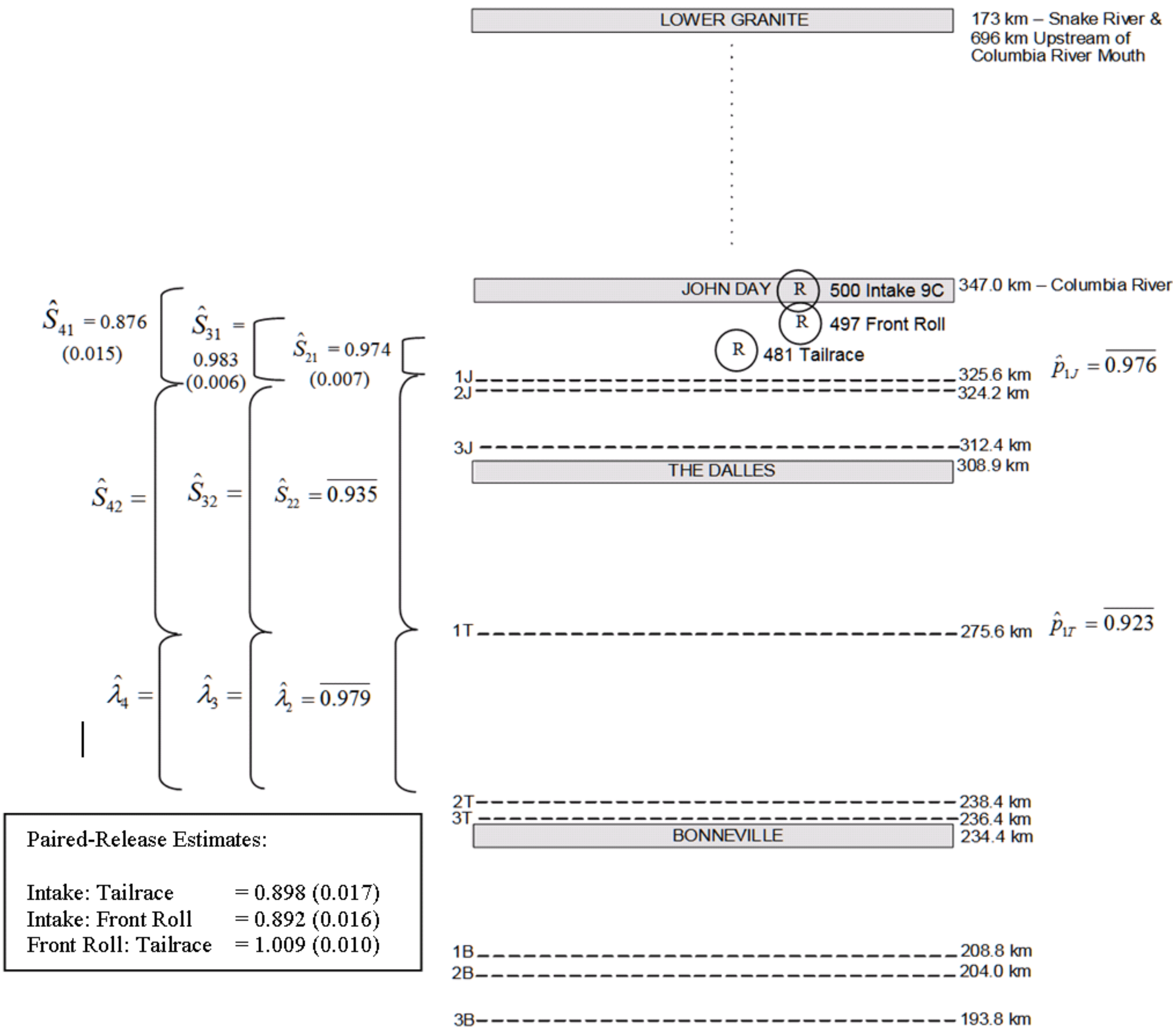


Figure 3.12. Summary of Results for the Single-Release and Paired-Release Analysis of the JDA Release Groups. Single-release estimates are adjacent to the figure and paired-release estimates are in the text box.

Table 3.6. Detection Histories for each Release Group from the TDA Tailrace. In the table heading, a 1 denotes detected and 0 not detected at the TDA primary and secondary arrays, and the BON primary array, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
5/16	72	0	0	0	22	0	1	1	96
5/19	77	0	1	0	36	2	3	1	120
5/21	68	4	0	0	41	1	1	5	120
5/23	50	1	0	0	35	2	0	2	90
5/25	19	0	0	0	27	1	1	0	48
5/27	33	3	0	0	43	4	1	1	85
6/01	36	1	0	0	29	1	0	0	67
6/03	93	1	1	0	58	0	0	0	153
6/05	94	2	1	0	97	1	3	1	199
Pooled	542	12	3	0	388	12	10	11	978

Table 3.7. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for each Group Released from the TDA Tailrace. The joint probability of survival from the TDA secondary array to the BON primary array and being detected at the BON primary array (λ) is in the last column. Standard errors are in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
	to 1T	1T to 2T	1T	2T	
5/16	0.99 (0.010)	0.99 (0.011)	1.000 (<0.0001)	1.000 (<0.0001)	0.766 (0.044)
5/19	0.992 (0.008)	0.979 (0.015)	0.983 (0.012)	0.987 (0.013)	0.670 (0.044)
5/21	0.959 (0.018)	0.991 (0.009)	0.956 (0.019)	1.000 (<0.0001)	0.632 (0.045)
5/23	0.978 (0.016)	1.000 (<0.0001)	0.966 (0.019)	1.000 (<0.0001)	0.580 (0.053)
5/25	1.001 (0.001)	0.979 (0.021)	0.979 (0.021)	1.000 (<0.0001)	0.404 (0.072)
5/27	0.989 (0.012)	0.987 (0.013)	0.916 (0.031)	1.000 (<0.0001)	0.434 (0.054)
6/01	1.000 (<0.0001)	1.000 (<0.0001)	0.970 (0.021)	1.000 (<0.0001)	0.552 (0.061)
6/03	1.000 (<0.0001)	1.004 (0.004)	0.994 (0.007)	0.990 (0.011)	0.618 (0.039)
6/05	0.995 (0.005)	0.990 (0.010)	0.985 (0.009)	0.990 (0.010)	0.495 (0.036)
Pooled	0.989 (0.003)	0.992 (0.004)	0.975 (0.005)	0.995 (0.003)	0.581 (0.016)

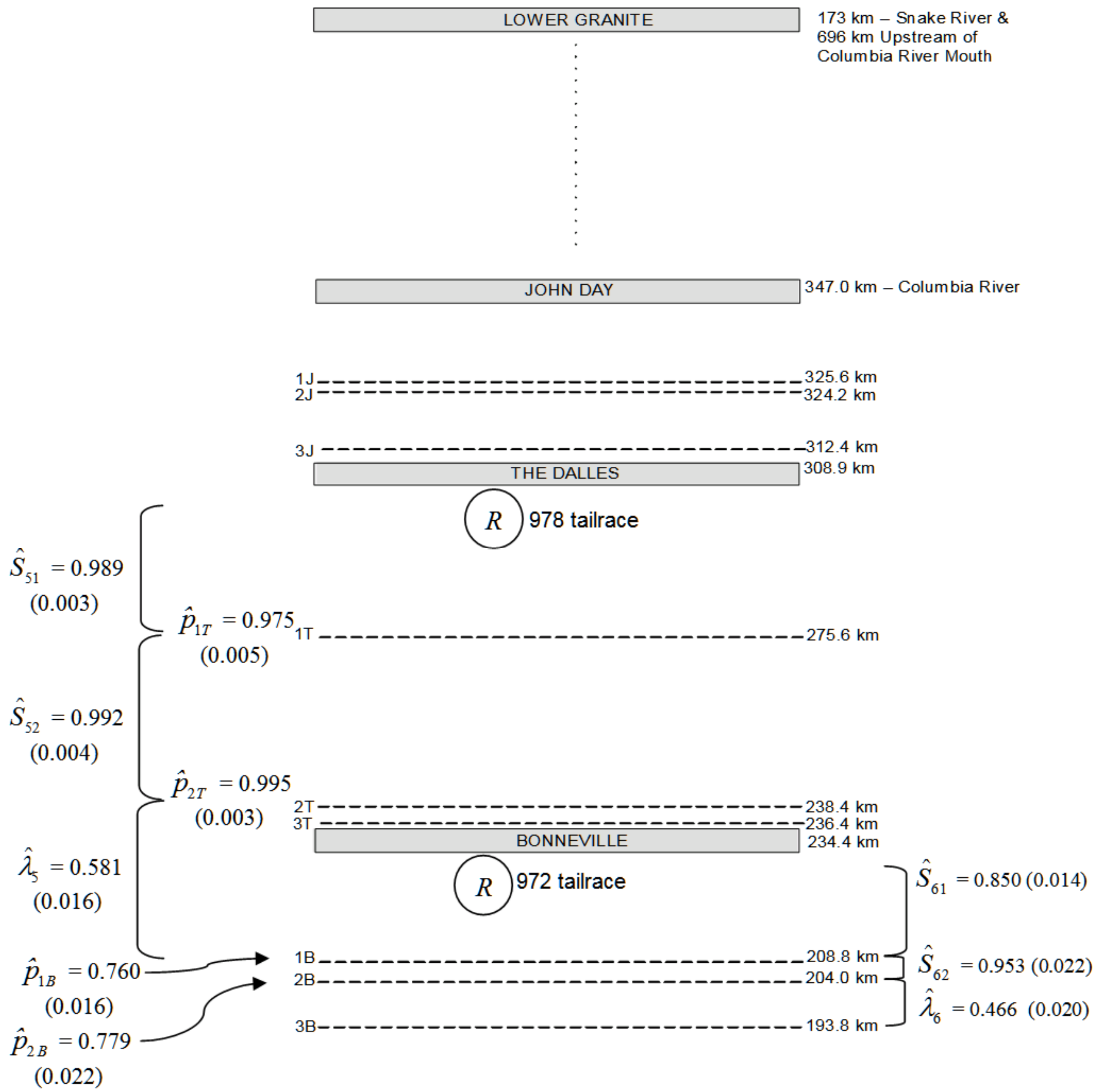


Figure 3.13. Summary of the Single-Release (SR) Analyses of TDA and BON Tailrace Releases

Four releases from BON Tailrace were performed from May 2 to 27, 2006 (Table 3.8) and detections were used to estimate detection probabilities and survivals in Table 3.9. From BON Tailrace to the BON primary array (rkm 208.8), survival ranged from 0.708 ($\widehat{\text{SE}}$ = 0.030) to 0.916 ($\widehat{\text{SE}}$ = 0.034), with a pooled value of 0.850 ($\widehat{\text{SE}}$ = 0.014). Between the BON primary (rkm 208.8) and secondary (rkm 204.0) array, survival ranged from 0.887 ($\widehat{\text{SE}}$ = 0.043) to 1.013 ($\widehat{\text{SE}}$ = 0.045), with a pooled estimated of 0.953 ($\widehat{\text{SE}}$ = 0.0222). Figure 3.13 summarizes the observed detection and survival probabilities resulting from the single-release analyses of the TDA and BON Tailrace releases.

Table 3.8. Detection Histories for each Release Group from the BON Tailrace. In the table heading, 1 denotes detected and 0 not detected at the BON primary, secondary, and tertiary arrays, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
5/02	48	10	8	1	88	22	34	28	239
5/11	66	6	6	1	71	8	14	73	245
5/19	62	20	31	11	51	13	23	33	244
5/27	43	31	13	10	41	34	29	43	244
Pooled	219	67	58	23	251	77	100	177	972

Table 3.9. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for each Group of Fish Released from the BON Tailrace. The joint probability of survival from the BON secondary array to the tertiary array and being detected at the tertiary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 3B
	to 1B	1B to 2B	1B	2B	
5/02	0.915 (0.023)	0.887 (0.043)	0.814 (0.030)	0.866 (0.042)	0.345 (0.037)
5/11	0.708 (0.030)	0.955 (0.030)	0.905 (0.023)	0.911 (0.032)	0.477 (0.041)
5/19	0.894 (0.024)	1.013 (0.045)	0.766 (0.031)	0.661 (0.043)	0.562 (0.041)
5/27	0.916 (0.034)	0.874 (0.050)	0.564 (0.038)	0.763 (0.043)	0.497 (0.041)
Pooled	0.850 (0.014)	0.953 (0.022)	0.760 (0.016)	0.779 (0.022)	0.466 (0.020)

3.4.5 Virtual Releases from The Dalles and Bonneville Forebays

Smolts known to have arrived at the JDA tertiary array (rkm 312.4) served as a virtual release of fish known to have gone through TDA (rkm 308.9). These fish were used to estimate reach survivals to rkm 275.6 and between rkm 275.6 and 238.4. Eight virtual release groups were formed from May 16 – June 3, 2006 (Table 3.10). In the first reach, survivals ranged from 0.885 ($\widehat{\text{SE}}$ = 0.030) to 0.982 ($\widehat{\text{SE}}$ = 0.013), with a pooled estimate of 0.947 ($\widehat{\text{SE}}$ = 0.007). In the second reach, replicate survival estimates ranged from 0.961 ($\widehat{\text{SE}}$ = 0.017) to 0.993 ($\widehat{\text{SE}}$ = 0.007), with a pooled estimate of 0.979 ($\widehat{\text{SE}}$ = 0.005) (Table 3.11). Survival through the joint reach from the forebay of TDA to the forebay of BON was estimated to be 0.947 × 0.979 = 0.927 ($\widehat{\text{SE}}$ = 0.008).

Table 3.10. Detection Histories for each Virtual Release Group through TDA. In the table heading, a 1 denotes detected and 0 not detected at the TDA primary and secondary arrays, and the BON primary array, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
5/16	68	0	0	0	30	0	2	13	113
5/19	78	8	0	0	35	10	3	3	137
5/21	68	7	0	0	43	7	2	9	136
5/23	80	5	0	0	43	13	5	9	155
5/25	50	5	0	0	43	4	3	11	116
5/27	59	5	0	0	71	3	1	5	144
6/01	90	2	0	0	60	0	1	4	157
6/03	55	1	0	0	57	0	3	5	121
Pooled	548	33	0	0	382	37	20	59	1079

Table 3.11. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for each Virtual Release Group through TDA. The joint probability of survival from the TDA secondary array to the BON primary array and being detected at the BON primary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
	to 1T	1T to 2T	1T	2T	
5/16	0.885 (0.030)	0.980 (0.014)	1.000 (<0.0001)	1.000 (<0.0001)	0.694 (0.047)
5/19	0.982 (0.013)	0.974 (0.015)	0.824 (0.030)	1.000 (<0.0001)	0.657 (0.042)
5/21	0.936 (0.021)	0.982 (0.012)	0.888 (0.028)	1.000 (<0.0001)	0.600 (0.044)
5/23	0.947 (0.019)	0.961 (0.017)	0.872 (0.028)	1.000 (<0.0001)	0.603 (0.041)
5/25	0.908 (0.027)	0.969 (0.018)	0.912 (0.028)	1.000 (<0.0001)	0.539 (0.049)
5/27	0.966 (0.015)	0.992 (0.008)	0.942 (0.020)	1.000 (<0.0001)	0.464 (0.043)
6/01	0.975 (0.013)	0.993 (0.007)	0.987 (0.009)	1.000 (<0.0001)	0.605 (0.040)
6/03	0.959 (0.018)	0.974 (0.015)	0.991 (0.009)	1.000 (<0.0001)	0.496 (0.047)
Pooled	0.947 (0.007)	0.979 (0.005)	0.930 (0.008)	1.000 (<0.0001)	0.581 (0.016)

Nine virtual releases were formed at the forebay of BON from May 14 through June 7, 2006 (Table 3.12). Survival from the BON forebay (rkm 236.4) to rkm 208.8 below BON ranged from 0.846 ($\widehat{SE}$ = 0.037) to 0.975 ($\widehat{SE}$ = 0.051), with a pooled estimate of 0.919 ($\widehat{SE}$ = 0.014) (Table 3.13). Figure 3.14 summarizes the results of the single release-recapture analysis for the virtual releases from the TDA and BON forebays.

Table 3.12. Detection History for each Virtual Release Group through BON. In the table heading, a 1 denotes detected and 0 not detected at BON primary, secondary, and tertiary arrays, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
Bonneville Dam									
5/14	39	6	9	1	24	3	7	5	94
5/17	31	11	14	2	30	8	11	10	117
5/19	39	7	10	7	22	7	7	15	114
5/21	30	13	6	5	15	6	4	7	86
5/23	11	6	3	2	6	8	3	7	46
5/25	26	15	2	4	10	17	3	4	81
5/30	21	9	6	2	16	7	1	5	67
6/01	49	23	15	4	27	17	11	9	155
6/03	52	23	17	9	32	15	11	36	195
Pooled	299	113	82	36	182	88	58	99	957

Table 3.13. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for each Virtual Release Group through BON. The joint probability of survival from the BON secondary array to the tertiary array and being detected at the tertiary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 3B
	to 1B	1B to 2B	1B	2B	
Bonneville Dam					
5/14	0.961 (0.028)	1.028 (0.071)	0.798 (0.045)	0.711 (0.068)	0.485 (0.062)
5/17	0.947 (0.041)	0.907 (0.087)	0.704 (0.051)	0.667 (0.073)	0.418 (0.060)
5/19	0.879 (0.039)	1.046 (0.088)	0.732 (0.049)	0.612 (0.070)	0.476 (0.063)
5/21	0.971 (0.047)	0.926 (0.086)	0.625 (0.061)	0.675 (0.074)	0.529 (0.070)
5/23	0.890 (0.112)	0.874 (0.176)	0.464 (0.094)	0.643 (0.128)	0.391 (0.102)
5/25	0.975 (0.051)	1.013 (0.094)	0.456 (0.060)	0.750 (0.077)	0.400 (0.063)
5/30	0.905 (0.039)	1.330 (0.140)	0.610 (0.064)	0.546 (0.087)	0.409 (0.074)
6/01	0.957 (0.033)	0.926 (0.059)	0.647 (0.044)	0.735 (0.054)	0.495 (0.050)
6/03	0.846 (0.037)	1.014 (0.071)	0.582 (0.043)	0.610 (0.054)	0.490 (0.050)
Pooled	0.919 (0.014)	0.998 (0.029)	0.636 (0.018)	0.662 (0.024)	0.464 (0.021)

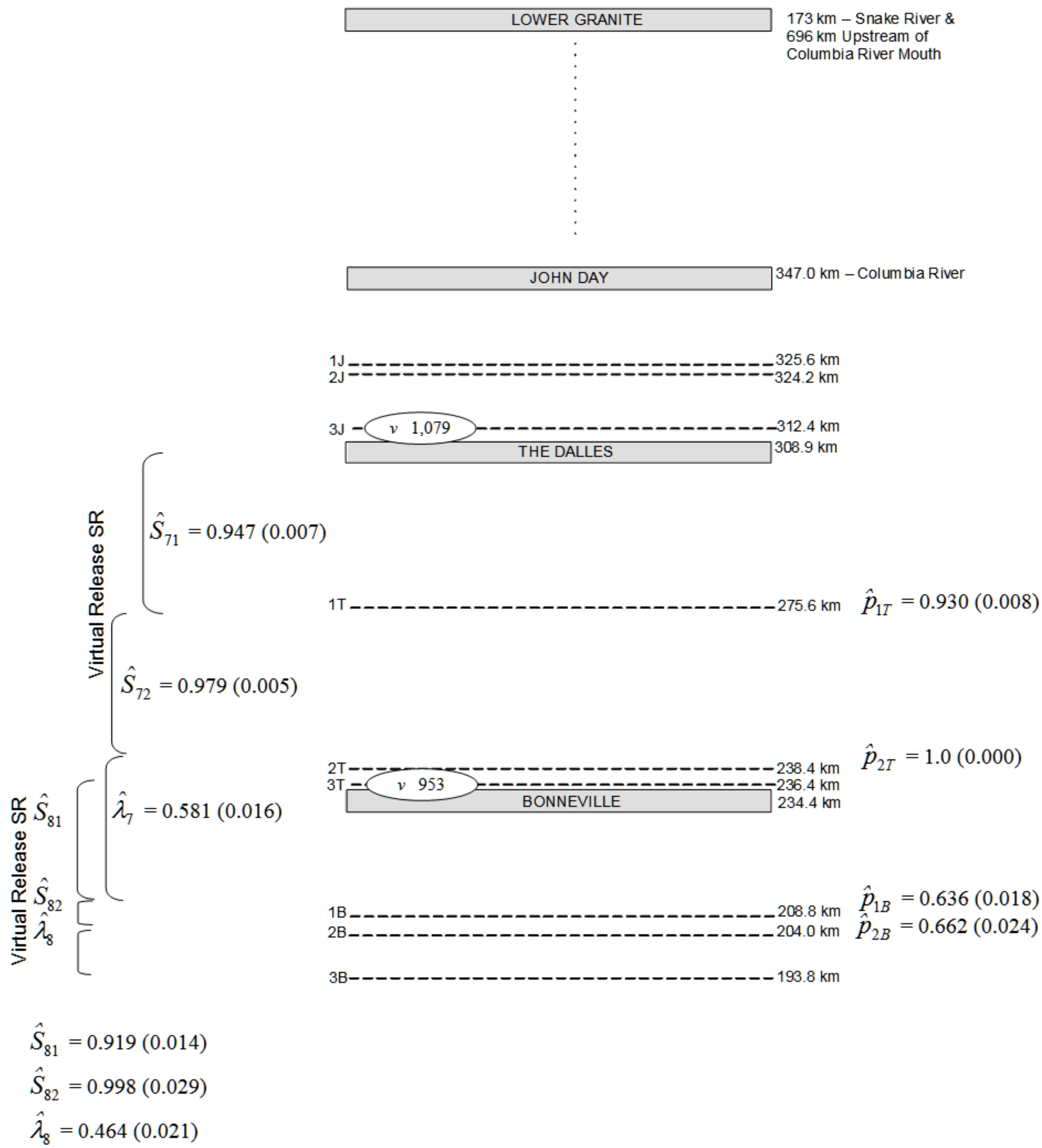


Figure 3.14. Summary of Single Release-Recapture Analyses of Virtual Releases of Yearling Chinook Salmon from the TDA and BON Forebays

3.4.6 The Dalles and Bonneville Project Passage Survivals

Tailrace releases from the JDA and the TDA Tailraces were used to estimate the TDA project passage survival using downstream detection histories at the TDA primary (rkm 275.6), TDA secondary (rkm 238.4), and BON primary (rkm 208.8) arrays (Table 3.14). Estimates of reach passage survival were based on the pooled release data from each tailrace (Table 3.15). Modeling of the paired-release data

(Appendix C, Table C.2.; Table 3.16) found homogeneous capture and survival parameters after the TDA primary array (i.e., Model M_{S_1, p_1}). Project passage survival was $\hat{S}_{\text{Dalles}} = 0.928$ ($\widehat{\text{SE}} = 0.013$).

Table 3.14. Detection History for the Pooled Release Groups Used to Estimate TDA Project Survival. In the table heading, 1 denotes detected and 0 not detected at the TDA primary and secondary arrays and the BON primary array, respectively.

Release Site	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
John Day Tailrace	232	12	0	0	173	17	7	40	481
The Dalles Tailrace	542	12	3	0	388	12	10	11	978

Table 3.15. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for the Pooled Release Groups Used to Estimate TDA Project Survival. The joint probability of survival from the TDA primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Release Site	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
	to 1T	1T to 2T	1T	2T	
JDA Tailrace	0.918 (0.013)	0.983 (0.006)	0.933 (0.012)	1.000 (<0.0001)	0.562 (0.024)
TDA Tailrace	0.989 (0.003)	0.992 (0.004)	0.975 (0.005)	0.995 (0.003)	0.581 (0.016)

Table 3.16. Modeled Single-Release Estimates of Survival and Detection Probabilities for JDA and TDA Tailrace Releases Used to Estimate TDA Project Passage Survival. Estimates were from pooled data from both single releases when differences in single-release estimates did not differ significantly. The joint probability of survival from the TDA secondary array to the BON primary array and being detected at the BON primary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Tailrace Release Site	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
	to 1T	1T to 2T	1T	2T	
JDA	0.918 (0.013)	0.989 (0.003)	0.934 (0.012)	0.996 (0.002)	0.575 (0.013)
TDA	0.989 (0.003)		0.975 (0.005)		

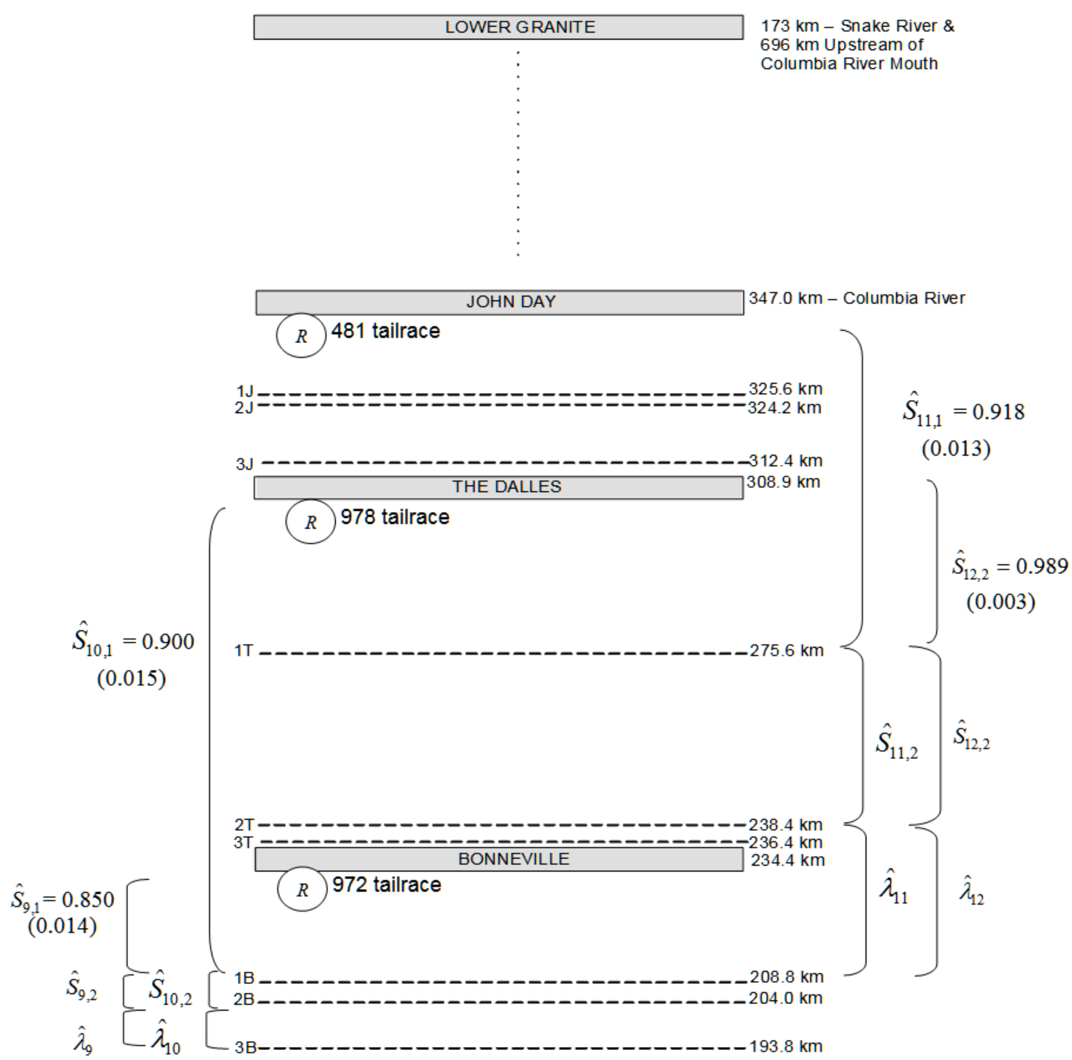
Bonneville project passage survival was estimated from tailrace releases at TDA and BON dams and subsequent detection histories at BON primary (rkm 208.8), secondary (rkm 204.0), and tertiary (rkm 193.8) arrays (Table 3.17). Estimates of reach passage survival were based on the single-release data (Table 3.18). Figure 3.15 summarizes the results of the paired release-recapture analyses at the TDA and BON dams.

Table 3.17. Detection Histories for the Pooled Release Groups Used to Estimate BON Project Survival. In the table heading, a 1 denotes detected and 0 not detected at the BON primary, secondary, and tertiary arrays, respectively.

Release Site	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
The Dalles Tailrace	173	95	93	45	189	124	102	157	978
Bonneville Tailrace	219	67	58	23	251	77	100	177	972

Table 3.18. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for the Pooled Release Groups Used to Estimate BON Project Survival. The joint probability of survival from the BON primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are in parentheses.

	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
Release Site	**to 1B**	**1B to 2B**	**1B**	**2B**	
The Dalles Tailrace	0.900 (0.015)	1.000 (0.029)	0.633 (0.018)	0.660 (0.024)	0.461 (0.021)
Bonneville Tailrace	0.850 (0.014)	0.953 (0.022)	0.760 (0.016)	0.779 (0.022)	0.466 (0.020)



Estimate $\hat{S}_{TDA} = 0.928(0.013)$ and $\hat{S}_{BON} = 1.058\ (0.024)$.

Figure 3.15. Summary of the Paired-Release Studies to Estimate The Dalles and Bonneville Project Passage Survivals for Yearling Chinook Salmon Smolts. Single-release estimates are presented adjacent to the diagram, and the paired-release estimates are at the bottom.

Modeling of the paired-release data (Appendix C, Table C.2; Table 3.19) found homogenous capture and survival parameters only in the last reach (i.e., Model $M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2}$). The project passage survival was estimated to be $\hat{S}_{\text{BON}}$ = 1.0583 ($\widehat{\text{SE}}$ = 0.0240).

Table 3.19. Modeled Single-Release Estimates of Survival and Detection Probabilities for TDA and BON Tailrace Releases Used to Estimate BON Project Passage Survival. The joint probability of survival from the BON primary array to the BON secondary array and being detected at BON tertiary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Tailrace Release Site	Survival Probability		Detection Probability		Detection and Survival (λ) to 3B
	to 1B	1B to 2B	1B	2B	
TDA	0.900 (0.015)	0.998 (0.027)	0.633 (0.018)	0.661 (0.022)	0.464 (0.014)
BON	0.850 (0.014)	0.954 (0.021)	0.760 (0.016)	0.779 (0.021)	

3.4.7 Tests of Assumptions

3.4.7.1 Assessment of Mixing

For the paired release-recapture analysis, mixing of upstream and downstream releases is a good indicator of whether the paired releases shared similar downstream conditions. There were a few significant Chi-square tests for homogeneous arrival distributions ($P < 0.05$) for all three JDA releases in spring (Appendix D, Figures D.1, D.2, and D.3), even though median arrival times per release day were within two hours of each other and 95% confidence intervals on arrival times overlapped (Figure 3.16).

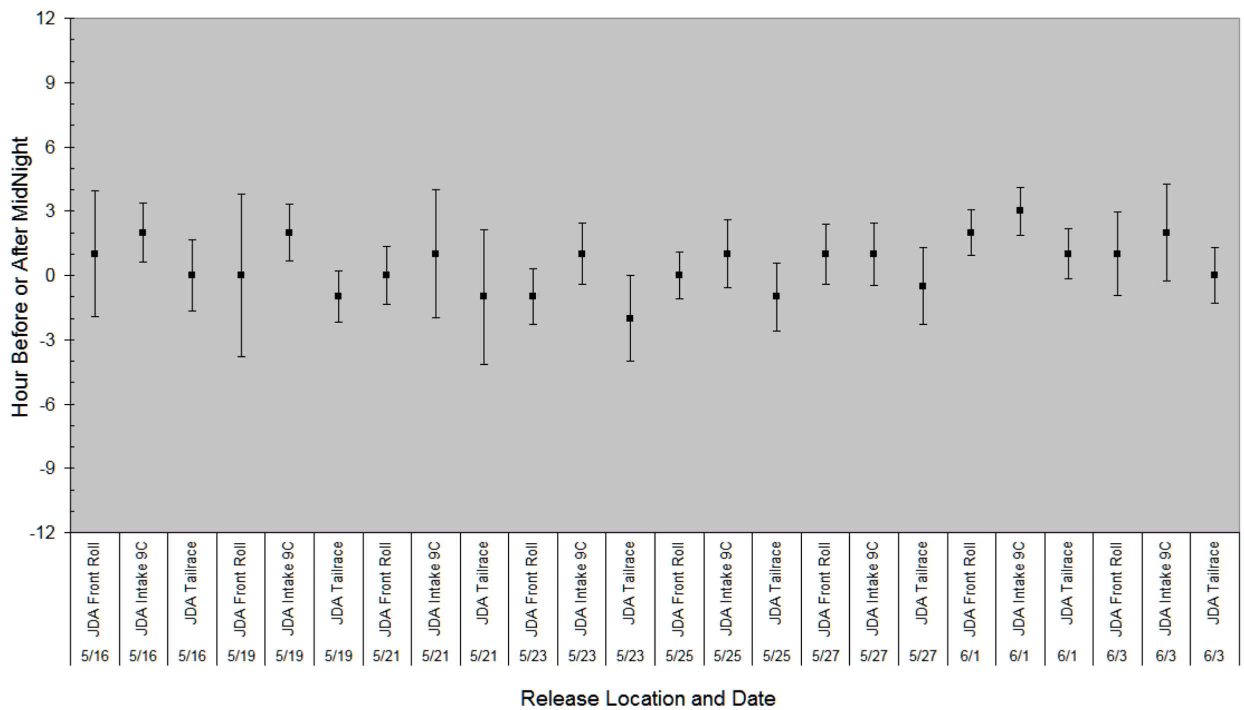


Figure 3.16. Plot of Median Hour of Arrival at Array 1J Below JDA Dam for Three Release Locations at JDA by Release Date. Vertical error bars represent 95% confidence intervals.

The JDA and TDA Tailrace releases used in estimating the TDA project passage survival seemed to show systemic departures from mixing in late spring (Appendix D, Figure D.4), but the apparent departure was a function of differences in the size of release groups and not differences in rates of movement of the two groups. Adding estimates of the cumulative percent of fish released to one of the three figures in Appendix D, Figure D.4 clearly shows that the apparent deviation was driven by differences in the number of tagged fish in late spring treatment and reference-release groups (e.g., Figure 3.17). The figure also shows that treatment and reference fish usually were detected on the same days. Within days, the distribution of arrivals ranged over all hours of the day based upon detections of the slowest and fastest fish from each release group at Array 1T. The minimum arrival time for most release dates was 0000 hours and the maximum arrival time was 2300 hours. However, the range in mean arrival times at 1T were different [1530 hours (SE = 4.6 hours)] for JDA Tailrace releases versus 0430 hours (SE = 4.2 hours), so most fish in treatment and reference release groups did not traverse the TDA Tailwater to Array 1T at the same time of day.

There was an appreciable departure from pair-release model mixing assumptions associated with the point estimate of $\hat{S}_{\text{BON}} = 1.058$ ($\widehat{\text{SE}} = 0.0240$). The TDA and BON Tailrace releases used in estimating BON project passage survival were very poorly mixed because there were only four "reference" releases below BON versus nine below TDA, and two of those BON releases occurred 5 to 14 days before the TDA releases began (Appendix D, Figure D.5). We ran the paired release model a second time after eliminating data acquired before May 16 from the BON releases and data acquired after May 27 from the TDA releases so that treatment fish and control fish were released during the same block of days. The resulting estimate $\hat{S}_{\text{BON}} = 1.057$ ($\widehat{\text{SE}} = 0.045$) was essentially the same as that produced using all release data.

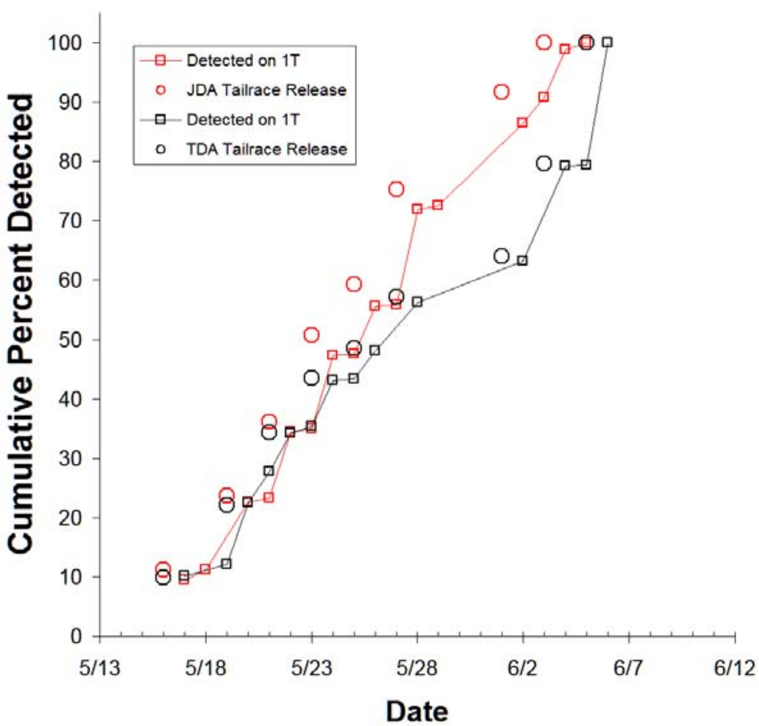


Figure 3.17. Cumulative Percent of Primary Array Detections of Treatment and Reference Fish Used to Make Paired-Release Estimates of TDA Project Survival in Spring 2006.

Close inspection of time of detection data indicate that fish released in the TDA Tailrace had an average arrival time at Array 1B of 1320 hours ($\widehat{\text{SE}}$ = 7.15 hours) and those from the BON Tailrace releases had an average arrival of 1239 hours ($\widehat{\text{SE}}$ = 10.4 hours) during the first two releases and 0210 hours (± 8 hours SE) during the second two releases. In summary, the first two reference releases preceded treatment releases by 5 to 14 days but had arrival hours that were similar to those of treatment fish, and the last two reference releases matched up well with days of treatment releases but not with hours of the day.

3.4.7.2 Goodness-of-Fit

Burnham et al.'s (1987) Tests 2 and 3 were performed to assess goodness-of-fit of the tagging data to the release-recapture models. Both tests assess whether the upstream detection history has an effect on downstream detections within a release group. Two of the three JDA releases had significant ($P < 0.10$) Test 2 results (Appendix D, Table D.1). No significant departures ($P > 0.10$) were observed for the JDA, TDA, or BON Tailrace releases (Appendix D, Tables D.2 and C3). None of the Burnham et al. (1987) Test 3 results were significant for any of the release groups tested (Appendix D, Tables D.4-D.6).

3.4.8 Survival through Successive Reaches

We made estimates of survival for yearling Chinook salmon from point of release to each successive array in our study area, except the last reach (Figure 3.18). We released tagged yearlings from four different locations (JDA turbine, JDA Front Roll, and JDA Tailrace, and TDA Tailrace); the tag-effects study released them in the LGR Tailrace and the estuary study released them in the BON Tailrace. Survival statistics in Figure 3.18 were calculated using a single release model and detections on the array of interest and on two successive arrays immediately downstream, except for Array 2B estimates, which were based upon detections on two arrays (2B and 3B).

3.4.9 Bonneville Route-Specific Survival (Pooled Releases)

We estimated detection probabilities and survival for yearling Chinook salmon based on the population of all tagged fish detected at specific sites while passing through BON, regardless of where the fish were originally released. Release sites that contributed fish to the detections included the LGR Tailrace, JDA Intake 9C, JDA Front Roll, JDA Tailrace, and TDA Tailrace. Even with pooling of data from all release sites, sample sizes were low and produced wide standard errors.

3.4.9.1 Spillway, B2 JBS, and B2CC

During spring, survival for three routes at BON was calculated. Each passage route had a specific collection type. Detection at the spillway was acoustic, based on an array of autonomous acoustic hydrophones in the forebay, while tagged fish at the B2CC and B2JBS were detected by PIT-tag detectors. Using data from the primary, secondary, and tertiary arrays below BON, pooled survival estimates were calculated for the B2CC and the B2JBS while a virtual estimate of survival was calculated for the spillway to increase the sample size (Table 3.20).

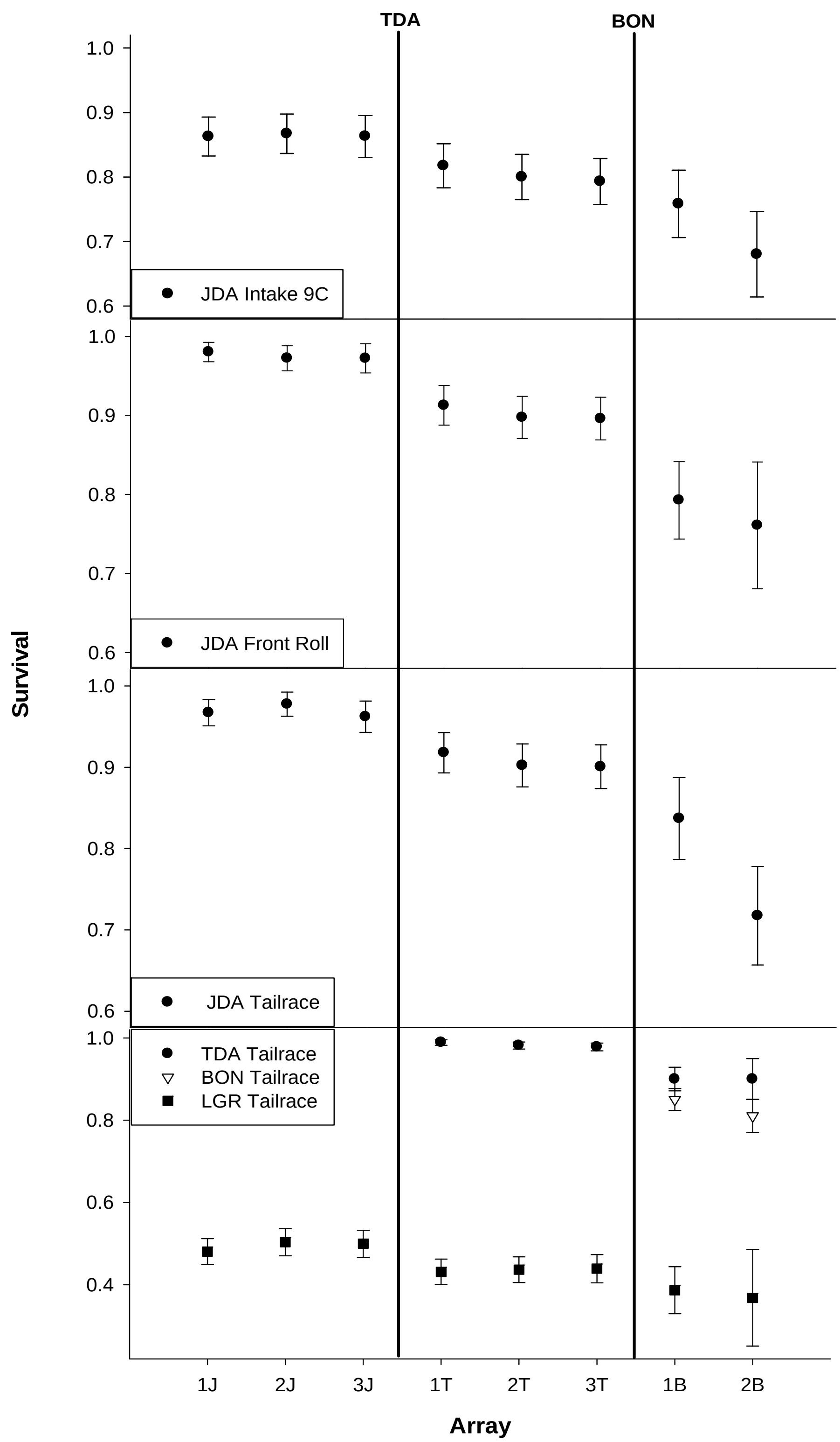


Figure 3.18. Spring Survival Percentages for Tagged Fish from Release Location to each Survival Array except the Last. These survival statistics were calculated using a single release model.

Table 3.20. Single-Release Survival and Detection Probabilities Based on Pooling of Releases from All Upstream Sites. Standard errors are in parentheses.

Detection Site	Survival Probability	Detection Probability	Detection Probability		Detection and Survival (λ)	Number of Fish (n)
	To 1B	1B to 2B	1B	2B	to 3B	
B2CC	0.946 (0.051)	0.966 (0.096)	0.610 (0.064)	0.669 (0.042)	0.533 (0.074)	78
B2JBS	0.893 (0.083)	1.173 (0.240)	0.533 (0.091)	0.867 (0.028)	0.364 (0.103)	42
Spillway	0.941 (0.036)	1.059 (0.088)	0.635 (0.047)	0.707 (0.032)	0.467 (0.129)	134

We also divided single-release estimates to Array 1B in Table 3.20 by the pooled single-release estimate to Array 1B for the BON Tailrace release to obtain paired-release estimates of survival for each route. Each paired-release estimate exceeded 100% (111.2% [1/2 95% CI = 98.9, 123.5] for the B2CC; 1.05% [1/2 95% CI = 85.5, 124.4] for the B2JBS; and 110.6% [1/2 95% CI = 101.7, 119.6] for the spillway).

3.4.9.2 Spillway by Time of Day

In spring, we also estimated BON spillway survival for day and night periods, although the exercise probably was not justified by the low numbers of tagged fish detected at the spillway (Table 3.21). Daytime was defined as from 0600 through 2100 hours each season, and the remaining hours of the day were assigned as nighttime hours. The detection array in the spillway forebay was not installed and functional until the last week of spring sampling because of delays in equipment availability. Survival estimates of 0.957 during the day and 0.875 at night differed by 8%, and this difference was smaller than the standard error for the night estimate alone.

Table 3.21. Day and Night Estimates of Single-Release Survival and Detection Probabilities for Fish Detected in the Spillway Forebay, Regardless of Upstream Release Location. Standard errors are in parentheses.

	Survival Probability	Detection Probability	Detection Probability		Detection and Survival (λ)	Number of Fish (n)
Time	To 1B	1B to 2B	1B	2B	to 3B	
Day	0.957 (0.038)	1.038 (0.095)	0.651 (0.052)	0.653 (0.040)	0.418 (0.060)	106
Night	0.875 (0.088)	1.137 (0.214)	0.571 (0.108)	0.828 (0.047)	0.467 (0.129)	28

Division of these day and night estimates by the pooled estimate for the BON Tailrace release (85.0 ± 1.40 SE) yields a paired release estimate of 112.5% [1/2 95% CI = 103.1, 122.0] for day and 102.9% [1/2 95% CI = 82.3, 123.4] for night. Confidence intervals overlap for single- and paired-release estimates.

3.5 Detection and Survival of Subyearling Chinook Salmon in Summer

3.5.1 Tag-Life Study Correction

Downstream arrival times on study arrays were sufficiently fast that tag-life corrections to the survival estimates were unnecessary. For subyearling Chinook salmon released below Little Goose Dam, 10-s tags were used with their own failure-time curve (see Section 3.3). Once again, examination of the tag-life curve and arrival distributions of fish to downstream detection arrays (Appendix E) indicated the vast majority of fish arrived before the time of first tag failure. In these cases, no tag-life correction was necessary. Only fish from the Bonneville tailrace (Appendix E, BON Tailrace (Figure E.5), the virtual release above Bonneville Dam (Appendix E, BON (Figure E.7), and the TDA Tailrace release (Appendix E, Figure E.9) showed the potential need for tag-life corrections. However, in all three cases, this was only for the last detection array and the expected probability of tag life was $\geq$ 0.999.

3.5.2 Little Goose Tailrace Releases

Ten replicate releases from Little Goose Tailrace were performed between June 16 and July 18, 2006. Reach survivals were estimated from release to JDA primary array (1J) and between the JDA primary and the TDA primary arrays (1T). In both reaches, obvious seasonal trends in the perceived survival were noticed. In the first reach, perceived survivals ranged from a high of 0.484 ($\widehat{\text{SE}}$ = 0.036) for the June 16 release to a low of 0.016 ($\widehat{\text{SE}}$ = 0.009) for the July 10 release. None of the fish released on either July 14 or 18 were ever observed at a downriver detection site (Table 3.22). For the eight release groups with observed survival rates (Table 3.23), the arithmetic average was $\hat{\bar{S}}$ = 0.196 ($\widehat{\text{SE}}$ = 0.056). Survival and detection probabilities cannot be estimated for the July 14 and 18 releases because there were no downstream detections after release. Survival estimates between the JDA primary and the TDA primary arrays showed a similar monotonic decline, with values ranging from 0.848 ($\widehat{\text{SE}}$ = 0.037) to 0.645 ($\widehat{\text{SE}}$ = 0.086). Average survival for the eight replicate releases with observed detections was $\hat{\bar{S}}$ = 0.603 ($\widehat{\text{SE}}$ = 0.104). Detection rates at all three JDA arrays (i.e., 1J, 1T, and 2T) exceeded 0.90 in all instances (Table 3.23). Figure 3.19 summarizes the results of the Little Goose Tailrace releases.

Table 3.22. Detection Histories for each Release Group at Little Goose Dam. In the table heading, a 1 denotes detected and 0 not detected on Arrays 1J, 1T, and 2T, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
6/16	76	2	0	0	2	0	14	101	195
6/21	62	2	1	0	2	0	15	113	195
6/24	46	5	0	0	1	0	6	137	195
6/27	41	4	1	0	3	0	12	134	195
7/01	18	2	0	0	2	0	11	162	195
7/04	14	0	0	0	1	0	8	172	195
7/07	15	1	0	0	1	0	6	171	194
7/10	2	0	0	0	0	0	1	189	192
7/14	0	0	0	0	0	0	0	198	198
7/18	0	0	0	0	0	0	0	195	195
Pooled	274	16	2	0	12	0	73	1572	1949

Table 3.23. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for each Release Group of Subyearling Chinook Salmon Released from Little Goose Tailrace. The joint probability of survival from the TDA primary array to the secondary array and being detected at the secondary array (λ) is in the last column. Standard errors are in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 2T
	to 1J	1J to 1T	1J	1T	
6/16	0.484 (0.036)	0.848 (0.037)	0.975 (0.018)	1.000 (<0.0001)	0.975 (0.018)
6/21	0.423 (0.036)	0.813 (0.044)	0.970 (0.021)	0.985 (0.015)	0.970 (0.021)
6/24	0.301 (0.033)	0.887 (0.044)	0.904 (0.041)	1.000 (<0.0001)	0.981 (0.019)
6/27	0.318 (0.034)	0.791 (0.054)	0.918 (0.039)	0.978 (0.022)	0.938 (0.035)
7/01	0.175 (0.028)	0.645 (0.086)	0.909 (0.061)	1.000 (<0.0001)	0.909 (0.061)
7/04	0.118 (0.023)	0.652 (0.099)	1.000 (<0.0001)	1.000 (<0.0001)	0.933 (0.064)
7/07	0.121 (0.0237)	0.727 (0.095)	0.941 (0.057)	1.000 (<0.0001)	0.941 (0.057)
7/10	0.016 (0.009)	0.667 (0.272)	1.000 (<0.0001)	1.000 (<0.0001)	1.000 (<0.0001)
7/14	NA	NA	NA	NA	NA
7/18	NA	NA	NA	NA	NA
Pooled			0.947 (0.013)	0.993 (0.005)	0.960 (0.011)
Arithmetic Avg.	0.196 (0.056)	0.603 (0.104)			

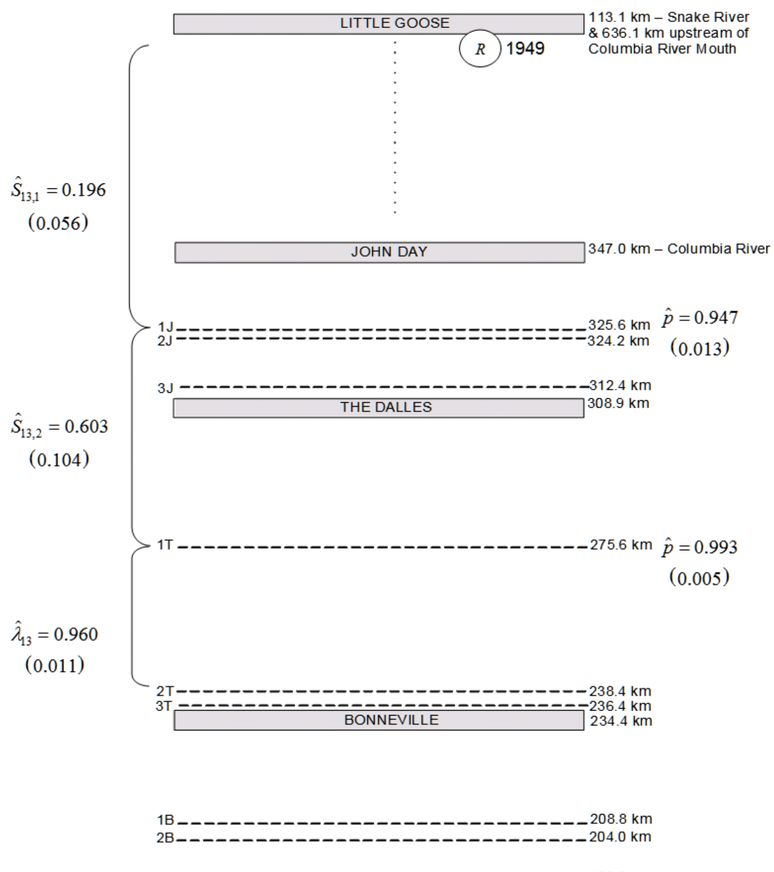


Figure 3.19. Summary of Single-Release Analysis of Reach Survival for Subyearling Chinook Salmon Smolts below Little Goose Dam

3.5.3 John Day Tailrace Releases

Five replicate groups of fish were released from the JDA Tailrace between June 13 and 27, 2006 (Table 3.24) to estimate survival to the JDA primary array (1J) and between the JDA primary and the TDA primary arrays (1J–1T). No obvious seasonal trends in survival were observed, with pooled estimates of $\hat{S}$ = 0.994 ($\widehat{\mathrm{SE}}$ = 0.005) and $\hat{S}$ = 0.828 ($\widehat{\mathrm{SE}}$ = 0.0220) for the first and second reaches, respectively (Table 3.25). Detection probabilities at arrays 1J and 1T were in excess of 0.95 with pooled values ranging from 0.988–987 to 0.996. Figure 3.20 summarizes the results of the single-release analysis.

Table 3.24. Detection Histories for the JDA Tailrace Releases in Summer 2006. In the table heading, a 1 denotes detected and 0 not detected at the JDA primary and the TDA primary and secondary arrays, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
6/13	41	0	1	0	0	0	8	0	50
6/15	42	0	0	0	0	0	7	1	50
6/20	45	0	0	0	1	0	4	0	50
6/22	37	1	2	0	1	0	8	0	49
6/27	75	0	0	0	0	0	24	1	100
Pooled	240	1	3	0	2	0	51	2	299

Table 3.25. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for the JDA Tailrace Releases in Summer. The joint probability of survival from the TDA primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 2T
	to 1J	1J to 1T	1J	1T	
6/13	1.000 (<0.0001)	0.840 (0.052)	1.000 (<0.0001)	0.976 (0.024)	1.000 (<0.0001)
6/15	0.980 (0.020)	0.857 (0.050)	1.000 (<0.0001)	1.000 (<0.0001)	1.000 (<0.0001)
6/20	1.000 (<0.0001)	0.920 (0.038)	1.000 (<0.0001)	1.000 (<0.0001)	0.978 (0.022)
6/22	1.004 (0.004)	0.834 (0.054)	0.976 (0.024)	0.950 (0.035)	0.974 (0.025)
6/27	0.990 (0.010)	0.758 (0.043)	1.000 (<0.0001)	1.000 (<0.0001)	1.000 (<0.0001)
Pooled	0.994 (0.005)	0.828 (0.022)	0.996 (0.004)	0.988 (0.007)	0.992 (0.006)
Arithmetic Avg.	0.995 (0.004)	0.862 (0.0333)			

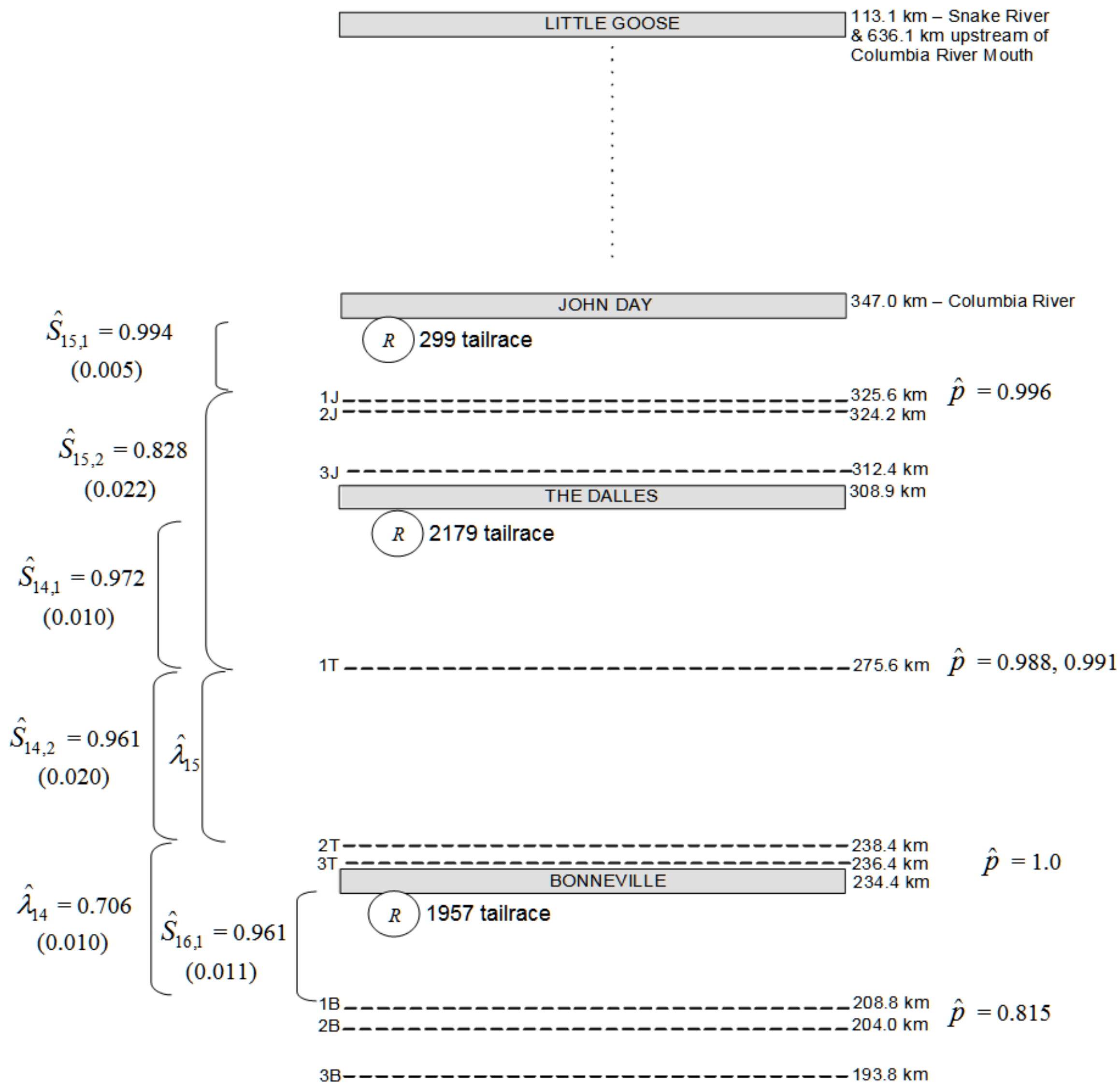


Figure 3.20. Release-Recapture Locations for the Single Releases Analyses of Reach Survival for Subyearling Chinook Salmon Smolts at JDA, TDA, and BON.

3.5.4 The Dalles and Bonneville Tailrace Releases

During summer 2006, ten replicate releases of subyearling Chinook salmon were performed between June 13 and July 13 at the TDA Tailrace (Table 3.26). Survival between release and the TDA primary array (T1) was estimated based on an arithmetic average to be $\hat{\bar{S}}$ = 0.9716 ($\widehat{\mathrm{SE}}$ = 0.0095). There was a moderate decline in survival estimates over the course of the study from a high of 1.0 ($\widehat{\mathrm{SE}}$ < 0.0001) to 0.9106 ($\widehat{\mathrm{SE}}$ = 0.0182) (Table 3.27). Perceived survival between the TDA primary and secondary arrays also showed a seasonal decline, with an arithmetic average of $\hat{\bar{S}}$ = 0.9611 ($\widehat{\mathrm{SE}}$ = 0.0203). Detection probabilities at arrays 1T and 2T exceeded 0.96 in all instances (Table 3.27).

Table 3.26. Detection Histories for the TDA Tailrace Releases. In the table heading, a 1 denotes detected and 0 not detected at the TDA primary and secondary arrays and BON primary, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
6/13	100	1	0	0	89	5	0	1	196
6/15	110	2	0	0	83	5	0	0	200
6/20	118	0	0	0	70	4	2	2	196
6/22	122	0	0	0	76	0	2	0	200
6/27	165	0	0	0	29	1	1	4	200
6/28	167	0	0	0	31	0	0	2	200
7/01	197	0	0	0	35	0	3	12	247
7/07	176	0	0	0	52	0	9	11	248
7/11	137	0	0	0	46	0	41	22	246
7/13	133	0	0	0	69	0	30	14	246
Pooled	1425	3	0	0	580	15	88	68	2179

Table 3.27. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for TDA Tailrace Release. The joint probability of survival from the TDA secondary array to the BON primary array and being detected at the primary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
	to 1T	1T to 2T	1T	2T	
6/13	0.995 (0.005)	1.000 (<0.0001)	0.969 (0.012)	1.000 (<0.0001)	0.518 (0.036)
6/15	1.000 (<0.0001)	1.000 (<0.0001)	0.965 (0.013)	1.000 (<0.0001)	0.560 (0.035)
6/20	0.990 (0.007)	0.990 (0.007)	0.979 (0.010)	1.000 (<0.0001)	0.615 (0.035)
6/22	1.000 (<0.0001)	0.990 (0.0070)	1.000 (<0.0001)	1.000 (<0.0001)	0.616 (0.035)
6/27	0.980 (0.010)	0.995 (0.005)	0.995 (0.005)	1.000 (<0.0001)	0.846 (0.026)
6/28	0.990 (0.007)	1.000 (<0.0001)	1.000 (<0.0001)	1.000 (<0.0001)	0.843 (0.026)
7/01	0.951 (0.014)	0.987 (0.007)	1.000 (<0.0001)	1.000 (<0.0001)	0.849 (0.024)
7/07	0.956 (0.013)	0.962 (0.012)	1.000 (<0.0001)	1.000 (<0.0001)	0.772 (0.028)
7/11	0.911 (0.018)	0.817 (0.026)	1.000 (<0.0001)	1.000 (<0.0001)	0.749 (0.032)
7/13	0.943 (0.015)	0.871 (0.022)	1.000 (<0.0001)	1.000 (<0.0001)	0.658 (0.033)
Pooled	0.969 (0.004)	0.958 (0.004)	0.991 (0.002)	1.000 (<0.0001)	0.706 (0.010)
Arithmetic Avg.	0.972 (0.010)	0.961 (0.020)			

Releases below BON were detected at the BON primary (1B) and secondary (2B) arrays (Table 3.28), providing perceived survival estimates only between the BON Tailrace and the first array (Table 3.29). Again, there is evidence of a seasonal decline in survival estimates, ranging from 1.003 ($\widehat{SE}$ = 0.052) to 0.914 ($\widehat{SE}$ = 0.018), with an arithmetic mean of $\hat{\bar{S}}$ = 0.961 ($\widehat{SE}$ = 0.011). Detection probabilities at array 1B increased dramatically over the season, from 0.468 ($\widehat{SE}$ = 0.040) to 0.970 ($\widehat{SE}$ = 0.012), with an arithmetic average of 0.815 ($\widehat{SE}$ = 0.065).

Table 3.28. Detection Histories for BON Tailrace Releases. In the table heading, a 1 denotes detected and 0 not detected at BON primary and secondary arrays, respectively. BON tertiary array was not available for the entire study.

Release	1 1	0 1	1 0	0 0	Total
6/17	73	83	42	47	245
6/22	120	54	45	26	245
6/27	140	71	20	14	245
7/02	176	16	44	9	245
7/07	156	11	60	16	243
7/12	205	11	17	12	245
7/17	175	13	35	21	244
7/22	191	6	26	22	245
Pooled	1236	265	289	167	1957

Table 3.29. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for the Bonneville Tailrace release. The joint probability of survival from Bonneville primary array to secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses. The BON tertiary array was not available all summer.

Day of Release	Survival Probability to 1B	Detection Probability to 1B	Detection and Survival (λ) to 2B
6/17	1.003 (0.052)	0.468 (0.040)	0.635 (0.045)
6/22	0.977 (0.028)	0.690 (0.035)	0.727 (0.035)
6/27	0.984 (0.019)	0.664 (0.033)	0.875 (0.026)
7/02	0.980 (0.013)	0.917 (0.020)	0.800 (0.027)
7/07	0.952 (0.017)	0.934 (0.019)	0.722 (0.031)
7/12	0.955 (0.014)	0.949 (0.015)	0.923 (0.018)
7/17	0.925 (0.019)	0.931 (0.019)	0.833 (0.026)
7/22	0.914 (0.018)	0.970 (0.012)	0.880 (0.022)
Pooled	0.946 (0.007)	0.824 (0.010)	0.811 (0.010)
Arithmetic Avg.	0.961 (0.011)	0.815 (0.065)	

3.5.5 Virtual Releases from The Dalles and Bonneville Forebays

Virtual release groups were constructed using tagged fish known to have arrived at the JDA tertiary array (3J) just above TDA. These fish were used to generate detection histories (Table 3.30) to estimate survival through TDA and below (Table 3.31). Using the pooled data from five virtual releases June 13-27, 2006, survival through TDA to primary array T1 was estimated to be 0.863 ($\widehat{SE}$ = 0.021). No obvious seasonal trends were observed (Table 3.31). Survival between the TDA primary (1T) and secondary (2T) arrays was estimated to be 0.991 ($\widehat{SE}$ = 0.006). In all cases, detection probabilities at arrays 1T and 2T were $\geq$ 0.950.

Figure 3.21 summarizes the results of the analysis of The Dalles forebay virtual releases. Using tagged fish known to have arrived at the TDA tertiary array (3T), just above BON Dam, virtual release groups were constructed (Table 3.32) to estimate survival through BON Dam (Table 3.33). The BON tertiary array was not available for the entire summer. Survival through BON Dam to BON primary array (1B) was estimated to be $\hat{S}_{BON}$ = 0.869 ($\widehat{SE}$ = 0.029) using the pooled data. Detection probabilities at 1B fluctuated over the course of the study, from a low of 0.583 ($\widehat{SE}$ = 0.044) to a high of 0.962 ($\widehat{SE}$ = 0.015), with an arithmetic average of $\hat{\bar{p}}$ = 0.804 ($\widehat{SE}$ = 0.052; Figure 3.21).

Table 3.30. Detection Histories for the TDA Virtual Releases at Array 3J. In the table heading, a 1 denotes detected and 0 not detected at the TDA primary and secondary arrays and BON primary, respectively.

Release	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
6/13	17	0	0	0	21	1	0	7	46
6/15	19	0	0	0	20	0	0	7	46
6/20	31	0	0	0	14	0	1	3	49
6/22	21	1	0	0	17	1	1	8	49
6/27	59	0	0	0	16	0	0	14	89
Pooled	147	1	0	0	88	2	2	39	279

Table 3.31. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for TDA Virtual Releases at Array 3J. The joint probability of survival from the TDA secondary array to BON primary array and being detected at the primary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Day of Release	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
	to 1T	1T to 2T	1T	2T	
6/13	0.848 (0.053)	1.000 (<0.0001)	0.974 (0.025)	1.000 (<0.0001)	0.436 (0.079)
6/15	0.848 (0.053)	1.000 (<0.0001)	1.000 (<0.0001)	1.000 (<0.0001)	0.487 (0.080)
6/20	0.939 (0.034)	0.978 (0.022)	1.000 (<0.0001)	1.000 (<0.0001)	0.689 (0.069)
6/22	0.838 (0.053)	0.974 (0.025)	0.950 (0.035)	1.000 (<0.0001)	0.550 (0.079)
6/27	0.843 (0.039)	1.000 (<0.0001)	1.000 (<0.0001)	1.000 (<0.0001)	0.787 (0.047)
Pooled	0.860 (0.021)	0.992 (0.006)	0.987 (0.007)	1.000 (<0.0001)	0.622 (0.031)
Arithmetic Avg.	0.863 (0.019)	0.991 (0.006)			

Table 3.32. Detection Histories in the BON Tailwater for the Virtual Releases above BON in Summer. In the table heading, a 1 denotes detected and 0 not detected at the BON primary and secondary arrays, respectively. The BON tertiary array was not available for the entire study.

Release	1 1	0 1	1 0	0 0	Total
6/13	74	53	27	41	195
6/15	88	46	24	42	200
6/20	71	40	47	34	192
6/22	58	40	64	36	198
6/27	111	12	54	18	195
6/28	117	11	50	20	198
7/1	153	6	44	29	232
7/7	113	11	63	41	228
7/11	127	5	10	41	183
7/13	101	9	32	59	201
Pooled	1013	233	415	361	2022

Table 3.33. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for Virtual Releases above BON to the Primary Array in the Tailwater. The joint probability of survival from Bonneville primary array to secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are in parentheses.

Day of Release	Survival Probability to 1B	Detection Probability to 1B	Detection and Survival (λ) to 2B
06/13	0.889 (0.041)	0.583 (0.044)	0.733 (0.044)
06/15	0.853 (0.035)	0.657 (0.041)	0.786 (0.039)
06/20	0.961 (0.045)	0.640 (0.046)	0.602 (0.045)
06/22	1.041 (0.062)	0.592 (0.050)	0.475 (0.045)
06/27	0.938 (0.024)	0.902 (0.027)	0.673 (0.037)
06/28	0.923 (0.023)	0.914 (0.025)	0.701 (0.035)
07/01	0.882 (0.022)	0.962 (0.015)	0.777 (0.030)
07/07	0.847 (0.028)	0.911 (0.026)	0.642 (0.036)
07/11	0.778 (0.031)	0.962 (0.017)	0.927 (0.022)
07/13	0.721 (0.033)	0.918 (0.026)	0.759 (0.037)
Pooled	0.869 (0.010)	0.813 (0.011)	0.709 (0.012)
Arithmetic Avg.	0.883 (0.029)	0.804 (0.052)	0.707 (0.038)

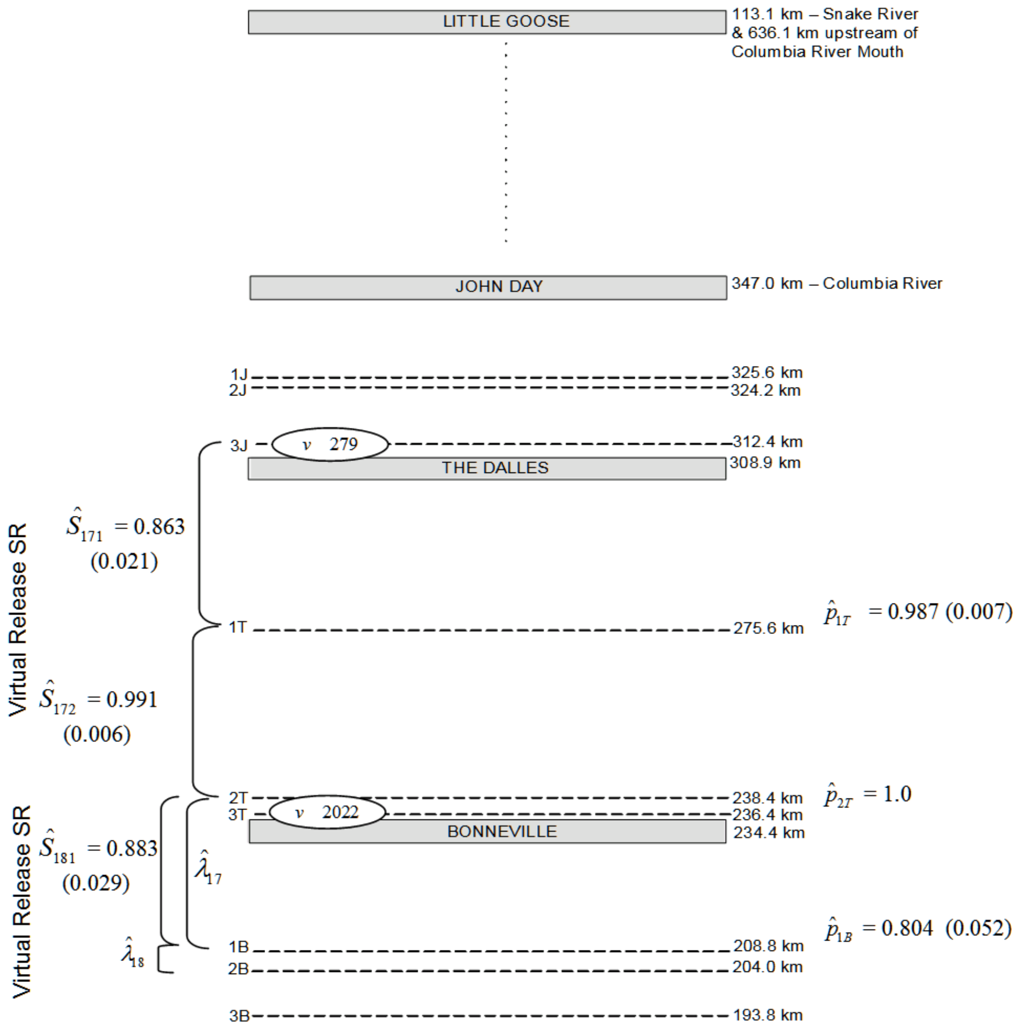


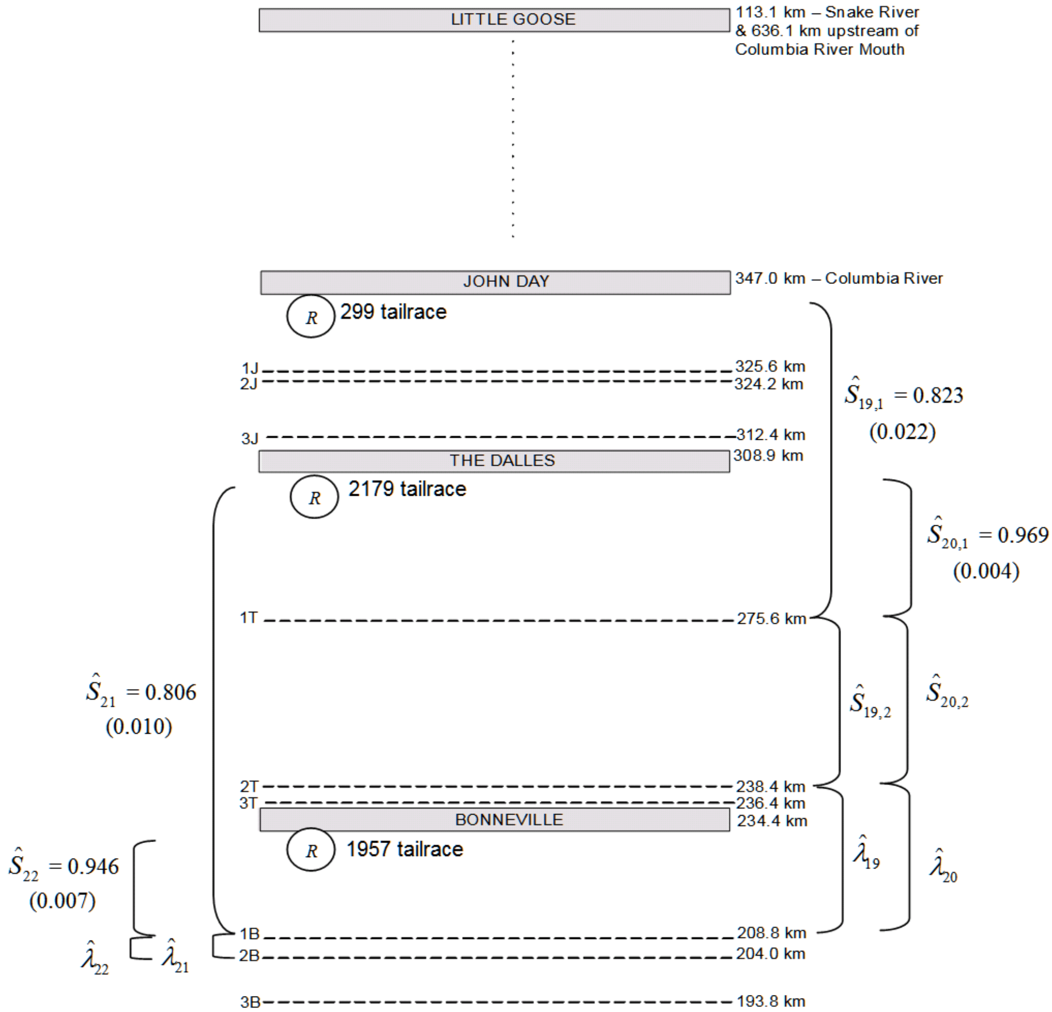
Figure 3.21. Summary of Single Release-Recapture Analysis of Virtual Releases of Subyearling Chinook Salmon from the TDA and BON Forebays

3.5.6 The Dalles and Bonneville Project Passage Survivals

Using the releases from the JDA and TDA tailraces, paired release recapture data (Table 3.34) were analyzed to estimate project passage survival at TDA, as summarized in Figure 3.22. The survival estimate through the TDA project was calculated using the reach survival estimates (Table 3.35) from each location. The most parsimonious model describing the paired release was the full CJS model (Table 3.35, Appendix F). The TDA project passage survival was estimated to be $\hat{S}_{\text{TDA}} = 0.849$ ($\widehat{\text{SE}} = 0.023$).

Table 3.34. Detection Histories for the Pooled Release Groups Used to Estimate TDA Project Survival. In the table heading, a 1 denotes detected and 0 not detected at the TDA primary and secondary arrays, and the BON primary array, respectively.

Release Site	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
JDA Tailrace	151	1	0	0	90	2	2	53	299
TDA Tailrace	1425	3	0	0	580	15	88	68	2179



Estimate $\hat{S}_{\text{TDA}} = 0.849$ (0.023) and $\hat{S}_{\text{BON}} = 0.852$ (0.013).

Figure 3.22. Summary of Single-Release Estimates of Survival that were Paired to Estimate TDA and BON Project Passage Survivals for Subyearling Chinook Salmon Smolts. Single-release estimates are adjacent to the diagram and the paired-release estimates are presented at the bottom of the diagram.

Table 3.35. Cormack-Jolly-Seber Estimates of Survival and Detection Probabilities for the Pooled Release Groups Used to Estimate TDA Project Survival. The joint probability of survival from the TDA primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses.

Release Site	Survival Probability		Detection Probability		Detection and Survival (λ) to 1B
	to 1T	1T to 2T	1T	2T	
JDA Tailrace	0.823 (0.022)	0.992 (0.006)	0.988 (0.007)	1.000 (<0.0001)	0.623 (0.031)
TDA Tailrace	0.969 (0.004)	0.958 (0.004)	0.991 (0.002)	1.000 (<0.0001)	0.706 (0.010)

The Dalles and BON Tailrace releases (Figure 3.22) were used to generate capture histories (Table 3.36) to estimate BON project passage survival. The individual release locations generated reach survivals (Table 3.37) that were then modeled to find the best parsimonious description of the data. In this case, the project passage survival estimate was $\hat{S}_{\text{BON}}$ = 0.852 ($\widehat{\text{SE}}$ = 0.013) based upon the fully parameterized model $M_{S_1, p_1, \lambda}$ (Appendix F), which best described the data.

Table 3.36. Detection Histories for the Pooled Release Groups Used to Estimate BON Project Survival. In the table heading, a 1 denotes detected and 0 not detected at BON primary and secondary arrays, respectively. The BON tertiary array was not available for the entire study.

Release Site	1 1	0 1	1 0	0 0	Total
TDA Tailrace	1013	233	415	518	2179
BON Tailrace	1236	265	289	167	1957

Table 3.37. Cormack-Jolly-Seber Single-Release Estimates of Survival and Detection Probabilities for the Pooled Release Groups Used to Estimate BON Project Survival. The joint probability of survival from the BON primary array to the secondary array and being detected at the secondary array (λ) is reported in the last column. Standard errors are reported in parentheses. This is also the most appropriate paired-release model. BON tertiary array was not available for the entire study.

Release Site	Survival Probability to 1B	Detection Probability 1B	Detection and Survival (λ) to 2B
TDA Tailrace	0.806 (0.010)	0.813 (0.011)	0.709 (0.012)
BON Tailrace	0.946 (0.007)	0.824 (0.010)	0.811 (0.010)

3.5.7 Tests of Assumptions

3.5.7.1 Assignment of Mixing

The JDA and TDA Tailrace releases used to estimate project survival at TDA again showed significant ($P < 0.001$) and apparently appreciable departures from mixing (Appendix G, Figure G.1) primarily because releases after 6/27 in the TDA Tailrace had no treatment counterparts (Figure 3.23). For the period of mostly concurrent paired releases, divergence in the two lines could be explained by differences in the numbers of fish released at each location and not by differences in arrival date, because travel times to Array 1T were very consistent (Figure 3.23). We reran the paired release survival estimate using data acquired during the period of concurrent releases, and the resulting survival estimates [0.830 ($\widehat{\text{SE}}$ = 0.022)] did not differ significantly from the estimate based upon all acquired data [0.852 ($\widehat{\text{SE}}$ = 0.013)]. Within days, for same-day releases, the average minimum, mean, and maximum detection hours for JDA Tailraces releases on 1T were 2.8, 15.1, and 21.8 hours compared with 0.8, 10.6, and 23.0 hours for TDA releases. In short, the slowest and fastest fish from either release group could show up at Array 1T almost any time of day, but on average, there was about a four-hour difference in the average arrival hour in summer.

Comparison of the TDA and BON Tailrace releases used to estimate project survival at BON indicated that all but two reference releases and one treatment release at the end of summer occurred on concurrent dates (Appendix G, Figure G.2). We reran the paired release survival estimate using only data acquired during the period of concurrent releases and the resulting survival estimates [0.837 ($\widehat{\text{SE}}$ = 0.015)] did not differ significantly from the estimate based upon all of the acquired data [0.849 ($\widehat{\text{SE}}$ = 0.0230)]. Close inspection revealed that BON releases usually were detected on the same day as treatment-released fish because travel times were quite consistent (Figure 3.24). In addition, within days fish from both release locations were detected at Array 1B at about the same time of day in summer. The average arrival hour at Array 1B for the TDA Tailrace releases was 1040 ($\widehat{SE}$ = 6 hours), and for BON releases, it was 0913 ($\widehat{SE}$ = 2.2 hours). Therefore, fish in summer releases from TDA and BON Tailraces should have been well mixed as they traversed the BON Tailwater at about the same time of day.

3.5.7.2 Goodness of Fit

Burnham et al. (1987) Tests 2 and 3 were performed on the JDA and TDA Tailrace releases (Appendix G, Tables G.1 and G.2). Test 2 could not be performed because of the high recapture probabilities at 2T. One of the Test 3's was significant at $P < 0.0001$, indicating capture history to 2T had an effect on detection at the 1B array.

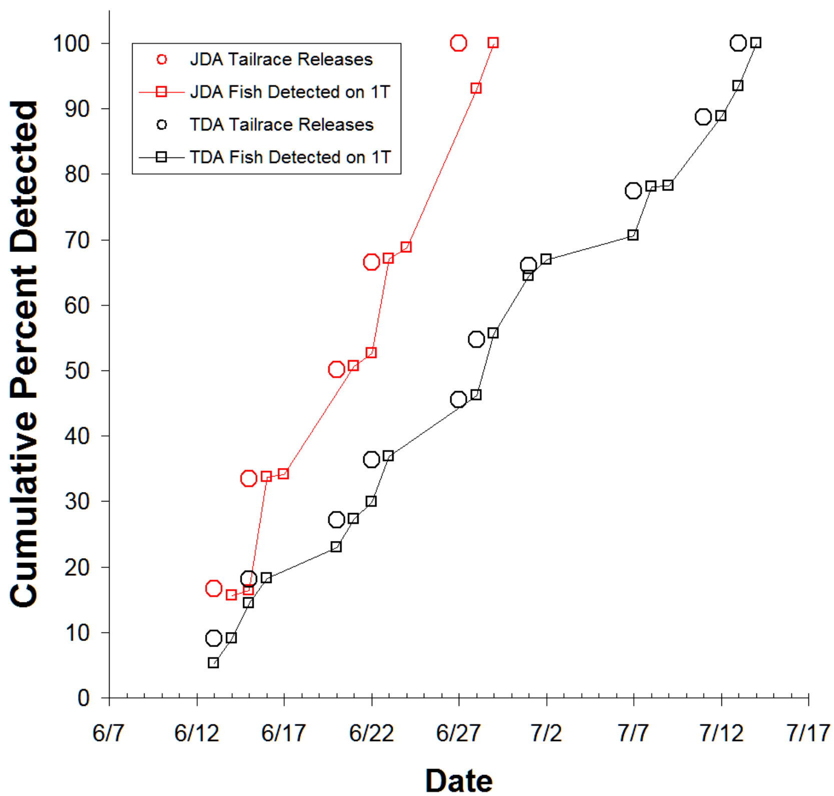


Figure 3.23. Plot of Dates of Release and Detections on Array 1T for Tagged Fish Released in the JDA Tailrace and TDA Tailrace

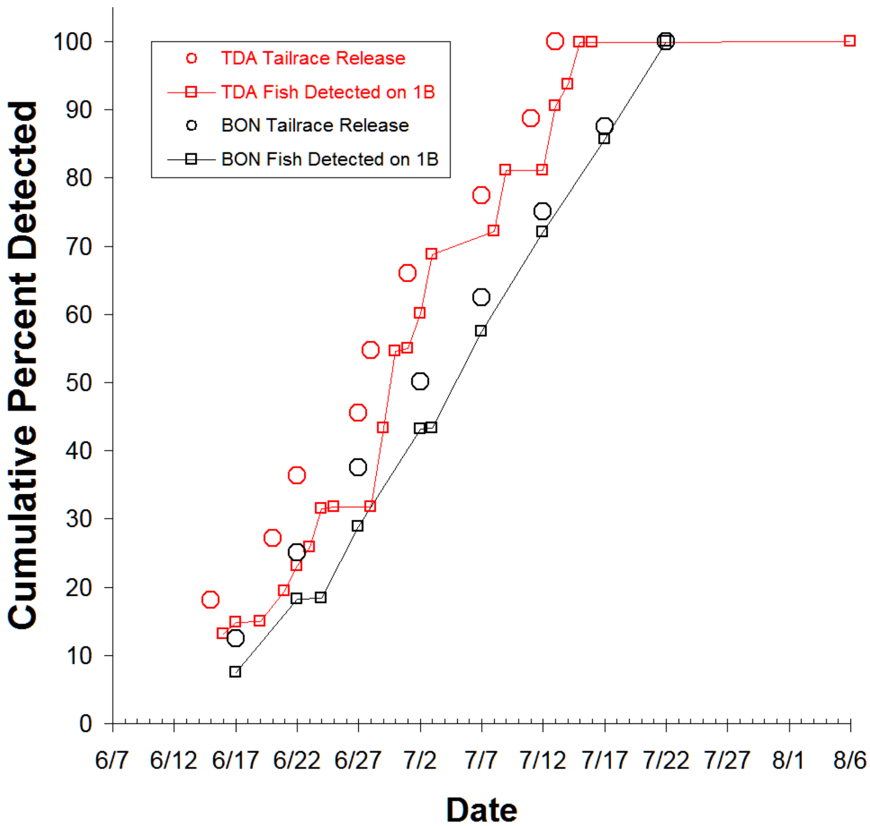


Figure 3.24. Plot of Dates of Release and Detections on Array 1B for Tagged Fish Released in the TDA Tailrace and BON Tailrace

3.5.8 Survival through Successive Reaches

We made estimates of survival for subyearling Chinook salmon from the point of release to each successive array in our study area, except the last reach (Figure 3.25). We released subyearlings in the JDA and TDA Tailraces, and the Lower Monumental and Columbia River Estuary studies released subyearlings into the Little Goose and BON Tailraces. Survival statistics were calculated using a single release model and detections for the array of interest two successive arrays immediately downstream, except for Array 1B estimates, which were based upon detections on two arrays. What is not indicated in the figure is the length of each reach, which was highly variable (see Figure 3.22). Obviously, the fish from the Little Goose Tailrace release had the farthest to travel to reach the first survival array at 1J.

3.5.9 Bonneville Route-Specific Survival (Pooled Releases)

We estimated detection probabilities and survival for subyearling Chinook salmon based on the population of all tagged fish detected at three sites while passing through BON, regardless of where the fish were originally released. Release sites that contributed fish to the detections included the LGR Tailrace, JDA Intake 9C, JDA Front Roll, JDA Tailrace, and TDA Tailrace. The pooled release groups included fish from the LGS Tailrace, the JDA Tailrace, and the TDA Tailrace.

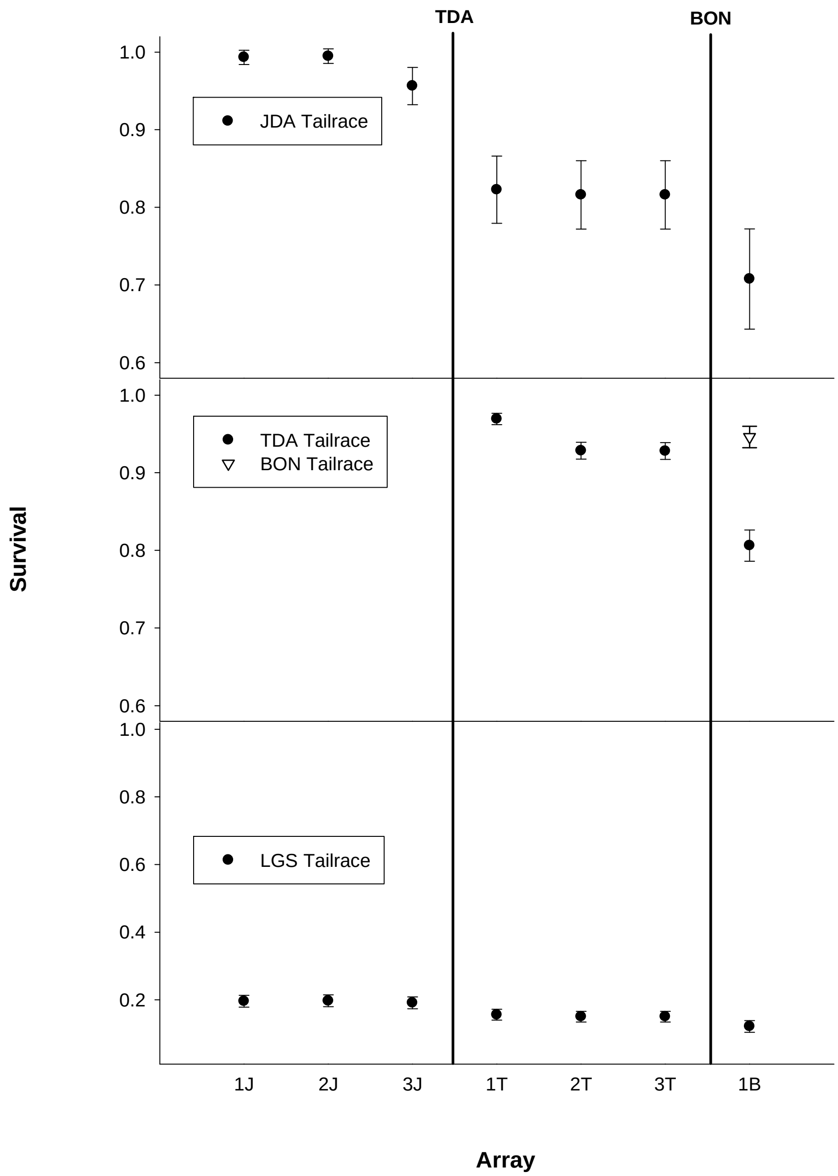


Figure 3.25. Summer Survival for Subyearling Chinook Salmon from Release Location to Each Successive Array, Except the Last. Vertical bars are 95% confidence intervals.

3.5.9.1 Spillway, B2 JBS, and B2CC

During summer, we estimated survival of fish passing several routes through BON. Tagged fish were detected by an array of autonomous acoustic hydrophones and dam-mounted hydrophones in the spillway forebay and by PIT tag detectors at the B2CC and the B2 JBS. Using data from the primary and secondary arrays below BON, pooled survival estimates and detection probabilities were calculated for each route (Table 3.38). The survival estimate for fish passing the B2CC was highest (95.2%), followed by the estimate for B2 JBS-passed fish (90.7%), and then by the estimate for spillway-passed fish (85.8%). Based upon non-overlap of 95% confidence limits calculated from standard errors listed in Table 3.38 (i.e., 95% CI = $\widehat{SE}$ x 1.96), estimates for the B2CC and the spillway could be significantly different, but the B2CC did not differ from the B2 JBS estimate and the B2 JBS estimate did not differ from the spillway estimate.

Table 3.38. Single-Release Survival and Detection Probabilities for Subyearling Chinook Salmon based on Pooled Releases from All Upstream Sites for Specific Passage Routes. Standard errors are in parentheses.

Route of Passage	Survival Probability	Detection Probability	Detection and Survival (λ) to	Number Detected by
	To 1B	1B	2B	Route
B2CC	0.952 (0.031)	0.877 (0.041)	0.750 (0.050)	91
B2 JBS	0.907 (0.031)	0.823 (0.036)	0.660 (0.040)	189
Spillway	0.858 (0.017)	0.822 (0.019)	0.808 (0.033)	706

We also calculated paired release estimates for the three passage routes in summer by dividing the single-release estimates in Table 3.38 by the pooled estimate for the BON Tailrace release in summer (0.946 ± 0.007 SE). Paired-release estimates ± standard errors were as follows: B2CC Survival = 100.6% [1/2 95% CI = 94.0, 107.2]; B2 JBS Survival = 95.9% [1/2 95% CI = 89.3, 102.4]; and B2 Spillway Survival = 90.6 % [1/2 95% CI = 86.9, 94.4]. The 95% confidence intervals had a lot of overlap for the B2CC and B2JBS and for the B2 JBS and spillway, but only slight overlap for the B2CC and spillway.

3.5.9.2 Spillway Survival by Spill Condition

In summer, when more tagged fish were detected passing the spillway, we calculated spillway survival for three periods that had different diel spill regimes (Figure 3.26). The first regime was 24-hour spill to the gas cap (94 to 149 kcfs from June 14 through June 25); the second regime was 24-hour low spill ranging from 63 to 83 kcfs (June 26 through July 5); the third regime was 75 kcfs day spill and spill to the gas cap at night after July 6. The detection array in the spillway forebay was operational for the entire summer season and consisted of five cabled nodes on piers and four autonomous nodes in the forebay. Both of these arrays were used to establish the population of tagged fish for detection and survival calculations.

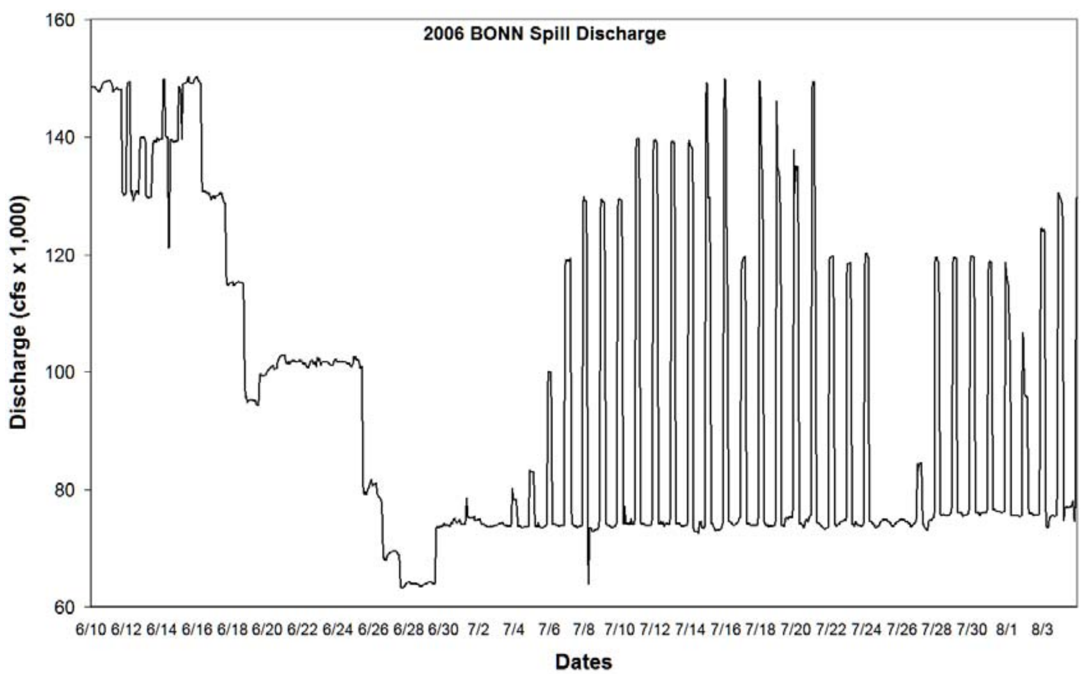


Figure 3.26. Spill Pattern during Summer 2006

After July 6, survival estimates for day (80%) and night (76%) did not differ significantly (Table 3.39), even though spill levels clearly were different (Figure 3.26). Therefore, we calculated a pooled survival estimate for fish passing the spillway during the day or night after July 6 and compared that estimate with estimates for the two other spill conditions (Table 3.40). Survival during the 24-hour gas cap condition was significantly higher than survival during the Biop-spill treatment (75 kcfs day; gas cap night), but the former condition occurred early in summer and the latter in late summer. There was a significant decline in survival of subyearling fish from LGS passing from Array 1J to 1T, TDA Tailrace subyearlings passing through the TDA Tailwater, TDA Tailrace fish passing through all routes through BON Project, and all subyearlings in the BON virtual releases (Figure 3.27).

Table 3.39. Single-Release Survival and Detection Probabilities for Subyearling Chinook Salmon Passing the BON Spillway after July 5 during the Day and Night Periods based on Pooled Releases from All Upstream Sites. Standard errors are in parentheses.

	Survival Probability	Detection Probability	Detection and Survival (λ) to	Number Detected by
Time	**To 1B**	**1B**	**2B**	**Condition**
Day	0.800 (0.034)	0.860 (0.034)	0.653 (0.040)	205
Night	0.758 (0.047)	0.982 (0.018)	0.828 (0.047)	86

Table 3.40. Single-Release Survival and Detection Probabilities for Subyearling Chinook Salmon Passing the BON Spillway and Released in the Bonneville Tailrace during Three Periods with Different Spill Conditions. The estimates were based on spillway-detected fish regardless of release location upstream or date unless a BON Tailrace release is indicated. Standard errors are in parentheses.

Spill-passed during Condition	Survival Probability	Detection Probability	Detection and Survival (λ) to	Number Detected by Condition
	To 1B	1B	2B	
24 h gas cap spill	0.960 (0.038)	0.670 (0.042)	0.669 (0.042)	193
BON Tailrace release during 24 h gas cap spill	0.990 (0.040)	0.579 (0.038)	0.681 (0.040)	490
Spill-passed during 24 h low spill	0.878 (0.027)	0.867 (0.028)	0.734 (0.034)	222
BON Tailrace release during 24 h low spill	0.982 (0.016)	0.790 (0.026)	0.838 (0.027)	490
Spill-passed during 75 kcfs day and gas-cap night spill	0.782 (0.027)	0.901 (0.024)	0.707 (0.032)	291
BON Tailrace during 75 kcfs day and gas-cap night spill	0.936 (0.017)	0.946 (0.016)	0.840 (0.024)	977

After dividing the single-release estimates for spilled fish by single-release estimates for the BON Tailrace releases for the same time periods (Table 3.40), we obtained the following paired-release survival estimates and ½ 95% CIs (in parentheses after the survival estimate) for each spill condition:

Condition	Survival
24 h gas cap spill	0.970 (0.863, 1.076)
24 h low spill	0.894 (0.834, 0.954)
75 kcfs day and gas cap night spill	0.836 (0.773, 0.899)

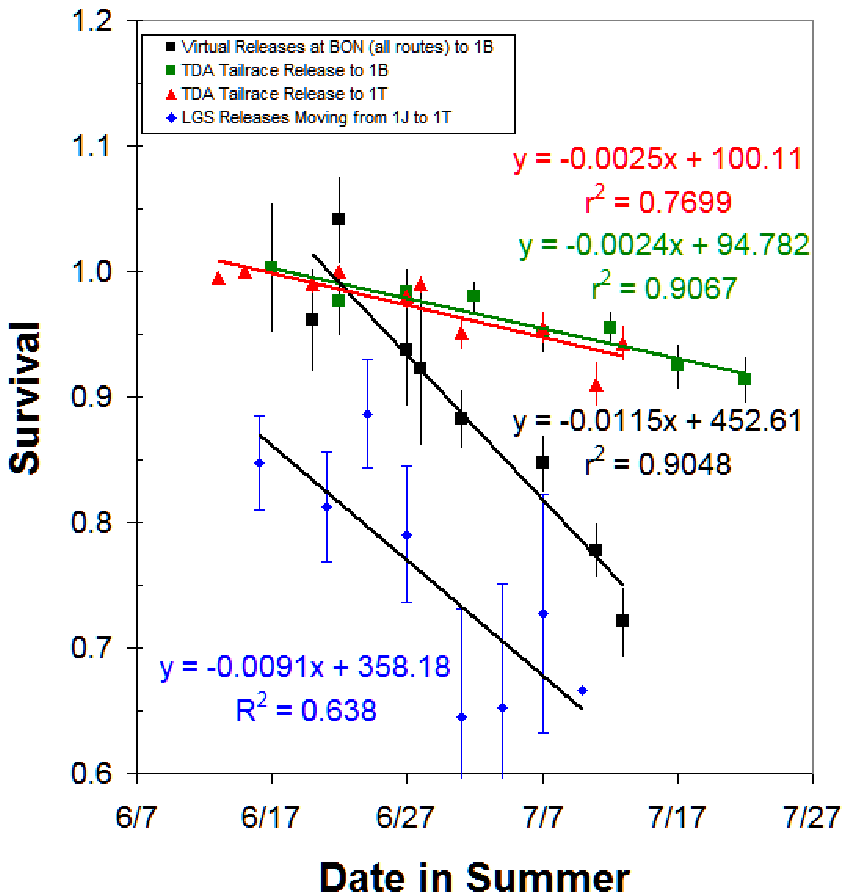


Figure 3.27. Trends in Survival during Summer 2006

3.6 Comparison of Estimates Using Preferred Versus As-Planned Arrays

In this section, we compare survival estimates calculated from detection data using different choices for secondary or tertiary arrays. Given the number of arrays deployed, there were choices for the arrays to be used as secondary or tertiary arrays in calculations for arrays upstream of Array 2B in the BON Tailwater. The most independent primary, secondary, and tertiary arrays based upon long intervening river reaches were considered to be "preferred arrays," and estimates from those arrays were compared with estimates from "as planned" arrays deployed in the same pool as the primary array. Survival and detection probability estimates based on the two approaches did not differ significantly in spring (Table 3.41 and Table 3.42) or summer (Table 3.43 and Table 3.44). A full list of detection frequencies and associated detection and survival estimates for as-planned arrays are presented in Appendix H.

Table 3.41. Uncorrected Cormack-Jolly-Seber Estimates of Survival Probabilities Calculated from Preferred and As-Planned Arrays in Spring. Standard errors (SE) in parenthesis that allow survival to overlap between the two estimate types were not considered to differ significantly. Differences in estimates are flagged with an * in the last column (Diff = difference).

Releases	Reach	Model	Preferred Arrays	Survival Estimates	As Planned Arrays	Survival Estimates	Diff
LGR TR	LGR TR to 1J	S	1J, 1T, 2T	0.487 (0.016)	1J, 2J, 3J	0.481 (0.016)	
9C	9C to 1J	S	1J, 1T, 2T	0.876 (0.015)	1J, 2J, 3J	0.863 (0.015)	
JDA FR	FR to 1J	S	1J, 1T, 2T	0.983 (0.006)	1J, 2J, 3J	0.980 (0.006)	
JDA TR	TR to 1J	S	1J, 1T, 2T	0.974 (0.007)	1J, 2J, 3J	0.967 (0.008)	
JDA FR & JDA TR	FR - TR	P	1J, 1T, 2T	1.009 (0.019)	1J, 2J, 3J	1.014 (0.021)	
JDA 9C & JDA TR	9C - TR	P	1J, 1T, 2T	0.898 (0.033)	1J, 2J, 3J	0.892 (0.035)	
JDA 9C & JDA FR	9C - FR	P	1J, 1T, 2T	0.892 (0.032)	1J, 2J, 3J	0.880 (0.033)	
TDA TR	TR to 1T	S	1T, 2T, 1B	0.989 (0.003)	1T, 2T, 3T	0.989 (0.003)	
TDA TR	1T to 2T	S	2T, 1B	0.992 (0.004)	2T, 3T	0.993 (0.003)	
JDA TR & TDA TR	JDA to 1T	P	1T, 2T, 1B	0.928 (0.013)	1T, 2T, 3T	0.928 (0.013)	
Virtual TDA	3J to 1T	VS	1T, 2T, 1B	0.947 (0.007)	1T, 2T, 3T	0.954 (0.011)	
Virtual TDA	1T to 2T	VS	2T, 1B	0.979 (0.005)	2T, 3T	0.988 (0.006)	

* TR – Tailrace; S – Single Release; FR – Front roll; P – Paired Release; 9C – Turbine Intake 9C; VS – Virtual Single Release; LGR – Lower Granite Dam.

Table 3.42. Uncorrected Cormack-Jolly-Seber Estimates of Detection Probabilities Calculated from Preferred and As-Planned Arrays in Spring. Standard errors (SE) in parenthesis that allow survival to overlap between the two estimate types were not considered to differ significantly. Differences in estimates are flagged with an * in the last column (Diff = difference).

Releases	Reach	Model	Preferred Arrays	Detection Probability Estimates	As Planned Arrays	Detection Probability Estimates	Diff
LGR TR	LGR TR to 1J	S	1J, 1T, 2T	0.896 (0.015)	1J, 2J, 3J	0.907 (0.014)	
9C	9C to 1J	S	1J, 1T, 2T	0.961 (0.010)	1J, 2J, 3J	0.976 (0.008)	
9C	9C to 1J	S	1J, 1T, 2T	0.989 (0.005)	1J, 2J, 3J	0.991 (0.004)	
JDA FR	FR to 1J	S	1J, 1T, 2T	0.977 (0.007)	1J, 2J, 3J	0.985 (0.006)	
JDA TR	TR	S	1J, 1T, 2T	0.983 (0.004)	1J, 2J, 3J	0.988 (0.004)	
JDA FR & JDA TR	FR - TR	P	1J, 1T, 2T	0.969 (0.006)	1J, 2J, 3J	0.981 (0.005)	
JDA 9C & JDA TR	9C - TR	P	1J, 1T, 2T	0.961 (0.010) 0.989 (0.005)	1J, 2J, 3J	0.976 (0.008) 0.991 (0.004)	
TDA TR	9C - FR	P	1T, 2T	0.975 (0.005)	1J, 2J, 3J	0.975 (0.005)	
TDA TR	TR to 1T	S	2T, 1B	0.995 (0.003)	2T, 3T	0.994 (0.003)	
TDA TR	1T to 2T	S	2T, 1B	0.934 (0.012) 0.975 (0.005)	2T, 3T	0.933 (0.0036)	
JDA TR & TDA	3J to 1T	P	1T, 2T, 1B	0.930 (0.008)	1T, 2T, 3T	0.936 (0.013)	
Virtual TDA	3J to 1T	VS	2T, 1B	0.9300 (0.008)	2T, 3T	0.9363 (0.0139)	
Virtual TDA	1T to 2T	VS	2T, 1B	1.000 (<0.0001)	2T, 3T	1.000 (<0.0001)	

* TR – Tailrace; S – Single Release; FR – Front roll; P – Paired Release; 9C – Turbine Intake 9C; VS – Virtual Single Release; LGR – Lower Granite Dam.

Table 3.43. Uncorrected Cormack-Jolly-Seber Estimates of Survival Probabilities Calculated from Preferred and As-Planned Arrays in Summer. Standard errors (SE) in parenthesis that allow survival to overlap between the two estimate types were not considered to differ significantly. Differences in estimates are flagged with an * in the last column (Diff = difference).

Releases	Reach	Model	Preferred Arrays	Survival Estimates	As Planned Arrays	Survival Estimates	Diff
LGS TR	LGS TR to 1J	S	1J, 1T, 2T	0.196 (0.056)	1J, 2J, 3J	0.196 (0.009)	
JDA TR	TR to 1J	S	1J, 1T, 2T	0.994 (0.005)	1J, 2J, 3J	0.993 (0.005)	
TDA TR	TR to 1T	S	1T, 2T, 1B	0.969 (0.004)	1T, 2T, 3T	0.969 (0.004)	
TDA TR	1T to 2T	S	2T, 1B	0.958 (0.004)	2T, 3T	0.958 (0.004)	
JDA TR & TDA TR	JDA to 1T	P	1T, 2T, 1B	0.849 (0.023)	1T, 2T, 3T	0.849 (0.023)	
Virtual TDA	3J to 1T	VS	1T, 2T, 1B	0.860 (0.021)	1T, 2T, 3T	0.860 (0.021)	
Virtual TDA	1T to 2T	VS	2T, 1B	0.992 (0.006)	2T, 3T	0.992 (0.006)	
* TR – Tailrace; S – Single Release; FR – Front roll; P – Paired Release; 9C – Turbine Intake 9C; VS – Virtual Single Release; LGS – Little Goose Dam.							

Table 3.44. Uncorrected Cormack-Jolly-Seber Estimates of Detection Probabilities Calculated from Preferred and As-Planned Arrays in Summer. Standard errors (SE) in parenthesis that allow survival to overlap between the two estimate types were not considered to differ significantly. Differences in estimates are flagged with an * in the last column (Diff = difference).

Releases	Reach	Model	Preferred Arrays	Detection Probability Estimates	As Planned Arrays	Detection Probability Estimates	Diff
LGS TR	LGS TR to 1J	S	1J, 1T, 2T	0.947 (0.013)	1J, 2J, 3J	0.945 (0.012)	
JDA TR	TR to 1J	S	1J, 1T, 2T	0.996 (0.004)	1J, 2J, 3J	0.997 (0.003)	
TDA TR	TR to 1T	S	1T, 2T, 1B	0.991 (0.002)	1T, 2T, 3T	0.991 (0.002)	
TDA TR	1T to 2T	S	2T, 1B	1.000 (<0.0001)	2T, 3T	1.000 (<0.0001)	
JDA TR & TDA TR	JDA to 1T	P	1T, 2T, 1B	0.988 (0.007) 0.991 (0.002)	1T, 2T, 3T	0.988 (0.007) 0.991 (0.002)	
Virtual TDA	3J to 1T	VS	1T, 2T, 1B	0.987 (0.007)	1T, 2T, 3T	0.987 (0.007)	
Virtual TDA	1T to 2T	VS	2T, 1B	1.000 (<0.0001)	2T, 3T	1.000 (<0.0001)	
* TR – Tailrace; S – Single Release; FR – Front roll; P – Paired Release; 9C – Turbine Intake 9C; VS – Virtual Single Release; LGS – Little Goose Dam.							

3.7 Travel Time and Rate

3.7.1 Spring

Yearling Chinook salmon smolts from six different release locations were detected on 11 arrays of acoustic nodes deployed below JDA, TDA, and BON. Four of these release locations were for this study and two were for other studies. For simplicity, we present statistics on travel time and rate of passage through dam projects.

3.7.1.1 LGR Releases

Yearling Chinook salmon smolts were also released from the LGR Tailrace as part of the Tag Effects project and we used the time of release and time of detection at Array 1J to estimate the median travel time, rate, and distance from LGR through JDA to the first survival array (1J; Table 3.45). Median travel time from LGR was 8.9 days to Array 1J, 9.5 days to Array 1T, and 10.2 days to Array 1B. This was much shorter than the expected 55-day tag life for these 10 s tags.

Table 3.45. Median Hours, Rate, and Distance of Travel from LGR Tailrace Release to Primary Arrays Below Each Project in Spring. Values after the ± signs are one-half 95% confidence limits.

Array	Time (hours)	Rate (m/s)	n	Distance (km)
1J	212.6 ± 4.6	0.48 ± 0.01	434	369.4
1T	228.6 ± 5.6	0.51 ± 0.01	327	419.4
1B	245.8 ± 9.2	0.55 ± 0.03	152	486.2

3.7.1.2 JDA Releases

Fish released into the tailrace arrived at the egress array faster than turbine-passed and front roll fish because they moved faster and had less distance to travel (Table 3.46). Front-roll fish also traveled faster than turbine-released fish to the egress array, although the distance traveled was only 110 m shorter than for turbine-released fish. The median rate of travel of LGR-released fish from Array 3T through TDA Dam to Array 1T was significantly faster than the rate for JDA turbine, front roll, and tailrace fish (Table 3.47).

Table 3.46. Median Hours, Rate, and Distance of Travel from Release Site at JDA to the JDA Egress Array in Spring. Values after the ± signs are one-half 95% confidence limits.

Release Site	Time (hours)	Rate (m/s)	n	Distance (km)
JDA Intake 9C	1.3 ± 0.1	1.7 ± 0.02	421	7.75
JDA Front Roll	1.2 ± 0.02	1.8 ± 0.02	444	7.64
JDA Tailrace	0.8 ± 0.2	1.9 ± 0.1	460	5.14

Table 3.47. Median Hours, Rate, and Distance of Travel from Array 3J to Array 1T through the TDA Project in Spring. Values after the ± signs are one-half 95% confidence limits.

Release Site	Time (hours)	Rate (m/s)	n	Distance (km)
LGR Tailrace	10.2 ± 1.7	1.0 ± 0.03	175	36.75
JDA Intake 9C	12.8 ± 0.4	0.8 ± 0.02	241	36.75
JDA Front Roll	12.2 ± 4.3	0.8 ± 0.02	299	36.75
JDA Tailrace	12.3 ± 0.4	0.8 ± 0.02	301	36.75

3.7.1.3 TDA Releases

We estimated travel time and rate for three parts of the passage journey through BON. First, we estimated the travel statistics for the entire trip from Array 3T above BON forebays and Boat Rock down to Array 1B in the tailwater (Table 3.48). Fish from LGR moved faster and took less time than other releases. Second, we estimated travel statistics for the first leg of the trip from Array 3T above Boat Rock to the point of detection for the three routes of passage. Times and rates were similar for spillway and B2CC-passed fish (mean time = 0.4 hours), but there was an obvious delay until detection of fish passing through the JBS (mean time= 4.9 hours; Table 3.49). Third, we estimated statistics from the point of passage detection down to Array 1B, and in most cases, travel time estimates did not differ based upon overlapping 95% CIs (mean = 7.7 hours; Table 3.50). The median rate of travel for LGR releases was lower than that of other releases passing through the B2CC and B2 JBS, although overlapping 95% CIs suggest that differences were not significant.

Table 3.48. Median Hours, Rate, and Distance of Travel through BON (from Array 3T to 1B) in Spring. Values after the ± signs are one-half 95% confidence limits.

Release Site	Time (hours)	Rate (m/s)	n	Distance (km)
LGR Tailrace	5.9 ± 0.5	1.3 ± 0.05	122	27.6
JDA Intake 9C	6.7 ± 1.5	1.2 ± 0.04	225	27.6
JDA Front Roll	6.7 ± 1.4	1.1 ± 0.04	251	27.6
JDA Tailrace	6.5 ± 0.7	1.29 ± 0.04	243	27.6
TDA Tailrace	7.0 ± 1.3	1.1 ± 0.02	557	27.6

Table 3.49. Spring Median Hours, Rate, and Distance of Travel from Array 3T Immediately above Boat Rock and BON Forebays to Specific Routes of Passage in Spring. Values after the ± signs are one-half 95% confidence limits.

Release Site	Route	Time (hours)	Rate (m/s)	n	Distance (km)
JDA Intake 9C	Array 3T to Spillway	0.4± 0.1	0.8 ± 0.18	10	1.2
JDA Front Roll	Array 3T to Spillway	0.4 ± 0.1	0.8 ± 0.12	25	1.2
JDA Tailrace	Array 3T to Spillway	0.4 ± 0.1	0.8 ± 0.13	21	1.2
TDA Tailrace	Array 3T to Spillway	0.4 ± 0.1	0.8 ± 0.08	75	1.2
LGR Tailrace	Array 3T to B2CC	0.3 ± 0.1	1.2 ± 0.21	19	1.5
JDA Intake 9C	Array 3T to B2CC	0.3 ± 0.1	1.1 ± 0.16	7	1.5
JDA Front Roll	Array 3T to B2CC	0.3 ± 0.04	1.1 ± 0.13	8	1.5
JDA Tailrace	Array 3T to B2CC	0.3 ± 0.1	1.2 ± 0.13	13	1.5
TDA Tailrace	Array 3T to B2CC	0.4 ± 0.1	0.8 ± 0.16	28	1.5
LGR Tailrace	Array 3T to B2 JBS	4.6 ± 2.1	0.1 ± 0.06	23	3.6
JDA Intake 9C	Array 3T to B2 JBS	5.7 ± 2.4	0.1 ± 0.05	31	3.6
JDA Front Roll	Array 3T to B2 JBS	7.1 ± 4.6	0.1 ± 0.05	26	3.6
JDA Tailrace	Array 3T to B2 JBS	4.7 ± 3.7	0.1 ± 0.06	22	3.6
TDA Tailrace	Array 3T to B2 JBS	2.7 ± 1.5	0.12 ± 0.03	61	3.6

Table 3.50. Median Hours, Rate, and Distance of Travel from Detection at Specific Routes to Array 1B below BON in Spring. Values after the ± signs are one-half 95% confidence limits.

Release Site	Route	Time (hours)	Rate (m/s)	n	Distance (km)
JDA Intake 9C	Spillway to 1B	6.2 ± 2.2	1.2 ± 0.28	6	26.4
JDA Front Roll	Spillway to 1B	7.1 ± 2.0	1.0 ± 0.15	12	26.4
JDA Tailrace	Spillway to 1B	7.2 ± 1.6	1.1 ± 0.15	14	26.4
TDA Tailrace	Spillway to 1B	6.6 ± 4.9	1.1 ± 0.08	46	26.4
LGR Tailrace	B2CC to 1B	7.7 ± 0.2	1.0 ± 0.03	7	26.2
JDA Intake 9C	B2CC to 1B	8.2 ± 3.7	0.9 ± 0.25	5	26.2
JDA Front Roll	B2CC to 1B	7.8 ± 1.7	0.9 ± 0.14	5	26.2
JDA Tailrace	B2CC to 1B	10.1 ± 3.2	0.7 ± 0.15	8	26.2
TDA Tailrace	B2CC to 1B	8.4 ± 0.8	0.9 ± 0.06	19	26.2
LGR Tailrace	B2JBS to 1B	7.1 ± 0.4	1.0 ± 0.05	9	24.0
JDA Intake 9C	B2JBS to 1B	7.5 ± 0.4	1.0 ± 0.04	31	24.0
JDA Front Roll	B2JBS to 1B	8.5 ± 2.3	0.9 ± 0.12	12	24.0
JDA Tailrace	B2JBS to 1B	7.5 ± 0.5	1.0 ± 0.06	12	24.0
TDA Tailrace	B2JBS to 1B	8.1 ± 0.3	0.9 ± 0.03	36	24.0

3.7.1.4 BON Releases

As smolts released in the SMF outfall passed downstream, they were detected on all BON arrays so we could calculate travel time and rate for fish traversing each reach below the BON Tailrace (Table 3.51). Based on median travel times from the tailrace, fish took about 7.8 hours to reach Array 1B, another 1.4 hours to reach Array 2B, and another 2.2 hours to reach Array 3B. The rate of travel was fastest for the long uppermost reach and decreased for each successive reach downstream.

Table 3.51. Median Hours, Rate, and Distance of Travel from the BON Tailrace to Array 1B, from Array 1B to 2B, and from Array 2B to 3B in Spring. Values after the ± signs are one-half 95% confidence limits.

Array	Time (hours)	Rate (m/s)	n	Distance (km)
1B	7.8 ± 0.7	0.9 ± 0.02	628	24.0
2B	1.4 ± 0.3	0.9 ± 0.03	470	4.8
3B	2.2 ± 0.6	1.3 ± 0.04	286	10.2

3.7.1.5 Pooled Releases

Using all arrays throughout the projects, total cumulative travel time was then measured and results are as follows (Figure 3.28).

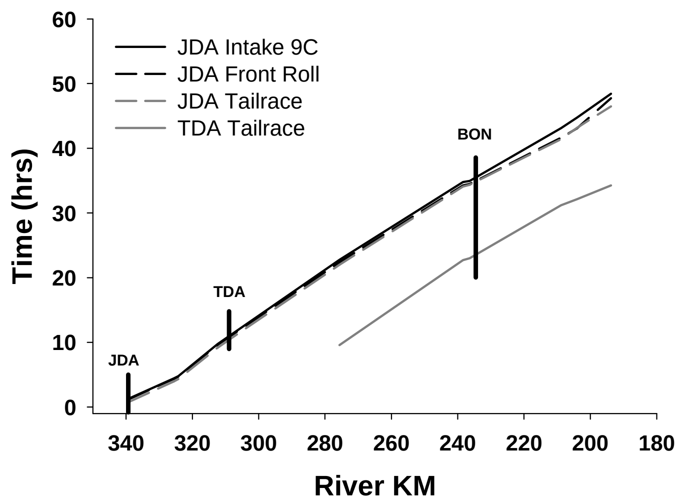


Figure 3.28. Median Time of Travel from Release Point through the Last Array in Spring 2006

3.7.2 Summer

3.7.2.1 LGS Releases

Subyearling Chinook salmon released in the LGS Tailrace as part of the Lower Monumental acoustic telemetry study had a median travel time of about 8.92 days to Array 1J, 9.92 days to Array 1T, and 11.2 days to Array 1B (Table 3.52). Rates of travel did not differ among the three reaches based on overlapping 95% CIs.

Table 3.52. Median Hours, Rate, and Distance of Travel from LGS Tailrace Release to Primary Arrays Below Three Projects in Summer. Values after the ± signs are one-half 95% confidence limits.

To Array	Time (hours)	Rate (m/s)	n	Distance (km)
1J	213.8 ± 10.1	0.4 ± 0.01	361	303.4
1T	238.0 ± 10.7	0.4± 0.01	302	353.4
1B	268.9 ± 10.7	0.4± 0.03	149	429.2

3.7.2.2 JDA Releases

The median travel time of JDA Tailrace-released fish to Array 1J was only 4.7 hours, and the speed of fish traveling from the JDA Tailrace to Array 1J was faster than that of fish moving from Array 3J above TDA downstream to Array 1T in the TDA Tailwater (Table 3.53 and Table 3.54).

Table 3.53. Median Hours, Rate, and Distance of Travel from the JDA Tailrace Release Site to Array 1J in Summer. Values after the ± signs are one-half 95% confidence limits.

Release Site	Time (hours)	Rate (m/s)	n	Distance (km)
JDA Tailrace	4.7 ± 0.2	1.1 ± 0.02	296	18.8

Table 3.54. Median Hours, Rate, and Distance of Travel from Array 3J through TDA to Array 1T in Summer. Values after the ± signs are one-half 95% confidence limits.

Release Site	Time (hours)	Rate (m/s)	n	Distance (km)
LGS Tailrace	13.2 ± 0.8	0.8 ± 0.02	286	36.8
JDA Tailrace	14.4 ± 1.7	0.7 ± 0.02	232	36.8

3.7.2.3 TDA Releases

We estimated travel time and rate for three parts of the passage journey through BON. First, we estimated the travel statistics for the entire trip from Array 3T above BON forebays and Boat Rock down to Array 1B in the tailwater for each of three summer releases (Table 3.55). Based upon overlap of 95% CIs, there were no differences in median travel times to Array 1B (7.8-8.6 hours), but rates may have been higher for LGS fish than for TDA fish. Second, we estimated travel statistics for the first leg of the trip from Array 3T above Boat Rock to the point of detection for three routes of passage. Times and rates were similar for spillway- and B2CC-passed fish (0.3-0.6 hours; mean = 0.5 hours), but travel rates were significantly slower (0.09 m / s) and travel times longer (4.3 hours) for fish passing the B2 JBS than for fish passing the spillway or B2CC (Table 3.56). Third, we estimated statistics from the point of passage detection down to Array 1B, and spillway-passed fish usually reached Array 1B in less time than fish passing the B2CC or B2 JBS (Table 3.57). Rates of travel for spillway fish usually were higher than for fish passed through the B2CC and B2 JBS, although LGS fish passing through the latter routes were just as fast based upon overlapping 95% CIs.

Table 3.55. Summer Median Time and Rate of Travel through BON (TDA3 to BON1). Values after the ± signs are one-half 95% confidence limits.

Release Site	Time (hours)	Rate (m/s)	n	Distance (km)
LGS Tailrace	7.8 ± 0.9	1.0 ± 0.04	143	27.6
JDA Tailrace	8.1 ± 0.5	0.9 ± 0.04	156	27.6
TDA Tailrace	8.6 ± 0.8	0.9 ± 0.01	1,428	27.6

Table 3.56. Summer Median Time and Rate of Travel to Specific Routes at BON. Values after the ± signs are one-half 95% confidence limits.

Release Site	Route	Time (hours)	Rate (m/s)	n	Distance (km)
LGS Tailrace	Array 3T to Spillway	0.6 ± 0.3	0.5 ± 0.18	86	1.2
JDA Tailrace	Array 3T to Spillway	0.6 ± 0.1	0.6 ± 0.09	46	1.2
TDA Tailrace	Array 3T to Spillway	0.6 ± 0.1	0.5 ± 0.08	574	1.2
LGS Tailrace	Array 3T to B2CC	0.4 ± 0.1	0.8 ± 0.17	16	1.5
JDA Tailrace	Array 3T to B2CC	0.3 ± 0.1	1.1 ± 0.30	3	1.5
TDA Tailrace	Array 3T to B2CC	0.5 ± 0.3	0.7 ± 0.09	72	1.5
LGS Tailrace	Array 3T to B2 JBS	6.5 ± 9.2	0.1± 0.06	12	3.6
JDA Tailrace	Array 3T to B2 JBS	3.5 ± 2.7	0.1 ± 0.04	31	3.6
TDA Tailrace	Array 3T to B2 JBS	2.9 ± 1.0	0.1 ± 0.02	146	3.6

Table 3.57. Summer Median Time and Rate of Travel through Specific Routes at Bonneville Dam Downstream to Array 1B. Values after the ± signs are one-half 95% confidence limits.

Release Site	Route	Time (hours)	Rate (m/s)	n	Distance (km)
LGS Tailrace	Spillway to 1B	7.4 ± 0.7	1.0 ± 0.08	44	26.4
JDA Tailrace	Spillway to 1B	7.2 ± 0.4	1.0 ± 0.05	31	26.4
TDA Tailrace	Spillway to 1B	7.7 ± 2.8	1.0 ± 0.02	423	26.4
LGS Tailrace	B2CC to 1B	8.5 ± 0.7	0.9 ± 0.08	9	26.2
JDA Tailrace	B2CC to 1B	9.5 ± 1.1	0.8 ± 0.09	2	26.2
TDA Tailrace	B2CC to 1B	9.6 ± 0.4	0.8 ± 0.03	63	26.2
LGS Tailrace	B2JBS to 1B	7.8 ± 0.6	0.9 ± 0.07	6	24.0
JDA Tailrace	B2JBS to 1B	8.6 ± 0.8	0.9 ± 0.05	21	24.0
TDA Tailrace	B2JBS to 1B	9.2 ± 0.3	0.8 ± 0.03	114	24.0
BON Tailrace	B2JBS to 1B	8.4 ± 0.1	0.8 ± 0.01	1,236	24.0

3.7.2.4 BON Releases

Travel times for subyearling Chinook salmon tagged and released through the BON SMF outfall pipe to Arrays 1B and from Array 1B to 2B are presented in Table 3.58. It took these fish about 8.4 hours to reach Array 1B, and this was very similar to the time it took for B2 JBS-detected fish to reach the same array (see Table 3.56). The rate of travel to Array 1B was similar to rates for fish passing through the B2CC, but slower than spillway-passed fish. The rate of travel from Array 1B to Array 2B was slower than the rate of travel from the tailrace to Array 1B.

Table 3.58. Travel Time for Subyearlings from the BON Smolt Monitoring Facility to Array 1B and from 1B to 2B. Values after the ± signs are one-half 95% confidence limits.

Time (hours)	Rate (m/s)	n	Distance (km)
8.4 ± 0.1	0.8 ± 0.01	1,525	24.0
1.5 ± 0.1	0.9 ± 0.01	1,236	4.8

3.7.2.5 Pooled Releases

Using array detection data, we plotted cumulative travel time for fish released from all projects in summer and calculated a combined travel time by river mile (Figure 3.29).

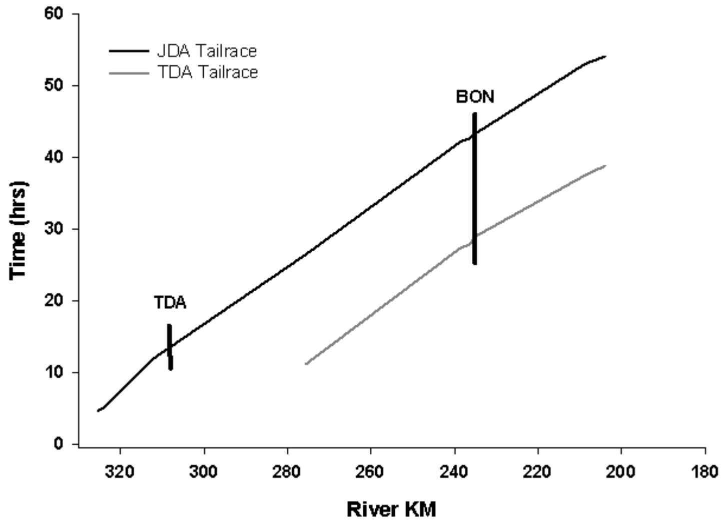


Figure 3.29. Median Time of Travel through All Reaches

3.8 Using Time of Travel to Lag Paired Releases in Future Studies

We estimated the lag time needed between upstream and downstream paired releases to maximize mixing of treatment and control fish in future studies. We calculated mean travel times from point and time of release from JDA, TDA, and BON to the primary array downstream of each dam, regressed those estimates on Columbia River discharge from each dam, and used the regression equations to predict a mean travel time as a function of discharge for all pairs of release locations (e.g., Figure 3.30 for spring and Figure 3.31 for summer). When regression slopes did not differ from zero, we used an average travel time over the range of river discharge. We subtracted predicted travel times for the downstream release from that of the upstream release at various river discharges to obtain an equation describing the required time lag as a function of river discharge. The equations can be used to calculate required lag times from expected river discharge. For JDA releases at the Turbine Intake and Front Roll, the lag time was short (12 to 17 minutes) and increased with discharge, but the order of releases was different for discharges below and above 345,000 cfs (Figure 3.32). Lag times ranged from 3 to 36 minutes for releases from the turbine and tailrace and from 18 to 26 minutes for releases from the front roll and the tailrace, but they consistently increased with increasing discharge (Figure 3.32). Lag times consistently decreased as river discharge increased for paired releases over greater distances such as the JDA and TDA Tailrace releases (Figure 3.33) and for TDA and BON Tailrace releases (Figure 3.34).

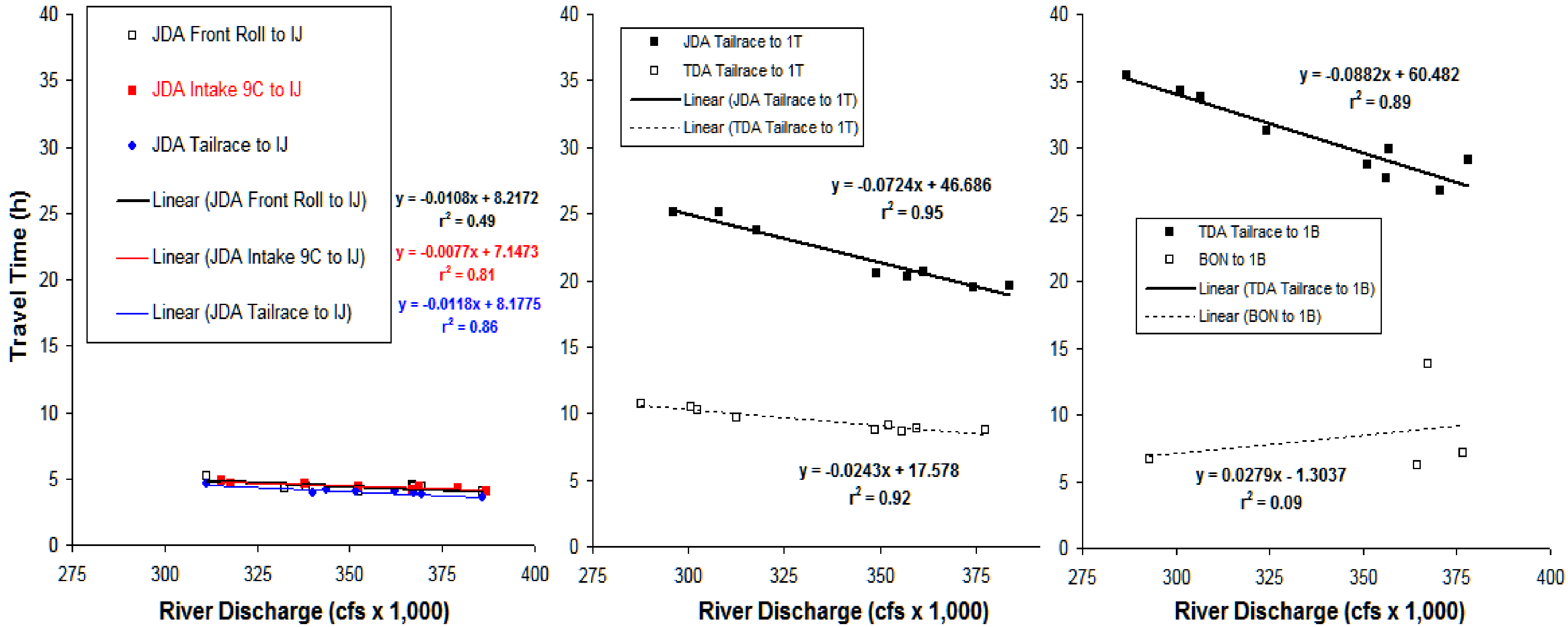


Figure 3.30. Median Travel Time as a Function of River Discharge for JDA Releases to Array 1J (Left), JDA and TDA Tailrace Releases to Array 1T (Center), and TDA and BON Tailrace Releases to Array 1B (Right) in Spring

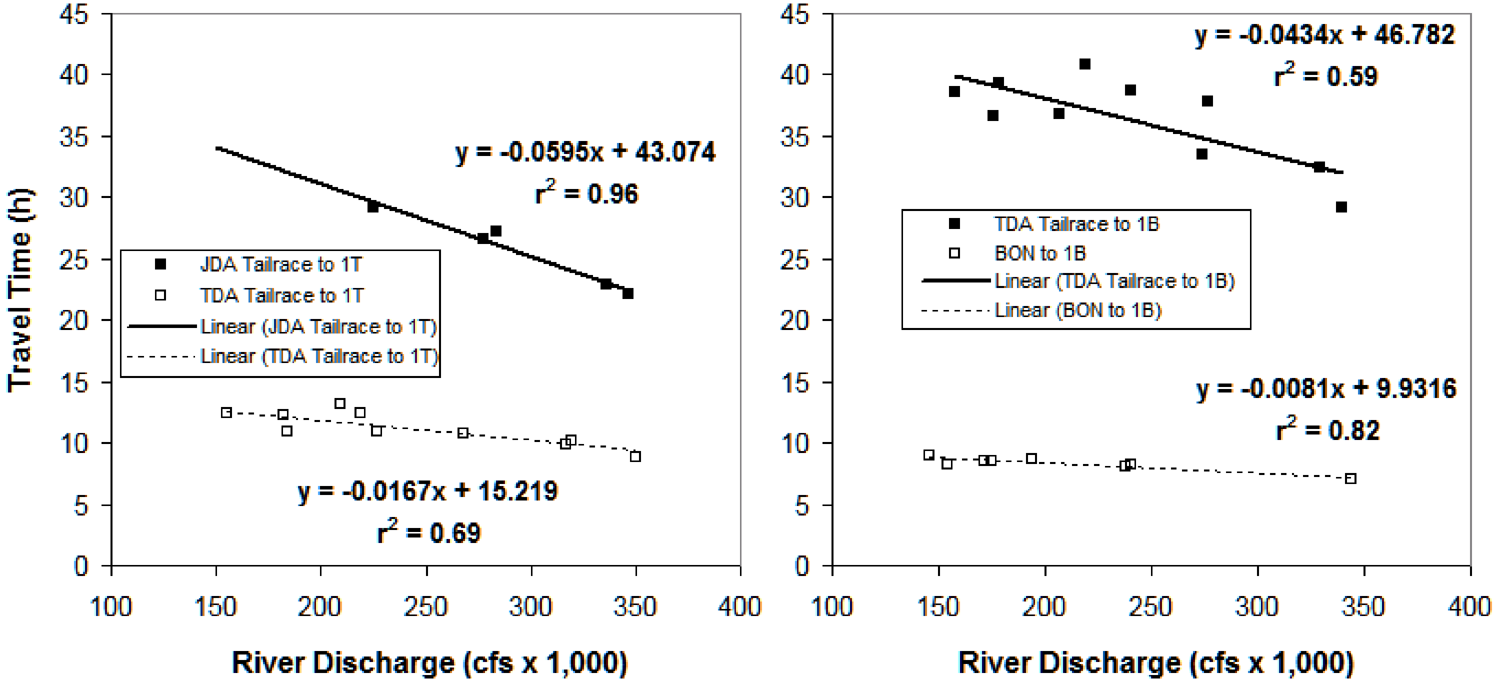


Figure 3.31. Median Travel Time as a Function of River Discharge for JDA and TDA Tailrace Releases to Array 1T (Left), and TDA and BON Tailrace Releases to Array 1B (Right) in Summer

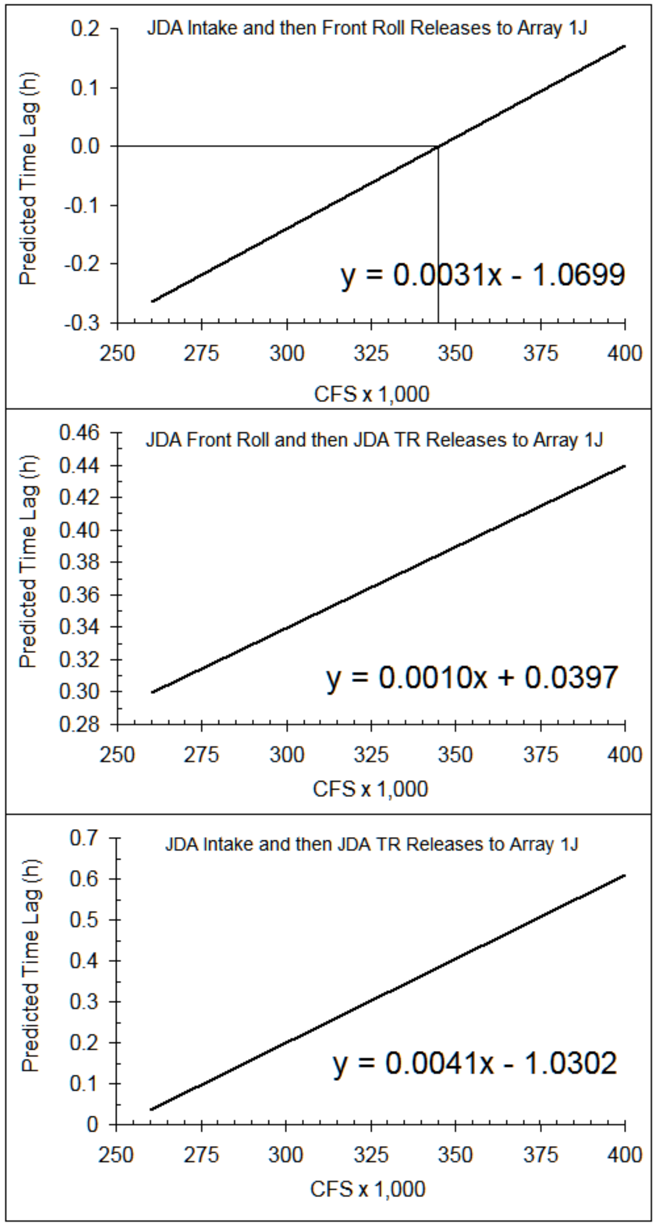


Figure 3.32. Lag Time Required Between Pairs of Releases of Yearling Chinook Salmon from JDA as a Function of River Discharge in Spring

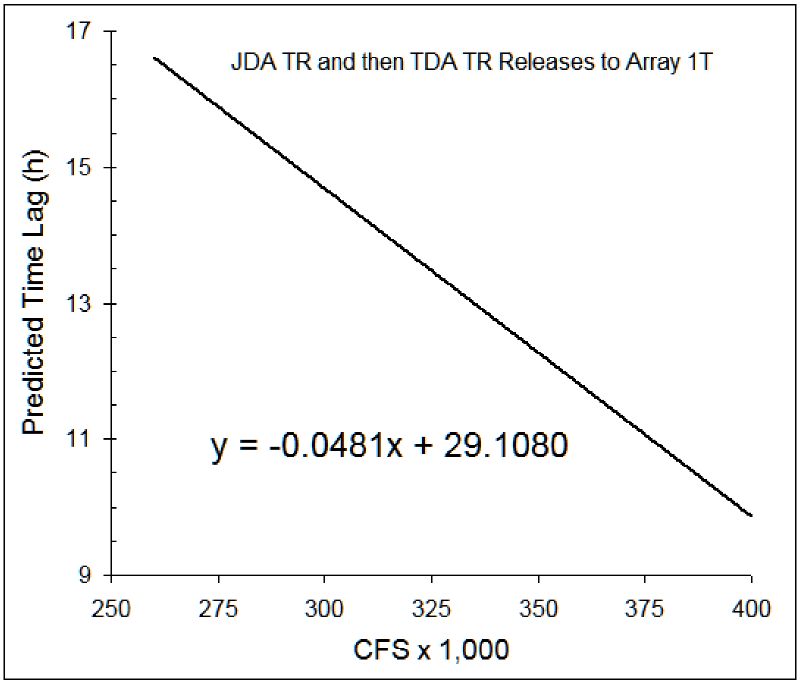


Figure 3.33. Lag Time Required Between Paired Releases of Yearling Chinook Salmon from JDA and TDA Tailrace (TR) as a Function of River Discharge in Spring

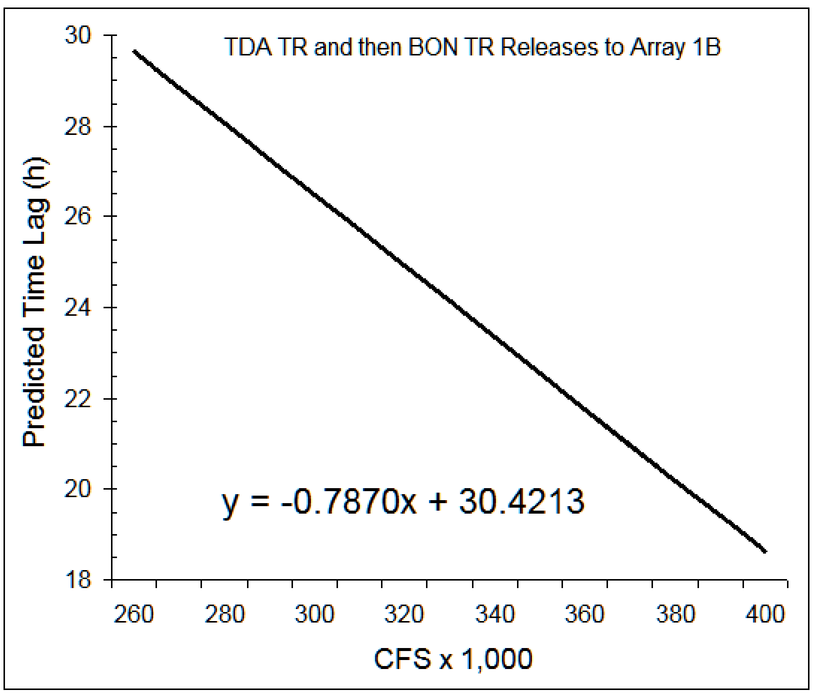


Figure 3.34. Lag Time Required Between Paired Releases of Yearling Chinook Salmon from TDA and BON Tailrace (TR) as a Function of River Discharge in Spring.

Lower river discharges were observed in summer than in spring, so relations describing lag times between paired releases from JDA and TDA (Figure 3.35) and from TDA and BON (Figure 3.36) in summer were different from those in spring (Figures 3.33 and 3.34 above).

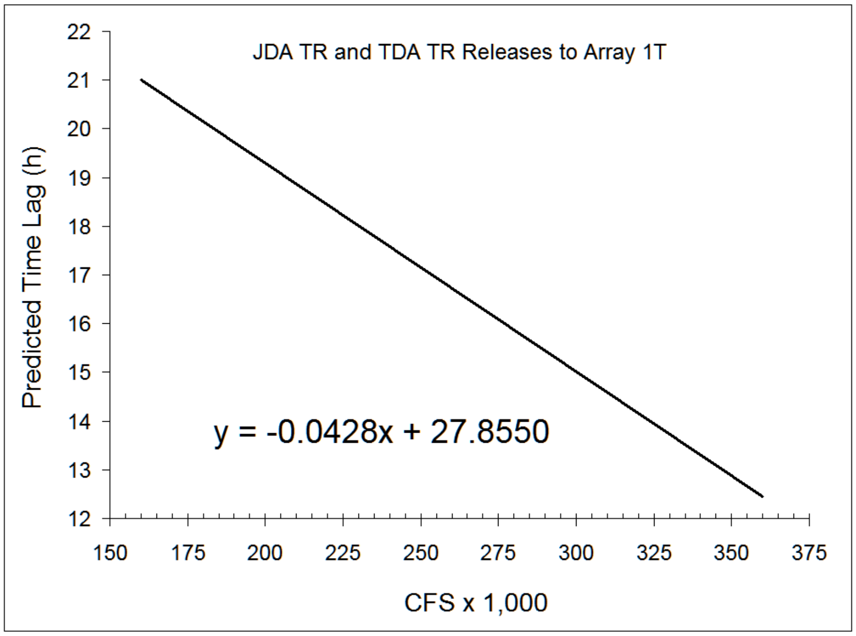


Figure 3.35. Lag Time Required Between Paired Releases of Subyearling Chinook Salmon from JDA and TDA Tailrace (TR) as a Function of River Discharge in Summer

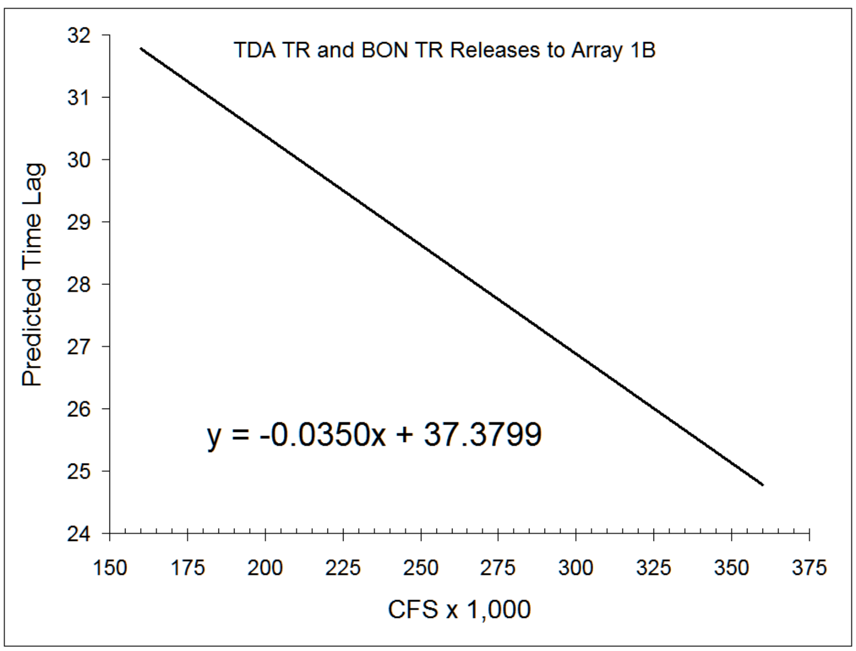


Figure 3.36. Lag Time Required Between Paired Releases of Subyearling Chinook Salmon from TDA and BON Tailrace (TR) as a Function of River Discharge in Summer

3.9 Diel Distribution

Fish arrived at BON during all hours of the day, although most fish from the JDA releases arrived at the BON forebay from 0000 to 1200 hours (Figure 3.37), whereas most fish from TDA releases arrived between 1000 and 2300 hours (Figure 3.38). This was true even when we examined the data by week within seasons. Between the two releases, the diel distribution of arrivals cover all hours relatively uniformly.

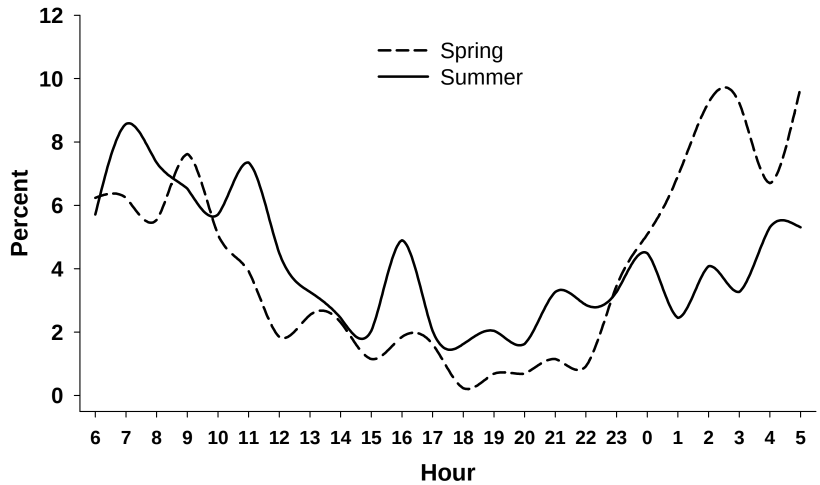


Figure 3.37. Diel Distribution of Tagged Fish Arriving at TDA3 (1.4 rkm above BON spillway) for Spring and Summer from the JDA Tailrace Release

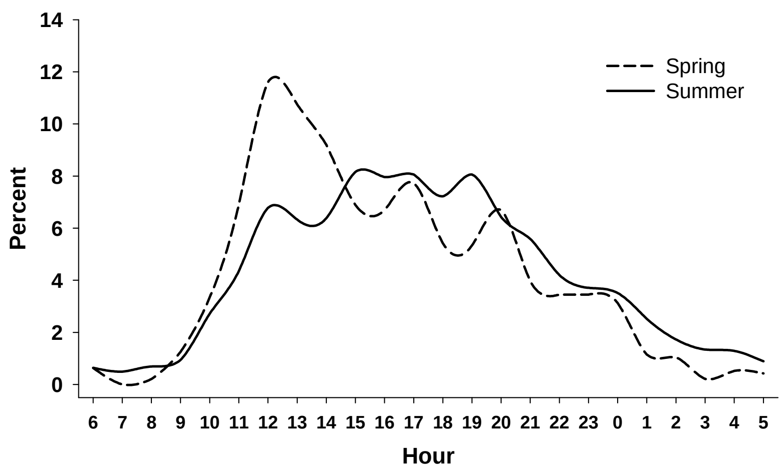


Figure 3.38. Diel Distribution of Tagged Fish Arriving at TDA3 (1.4 rkm above BON Spillway) in Spring and Summer, from the TDA Tailrace Release.

3.10 Cross Channel Distribution

Detections of tagged fish on downstream arrays were compiled to examine the distribution of passage through study cross sections where arrays were located (Figure 3.39). The cross-channel detection distributions show the percent of code detections weighted by the number of days each node was deployed and functional. Columns of plots from left to right are for the first, second, and third array in each tailwater including the JDA Tailwater (top row), TDA Tailwater (middle row), and BON Tailwater (bottom row). Spring and summer lateral distributions usually were similar, and there was no evidence of a shift of migrants to near-shore nodes in summer. There appeared to be a skew in the lateral distributions toward the Oregon shore at Array 1T and perhaps toward the Washington shore at Array 3B, but other complete distributions appeared to be detected most frequently on mid-river nodes (1J, 1B, 2T, 2B, and 3T). Nodes most likely to detect fish passing behind islands on the BON primary (Node 1 downstream of the Sand Island side channel) and BON secondary (Node 4 downstream of the Miller Island side channel) had the lowest detection percentages each season. However, Node 4 at the upstream entrance to Camas Slough behind Lady Island had among the highest percent detection each season on Array 3B.

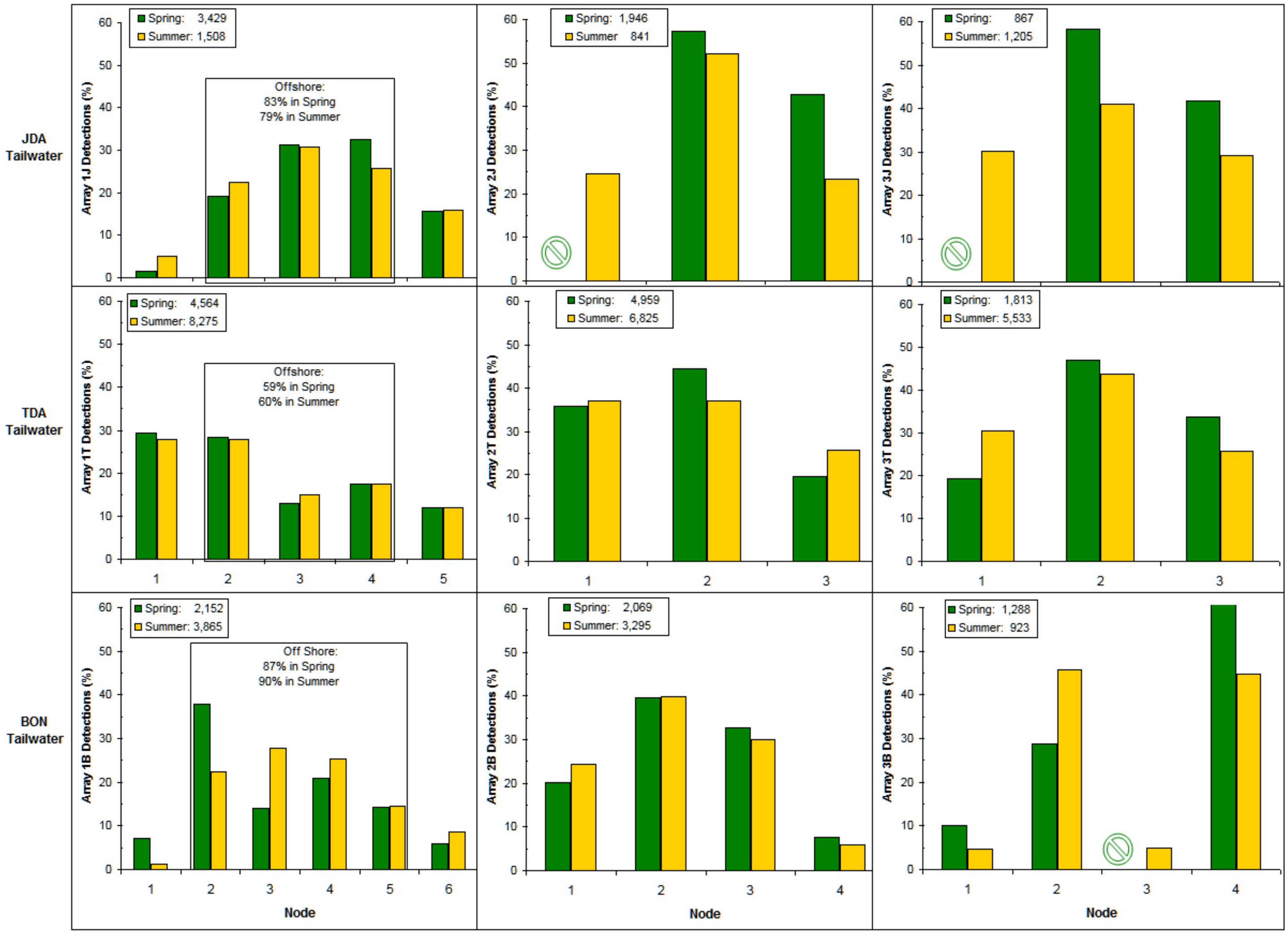


Figure 3.39. Cross Channel Distribution of Detections at Each Survival Array in the JDA Tailwater (top row), TDA Tailwater (middle row), and BON Tailwater (bottom row). Autonomous nodes detecting tags are numbered consecutively and represent locations from the Oregon to the Washington Shore. Each bar represents the percent of detections by node adjusted for the number of days each node was deployed or functional.

During the last week of spring and all of summer, the BON spillway was outfitted with five fixed hydrophones attached to piers between spill bays 1 and 2, 5 and 6, 9 and 10, 13 and 14, and 17 and 18, and there were four autonomous nodes deployed in the spillway forebay within 150 ft of the structure.

We examined the distribution of detections on the nine nodes and made a crude histogram of detections relative to the length of the spillway (Figure 3.40). The distribution includes multiple detections and does not provide information about where tagged fish passed the spillway.

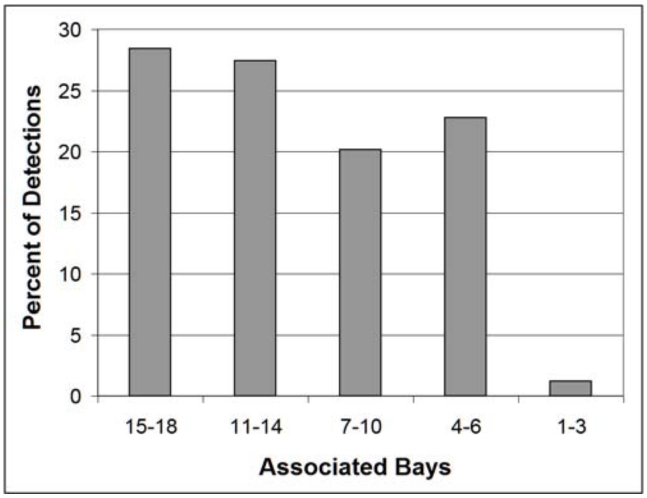


Figure 3.40. Distribution of Detections at the BON Spillway

3.11 Physical Factors Affecting Array Detection Probabilities

In order of significance, array detection probabilities were negatively correlated with river width, mean offshore distance to first nodes on either side of the river, and mean inter-node distance, and they were positively correlated with node density, and mean depth (Table 3.59). Inter-node spacing was calculated as sampled river width divided by the mean number of functional nodes, and the latter was weighted by the time that each node was functional. In short, high inter-node distances were realized not planned. There were no significant correlations of detection probabilities with the mean number of nodes nor with the standard deviation in depth. Plots of these relations are shown in Figure 3.41.

Table 3.59. Input Data, Simple Statistics, and Pearson Correlation Statistics for Physical Variables Affecting Detection Probabilities in 2006.

SEASON	ARRAY	Mean Depth (m)	SE Depth (m)	River Width (Km)	Mean Number of Nodes	Node Density (Nodes /Km)	Inter-Node Distance (m)	Mean Offshore Distance (m)	Mean Detection Probability
Spring	1J	16.2	3.7	0.7	5.00	7.02	142	71	0.9660
Spring	2J	13.9	3.4	0.7	2.00	2.83	354	125	0.9755
Spring	3J	20.1	4.9	0.6	2.00	3.15	317	100	0.8174
Spring	1T	16.7	12.8	0.5	4.00	7.72	130	65	0.9083
Spring	2T	18.2	4.6	0.3	2.80	9.33	107	54	0.9929
Spring	3T	18.3	1.8	0.3	2.40	7.27	138	69	0.9710
Spring	1B	8.6	4.8	1.2	5.67	4.91	204	102	0.6346
Spring	2B	13.5	6.1	1.1	4.00	3.61	277	139	0.7110
Spring	3B	13.3	3.6	1.0	2.67	2.58	388	194	0.4370
Summer	1J	14.6	3.7	0.7	4.81	6.76	148	74	0.8880
Summer	2J	12.4	3.4	0.7	2.88	4.07	245	60	1.0000
Summer	3J	18.6	4.9	0.6	2.88	4.54	220	48	0.9849
Summer	1T	16.2	11.6	0.5	4.88	9.42	106	53	0.9766
Summer	2T	16.7	4.6	0.3	3.00	10.00	100	50	1.0000
Summer	3T	16.8	1.8	0.3	2.25	6.82	147	73	1.0000
Summer	1B	7.4	4.3	1.2	5.75	4.98	201	100	0.7832
Summer	2B	11.9	6.1	1.1	2.31	2.09	479	240	0.7394

Simple Statistics

Variable	N	Mean	SE	Sum	Minimum	Maximum	Label
DP	17	0.8698	0.1617	14.7859	0.4370	1.0000	Mean Detection Probability
X_Z_m	17	14.91749	3.47727	253.59726	7.37482	20.14716	Mean Depth (m)
STD_Z_m	17	5.06257	2.94266	86.06369	1.78588	12.76355	SE Depth (m)
Width_km	17	0.70371	0.30904	11.96300	0.30000	1.15500	River Width (Km)
X_Nodes	17	3.48841	1.29949	59.30300	2.00000	5.75000	Mean Number of Nodes
Nodes_Km	17	5.71176	2.53953	97.10000	2.09000	10.00000	Node Density (Nodes / Km)
Space_m	17	217.75000	111.39770	3702	100.00000	479.03000	Inter-node Distance (m)
Offshore_m	17	95.11588	53.32725	1617	48.46000	239.52000	Mean Offshore Distance (m)

Pearson Correlation Coefficients; N = 17; Prob > |r| under H0: Rho=0							
Variable	Width_km	Offshore_m	Space_m	Nodes_Km	X_Z_m	X_Nodes	STD_Z_m
Coef.	-0.78041	-0.74197	-0.58771	0.58124	0.52399	-0.17649	0.00485
P	0.0002	0.0006	0.0131	0.0144	0.0309	0.4980	0.9853

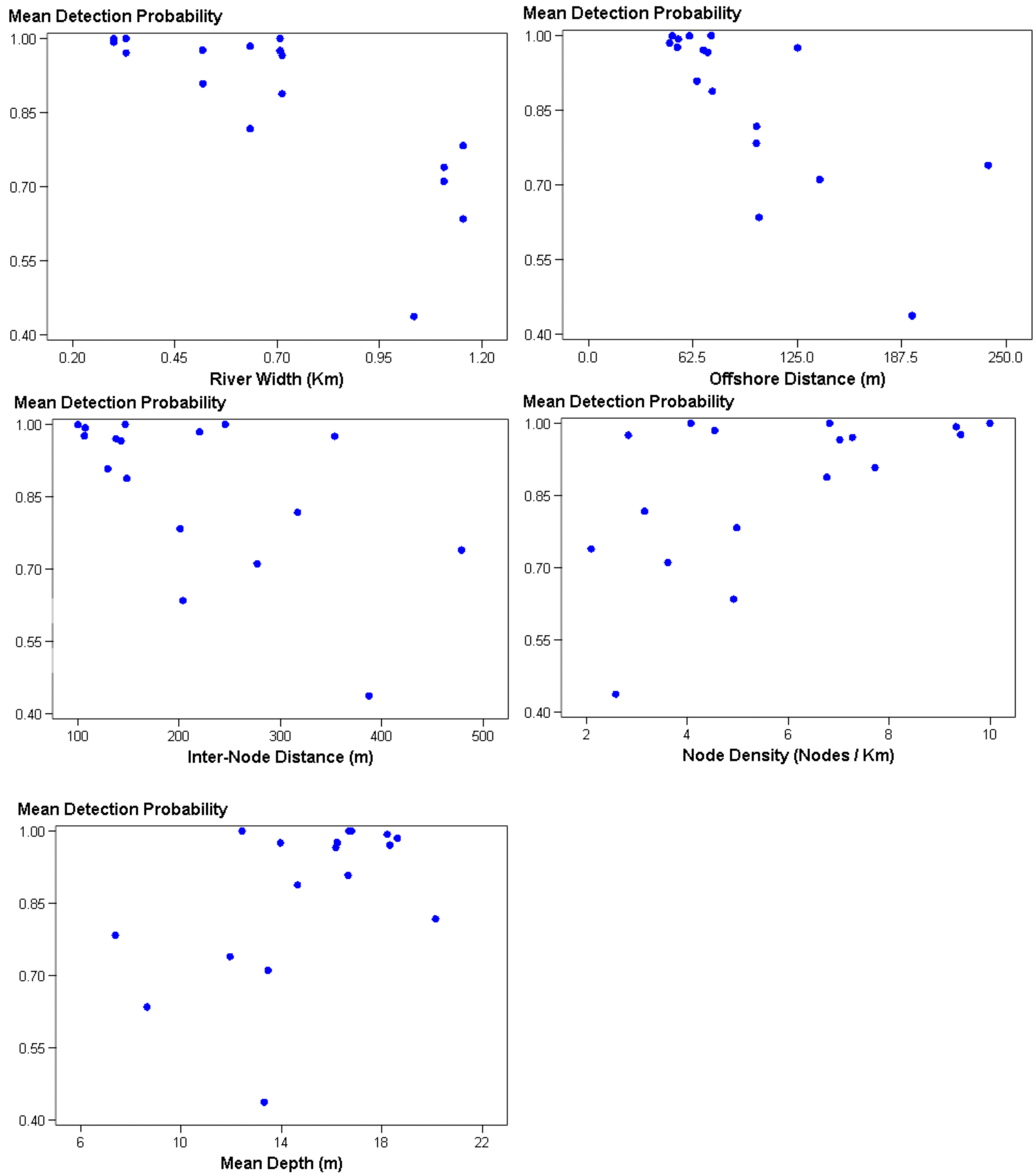


Figure 3.41. Scatter Plot of Mean Detection Probability as a Function of Physical Factors that Affect Array Performance

Arrays in the JDA and TDA Tailwaters had a higher percentage of simultaneous detections on multiple nodes than did arrays in the BON Tailwater, where single-node detections predominated (Figure 3.42). The percent of multiple-node detections was higher than that of single-node detections on arrays 1J, 3J, 1T, 2T, and 3T. About 30% of detections on Array 2J were on two or more nodes. Over 80% of detections on BON arrays were on a single node (Figure 3.42).

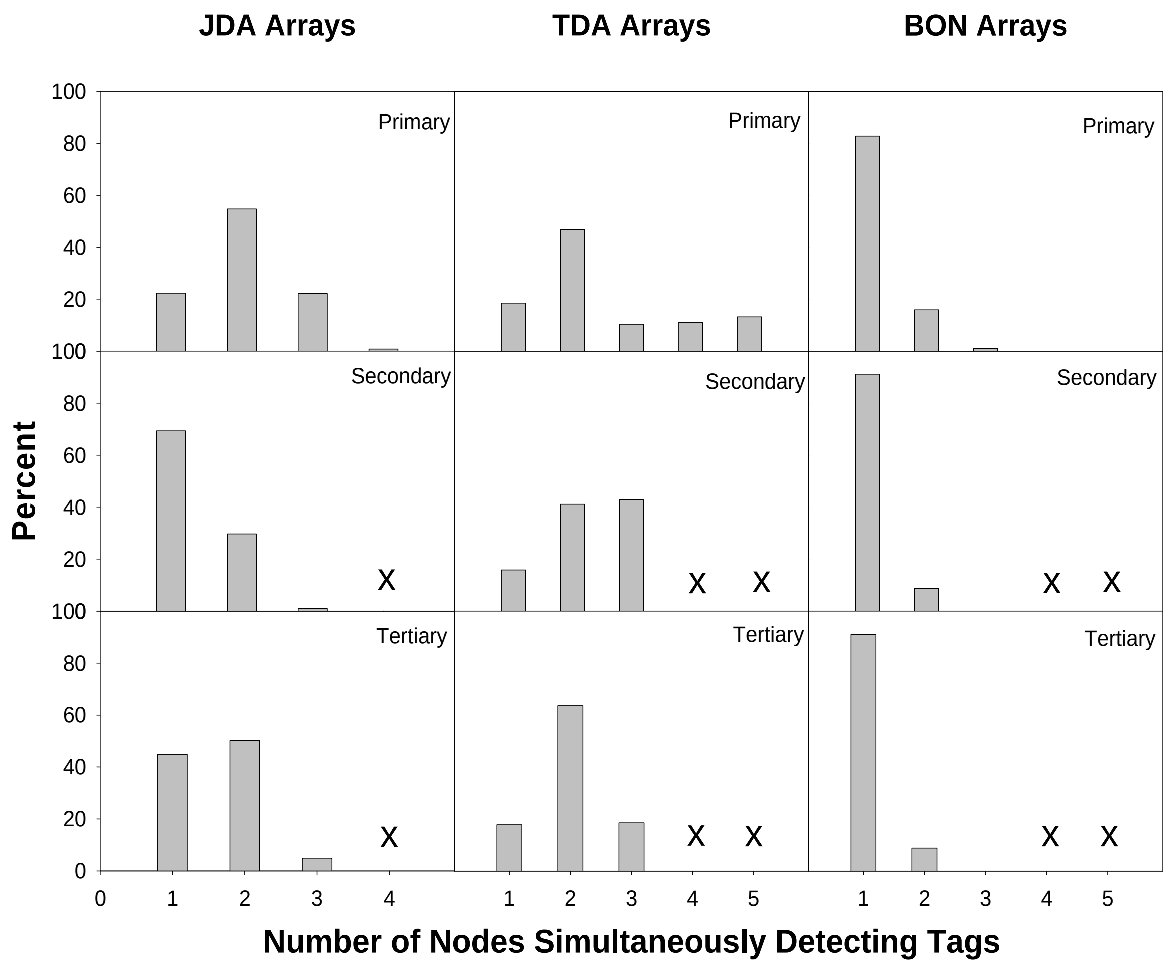


Figure 3.42. Percent of Single and Multiple-Node Detections on Survival Arrays in Spring and Summer 2006. An X indicates that no node was deployed, whereas a non-X position lacking a vertical bar indicates no detections on that many nodes.

3.12 Node Gaps

Some autonomous nodes malfunctioned, which resulted in gaps in detection fields within arrays in spring (Figure 3.43) and summer (Figure 3.44). In most cases, only one node in any given array was out at a time. In designing deployments, we spaced nodes closely enough in most arrays to provide some overlap in fields of detection, and this is reflected in the high percentage of multiple-node detections on many arrays in Figure 3.42. In summer, we had to take nodes from the tertiary array below BON Dam to supply other arrays upstream with adequate numbers of nodes.

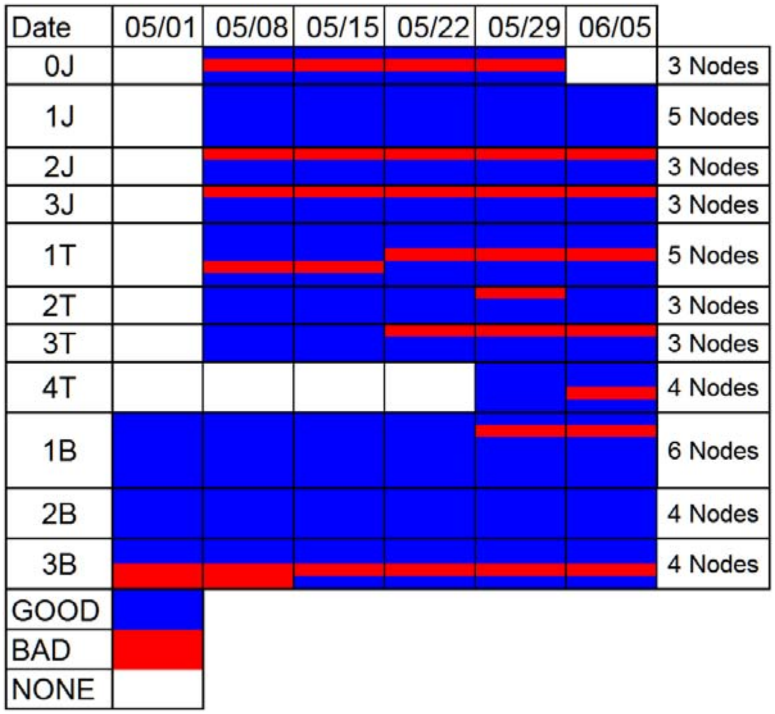


Figure 3.43. Spring Node Gap Chart for All Arrays. Blue Indicates Data Collected, Red Indicates missing data resulting from a malfunctioning or missing node.

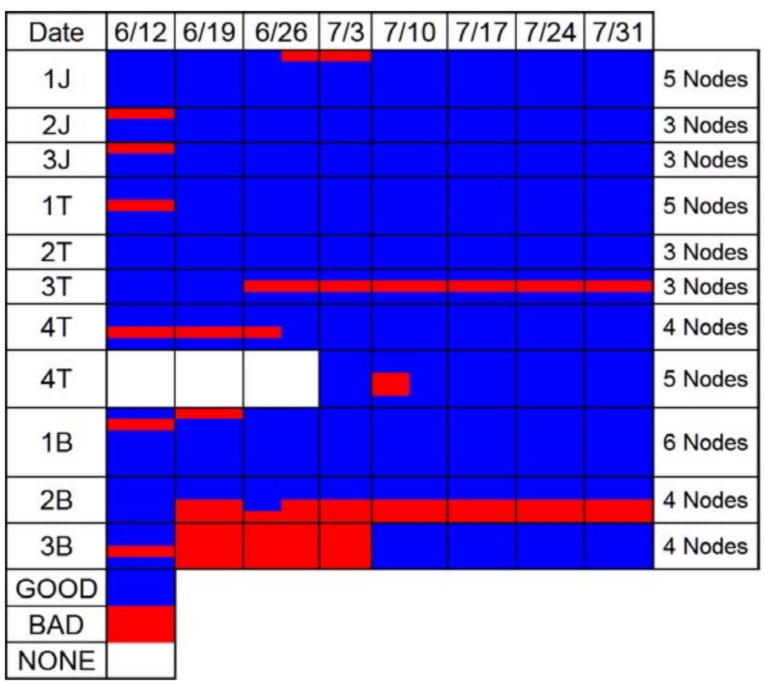


Figure 3.44. Summer Data Gap Chart for all Arrays. Blue indicates data collected, red indicates a data gap.

3.13 Survival and Dam Operations, Rate of Travel, Water Temperature

We calculated and examined correlations of survival probabilities with rate of travel (m/s), total project discharge, and forebay water temperature (^{o}C) for each release location in spring and summer. In spring, survival probabilities were positively correlated with rate of travel (m / s) for all JDA releases and inversely correlated with water temperature for the tailwater release (Table 3.60). No other significant correlations were found.

Table 3.60. Pearson's Correlations on Survival Probabilities with Rate of Tagged Fish Travel, Forebay Water Temperature (^{o}C), and Discharge (kcfs) by JDA and TDA Release Locations for Spring 2006

Variable	With	BY		Correlation		N
		Release	Array	Correlation	Prob > |r|	
Survival Prob.	Rate(m/s) of travel	JDA Front Roll	All	**0.4927**	**<0.0001**	64
		JDA Intake 9C		0.4528	**0.0002**	64
		JDA Tailrace		**0.4958**	**<0.0001**	64
		TDA Tailrace		-0.1607	0.2917	45
Survival Prob.	Temperature (^{o}C)	JDA Front Roll	All	-0.1592	0.2089	64
		JDA Intake 9C		0.0502	0.6938	64
		JDA Tailrace		-0.0710	0.5771	64
		TDA Tailrace		**-0.3349**	**0.0245**	45
Survival Prob.	Discharge (kcfs)	JDA Front Roll	All	-0.0258	0.8394	64
		JDA Intake 9C		0.2101	0.0957	64
		JDA Tailrace		-0.0106	0.9339	64
		TDA Tailrace		-0.2542	0.0920	45

In summer, survival was inversely correlated with water temperature for releases in the JDA Tailrace ($P = 0.18$; at $\alpha = 0.20$) and TDA Tailrace ($P < 0.0001$), and it was positively correlated with river discharge (releases in the JDA Tailrace at $\alpha = 0.10$ and in TDA Tailrace at $\alpha = 0.01$) and rate of travel, at least for JDA Tailrace releases. There was no significant correlation of survival with rate of travel for fish in the TDA Tailrace (Table 3.61).

Table 3.61. Pearson's Correlations on Survival Probabilities with Rate of Tagged Fish Travel, Forebay Water Temperature (^{o}C), and Discharge (kcfs) by JDA and TDA Release Locations for Summer 2006

Variable	With	By		Correlation		N
		Release	Array	Correlation	Prob > |r|	
Survival Prob.	Rate(m/s) of travel	JDA Tailrace	All	0.7048	<0.0001	35
		TDA Tailrace		0.0486	0.7657	40
Survival Prob.	Temperature (^{o}C)	JDA Tailrace	All	-0.2336	0.1769	35
		TDA Tailrace		-0.6739	<0.0001	40
Survival Prob.	Discharge (kcfs)	JDA Tailrace	All	0.3318	0.0515	35
		TDA Tailrace		0.4353	0.0050	40

3.14 Required Sample Sizes

We ran the Model SampleSize v1.3 using detection and survival statistics estimated in this study to calculate one-half 95% confidence intervals (CIs) as a function of the total number of tags that might be released in a future study. Lookup-tables to find an estimate of the pooled sample size required to achieve a desired level of precision are presented for yearling Chinook salmon in spring for single-release models (Appendix I) and paired release models (Appendix J). Similar tables are presented for subyearling Chinook salmon in summer for single-release models (Appendix K) and paired-release models (Appendix L).

Most of the precision estimates were very similar to the precision obtained in the study. However, the predicted 95% CI for the summer paired release model based on releases of 2,200 subyearlings from the TDA Tailrace and the BON Tailrace (0.0312) was slightly higher than the observed estimate (0.0247) based upon releases of 2,179 fish from the TDA Tailrace and 1,957 fish from the BON Tailrace. This tendency for predicted precision being slightly higher than observed precision also was observed for other paired release data (Figure 3.45), and it results from slightly conservative variance estimators in the SAMPLESIZE program.

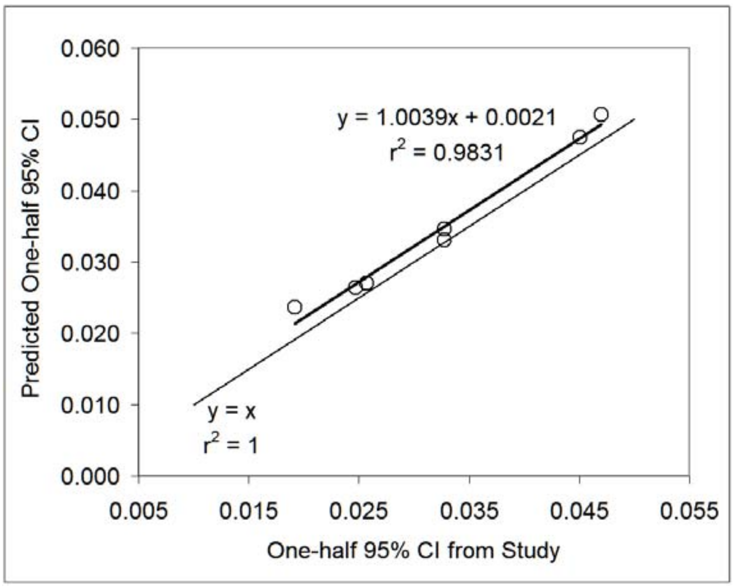


Figure 3.45. Regression of Predicted One-half 95% Confidence Intervals on Observed Estimates in the 2006 Study. The light line shows a 1:1 relationship of comparison to the fitted line.

3.15 Detection History Data for Every Acoustic Tag

Detection history data for every tag released in the 2006 study are presented in Appendix M.

4.0 Discussion

4.1 Environmental Conditions

Above-average river discharge during the spring release period precluded successful deployment of a release hose to the downstream side of the JDA Front Roll and forced us to deliver most releases to the site by boat. Days with the highest discharge forced us to release front roll fish near the JBS outfall about 100 m downstream of the front roll. We also had to abandon tag-line rigging of autonomous nodes. In our first round of deployments in spring, autonomous nodes were rigged with 250 ft of tag line to allow retrieval of anchors as well as nodes and acoustic-release mechanisms. With tag-line deployments, the node and acoustic release pop to the surface briefly after the release is triggered but submerge again very quickly in high flow. We had intended to retrieve and download data weekly, but wound up leaving the first round of nodes deployed for almost a month (the expected battery life) to avoid damaging nodes with the boat during high-speed retrievals. After retrieving the first round of nodes, which included frequent prolonged dragging for many nodes re-submerged by high flow, we abandoned tag-line deployments and sacrificed anchors for the rest of the study.

4.1.1 Project Discharge and Temperature

Water temperatures were 1 to 2 °C higher than the average of the preceding 10 years during the first 60% of spring releases and during the last 50% of summer releases. Water temperatures did not reach 20-21°C until the last couple of releases in summer, and most of those fish made it through the study area within a week. Observed water temperatures were below critical levels for juvenile Chinook salmon (Brett 1952), but higher water temperatures may increase susceptibility to disease (Tiffan et al. 2000) and may be an additional stressor on young Chinook salmon, particularly those that are not well fed (Cobleigh 2003).

4.1.2 Run Timing and Smolt Species Composition

The spring tagging season ran from May 13 to June 6, 2006, and encompassed the peak of the targeted yearling Chinook salmon run, which ran from May 20 to June 1, 2006. This collection period also encompassed peaks in the spring steelhead, sockeye, and coho runs at JDA, which required us to handle many non-target fish to obtain spring tagging quotas. Collection was in conjunction with normal collection at the JDA SMF to reduce the amount of by-catch and handling of in-stream migrants. In spring, the sockeye run was much larger than in 2005. It made up almost 10% of the entire spring salmonid run (DART Website), which probably can be attributed to increased spill from Dworshak Reservoir.

The summer tagging season ran from June 11 to July 11, 2006, and, as in spring, encompassed the peak of the migration of the targeted subyearling Chinook salmon run, which occurred around July 1. Sampling had to be increased at the JDA SMF to ensure that adequate numbers of clipped subyearlings from hatcheries were collected for tagging. Over the course of the summer tagging season, only 14% of collected subyearlings were clipped; large numbers of unclipped fish had to be processed to find the required numbers of clipped individuals.

4.1.3 Length Frequency

A 95-mm minimum length limitation on tagging did not restrict the lengths of fish that could be tagged in the spring, and the length frequencies of tagged and untagged yearling Chinook salmon in the JBS samples were very similar. Only two yearling Chinook salmon smolts were measured that were smaller than the 95-mm size requirement.

The 95-mm minimum length limitation clearly excluded most subyearlings less than 100 mm in the summer sample (Figure 3.5); tagging would need to include 80 to 100 mm subyearlings to be fully representative of the population passing through the SMF at JDA in summer. The 95-mm minimum tagging length effectively eliminated about 23% of the run-of-river sub-yearlings from the sample because they were too small. Tagging subyearlings 80 mm long will require further miniaturization of tags and reduction in tag weight, according to results of a 2006 tag-effects study (Hockersmith et al. 2007).

Collection of fish exclusively from the JDA SMF also could limit inference about survival to the population of bypassed fish, which may or may not be representative of the entire run migrating seaward. According to previous route-specific survival studies, about 28.7% to 35.1% of yearling Chinook salmon pass JDA through the SMF (Counihan et al. 2006a, 2006b). In 2003, only 12.9% to 21.3% of subyearling Chinook salmon passed the JDA Project through the JDA SMF. The summer length limitations for tagging further restricts known inference to the larger subyearlings in the SMF samples. Length-related detection biases associated with acoustic telemetry have not yet been documented like those for PIT detection systems (Zabel et al. 2005), although this bias could not be large, if it exists at all, because detection probabilities like those observed for releases down to primary arrays in the JDA and TDA tailwaters usually were very high. For example, detection probabilities were 96.1% to 98.9% for JDA-released fish and 97.5% for TDA Tailrace releases in spring, and 99.2% for TDA Tailrace fish in summer).

4.2 Tag-Life Study

The tag-life study verified that most tags lasted about as long as expected. All 10-s tags sampled from lots of tags implanted in Snake River fish lasted at least 57 days relative to an expected 55 days, and all 5-s tags exceeded the expected 30-day life by about 5 days.

Future tag-life studies need to be strategically performed so any corrections for tag failure can be properly applied. Recommendations include the following:

1. Systematically sample tags as they are activated for survival studies.
2. Record tag lot number as well as tag codes when fish are tagged, so that specific tag-life corrections can be made in the case of tag-manufacturing problems.
3. Record date and time to the nearest minute that each tag is activated for the tag-life study or JSATS survival studies. This could be accomplished by using a data-logging device when tag activations are verified with a hydrophone. The date and time settings are critical and should be checked regularly.

4.3 Detection Probabilities and Required Sample Sizes

Results obtained in spring and summer 2006 accomplished the study goals. Our primary goals were to estimate detection and survival probabilities for JSATS acoustic telemetry equipment in the lower Columbia River to assess the feasibility of using JSATS and to provide a basis for estimating required sample sizes to achieve desired precision in future studies. The importance of multi-node detections within the upstream arrays (Figure 3.42) is illustrated by high detection probabilities for Columbia River releases in the JDA and TDA tailwaters, in contrast to lower detection probabilities observed at arrays in the BON Tailwater (Table 4.1). The high detection probabilities in the JDA and TDA tailwaters were achieved in spite of a number of gaps in node arrays (Figures 3.41 and 3.42). One reason for the low detectability in the BON Tailwater resulted from equipment problems, including the loss of nodes to fishermen and commercial boat traffic. However, some of it is undoubtedly related to the relatively shallow bathymetry and extensive sand bars, which limit the range of sound propagation.

Table 4.1. Means and Standard Errors of Mean Detection Probabilities for Columbia River Releases of Chinook Salmon in Spring and Summer 2006. These estimates were calculated from pooled detection estimates.

Statistic	To 1J	To 1T	To 2T	To 1B	To 2B
Spring					
Mean	96.2	91.3	99.7	67.6	72.5
SE of Mean	3.1	5.3	0.3	5.9	5.9
Summer					
Mean	97.2	99.0	100.0	80.2	N/A
SE of Mean	2.4	0.2	0.0	11.4	N/A

We could not compare detection probabilities for the primary and secondary arrays in this study with estimates in previous radio telemetry studies because those statistics were not reported, although they were mentioned. Capture history data presented in radio telemetry reports were not sufficient to calculate detection probabilities for individual arrays, so we compared the probability of fish being detected on any one of the downstream survival arrays in spring (Table 4.2) and summer (Table 4.3). This probability includes survival and detection probabilities inasmuch as tagged fish might miss detection because they died or because they passed through all three arrays undetected but alive.

According to results in Tables 4.2 and 4.3, the 2006 JSATS arrays usually performed as well as or better than radio telemetry arrays in the JDA and TDA tailwaters and usually underperformed radio arrays in the BON Tailwater. Acoustic arrays in the upstream pools likely perform better than arrays in the BON Tailwater because transects tend to be deeper, and there were few shallow bars and islands upstream to impede underwater sound transmission. Aerial radio antennas may perform better in the shallower BON Tailwater than in the upstream pools because tagged fish are less likely to evade detection by passing deep. Our comparison assumes that survival was similar among years and that most of the differences in detection probabilities were due to detectability. Given among-year variability in survival, this assumption may not be true, although we limited comparison to years with similar project configurations at TDA and BON. Regardless, most of the probabilities of detection on at least one of all survival arrays exceeded 80% for each method, which should be sufficient to provide confidence in survival estimates.

Deploying additional nodes below BON, where P1 detection probabilities averaged 67.6% in spring and 80.2% in summer, has the potential to significantly increase detectability and to reduce the need for large numbers of tags for future studies employing paired-release models. Sample-size tables for BON in Appendix I (Tables I.15 – I.18 for spring) and Appendix K (Tables K.9 – K.14 for summer) indicate that high precision can be obtained for single-release models with existing sampling effort and a reasonable number of tags in either season. However, tables for paired-release models in spring (Appendix J,

Table J.3) and especially summer (Appendix L, Table L.2) indicate that buying a lot more tags will not improve precision significantly. The density of detection nodes will have to be increased to achieve a 2% one-half 95% CI on paired-release survival estimates with a reasonable number of tags.

Table 4.2. Probability of Tagged Yearling Chinook Salmon Being Detected on at Least One of Three Arrays Downstream by JSATS Receivers in 2006 or by Radio Telemetry Receivers in Prior Studies in Spring

Dam	Acoustic Telemetry Release in 2006	Probability of Detection on All Downstream Acoustic Arrays (2006)	Probability of Detection on All Downstream Radio Arrays	Difference Acoustic Minus Radio Estimate	Radio Telemetry Study Year	Radio Telemetry Study Release, Treatment, or Condition
JDA	Turbine I9C	0.874	0.764	0.110	2002	Powerhouse = Turbine + JBS
JDA	Turbine I9C	0.874	0.804	0.070	2003	Turbines
JDA	Tailrace Control	0.973	0.956	0.017	2002	Tailrace Control
JDA	Tailrace Control	0.973	0.971	0.002	2003	Tailrace Control
TDA	JDA Tailrace	0.917	0.844	0.072	2004	JDA Tailrace
TDA	JDA Tailrace	0.917	0.881	0.036	2005	JDA Tailrace
TDA	TDA Control	0.989	0.975	0.014	2004	TDA Control
TDA	TDA Control	0.989	0.987	0.001	2005	TDA Control
BON	TDA Tailrace	0.839	0.846	-0.006	2004	TDA Tailrace; 56 kcfs day / gas cap night
BON	TDA Tailrace	0.839	0.903	-0.063	2005	TDA Tailrace; 75 kcfs day / gas cap night
BON	BON Tailrace	0.818	0.958	-0.140	2004	BON Tailrace; 56 kcfs day / gas cap night
BON	BON Tailrace	0.818	0.971	-0.154	2005	BON Tailrace; 75 kcfs day / gas cap night

Table 4.3. Probability of Tagged Subyearling Chinook Salmon Being Detected on at Least One of the Downstream Survival Arrays by JSATS Receivers in 2006 or by Radio Telemetry Receivers in Prior Studies in Summer. There were only two acoustic survival arrays below BON in 2006, whereas there were three survival arrays below TDA in acoustic and radio telemetry studies.

Dam	Acoustic Telemetry Release in 2006	Probability of Detection on All Downstream Acoustic Arrays (2006)	Probability of Detection on All Downstream Radio Arrays	Difference Acoustic Minus Radio Estimate	Radio Telemetry Study Year	Radio Telemetry Study Release, Treatment, or Condition
JDA	JDA Tailrace	0.993	0.993	0.955	2002	JDA Tailrace Control
JDA	JDA Tailrace	0.993	0.993	0.988	2003	JDA Tailrace Control
TDA	JDA Tailrace	0.823	0.662	0.161	2004	JDA Tailrace; TDA Treatment
TDA	JDA Tailrace	0.823	0.825	-0.002	2005	JDA Tailrace; TDA Treatment
TDA	TDA Tailrace	0.969	0.954	0.015	2004	TDA Tailrace Control
TDA	TDA Tailrace	0.969	0.968	0.001	2005	TDA Tailrace Control
BON	TDA Tailrace	0.762	0.802	-0.040	2005	TDA Tailrace; 75 kcfs day/gas cap night
BON	BON Control	0.915	0.960	-0.046	2005	BON Tailrace Control

The tradeoff between buying tags and buying autonomous nodes can easily be calculated and compared to find an optimum balance between detectability and sample size. For example, in 2006, one fully rigged node and acoustic release mechanism cost about as much as 67 acoustic tags. In Appendix L, Table L.2, it is clear that doubling the number of tags from 2,500 to 5,000 only reduces the one-half 95% CI from 0.0304 to 0.0271, but that amount of money could more than double node density in downstream arrays. We estimate that adding just two nodes to each array and deploying three arrays in summer would provide a 90% detection probability for BON Tailwater arrays and, everything else being equal, would achieve the same precision with just 1,800 tags. If there is room for improvement in detectability, then increasing detectability probably is more cost effective than buying tags up to some detection saturation point.

The choice of array locations and spacing between arrays can provide savings for future studies seeking to evaluate survival at multiple projects. We deployed nine survival arrays (three per tailwater) to thoroughly assess detection and survival probabilities in three tailwaters, but our results indicate that all survival estimates could have been obtained with just six arrays. Those arrays would include:

1. One in the JDA Tailwater located near the TDA forebay serving as both a primary survival array and as a TDA forebay array.
2. Two in the TDA Tailwater (2006 arrays 1T and 3T), where 1T would serve as a secondary for JDA releases or as a primary for TDA virtual and Tailrace releases, and 2T located near the BON forebay would serve as a tertiary array for JDA releases, a secondary array for TDA virtual and tailrace releases, and a forebay array for constructing BON virtual releases.
3. Three in the BON Tailwater.

We compared survival estimates calculated from detections on "as planned" arrays in each tailwater with estimates based on detection on "preferred arrays" in Chapter 3, Section 3.6, and found no significant differences in any estimates (Tables 3.41 through 3.44). Therefore, we recommend that future studies maximize return on investment by using the arrays described above when multiple projects are being studied. Had we known that the use of the preferred arrays would yield similar results to the "as planned" arrays, we could have saved deployment and servicing of two arrays and six autonomous nodes in the JDA Tailwater, and one array and three autonomous nodes in the TDA Tailwater without detriment. Some of these nine nodes could have been used as spares, which would have eliminated our need to cannibalize the BON tertiary array in summer to keep upstream arrays populated, and the rest would have been available for other studies. However, our results also indicate that if a single study is planned, survival arrays can be located in one tailwater and can be relatively close together without detriment, as long as detections cannot be made simultaneously on two successive arrays. However, spreading out three arrays within a pool will provide greater inference about survival in the first two river reaches. There may be other considerations of consequence, including increased servicing of widely dispersed arrays. Nevertheless, these are tradeoffs worth considering when planning future studies.

The primary array clearly needs to be far enough downstream so that the probability of detecting dead fish is near zero, and so that time is allowed for injuries associated with dam passage to result in death. We did not detect dead fish on any array in this study, so apparently the primary arrays were located far enough downstream to avoid detecting dead fish. In spring, survival to the primary, secondary, and tertiary arrays in each tailwater did not differ significantly (see Figure 3.18); therefore, locating the primary in any of the three locations would not have made a significant difference. However, in summer, the survival to Array 3J was significantly lower than it was to Arrays 1J and 2J, and survival to Array 2T and 3T was significantly lower than it was to Array 1T (Figure 3.25). Consequently, locating a primary

JDA array near the TDA forebay (where Array 3J was in this study) or the primary TDA array just above the BON forebay (where 3T was located in this study) would have provided a significantly lower single-release survival estimate than we observed with primaries located further upstream. The reduced survival for the most downstream arrays in the JDA and TDA tailwaters in summer may have resulted from the realization of mortality of injured fish or just from fish having to travel through a longer reach. On the chance that the cause was delayed mortality, it might be prudent to locate primary arrays as far downstream as possible. Paired release models will remove the tailwater effect in either case.

4.4 Detection and Survival of Yearling Chinook Salmon in Spring

4.4.1 Tag-Life Study Correction

No tag-life correction was needed or used for the 2006 yearling Chinook survival studies. The only releases with tags potentially needing corrections were those at the last array below BON and even then the expected probability of tag life exceeded 99.9% (Appendix B). In these circumstances, the tag-life correction of the reach survival estimates would be inconsequential. It would not change the point estimate and would only slightly inflate the variance of detection and survival estimates.

4.4.2 Lower Granite Release Group

A pooled survival estimate of 48.7% for these yearlings that traveled through five dams over 370 km down to Array 1J equates to an average loss of about 10.2% per dam and tailwater, and this is within the range of previous observations for the lower Columbia River. The Lower Granite fish traveled 370 km and passed five dams to reach Array 1J. These two release groups were the first groups of active tagged fish released on the Snake River and detected on the Columbia River. Within this study, we observed dam and tailwater mortalities of 12.4% for fish released into the JDA turbine, 5.3% for virtual releases through TDA, and 8.2% for virtual releases through BON. High spillway passage at TDA may account for 95% survival there. From 2002 through 2005, the TDA spillway passed about 76% of yearling Chinook salmon (Johnson et al. 2007), and survival of yearling Chinook salmon there was reported to be 90.6% in 2004 (Counihan et al. 2006a) and 94% in 2005 (Counihan et al. 2006b).

4.4.3 John Day Dam Releases

Paired releases at JDA provided reasonably precise estimates of survival for yearlings passing through a turbine to the front roll (89.2% with a 3.2% one half 95% CI) and through the turbine to the tailrace (89.8% with a 3.3% one half 95% CI). Survival of yearling Chinook salmon to the primary array after release in Turbine Intake 9C was significantly lower than that of yearlings released in the downstream front roll or tailrace according to a Z-test. A paired-release survival estimate for yearlings passing through Intake 9C to the tailrace was significantly lower than a paired-release estimate for yearlings released in the front roll and traveling to the tailrace ($Z = -4.945$; $P < 0.0001$; $n = 8$). Our estimates of 89% to 90% are 5.8% to 9.3% higher than some previous route-specific survival estimates including 83.2% in 2002 (Counihan 2006d) and 80.7% during the night in 2003 (Counihan et al. 2006e), but our estimates were comparable to an estimate of 89.1% during the day in 2003 (Counihan et al. 2006e). Estimates of survival through turbines may vary depending upon the exact geometry associated with operations under different flow regimes. With very high river discharge in 2006, it is possible that turbines were run to maximize discharge, and such a fully open runner-blade geometry is known to reduce injury and mortality associated with blade strike (Ploskey and Carlson 2004).

There were Burnham Test 2 violations of independence assumptions for the primary and secondary arrays for two of the three releases, but it is difficult to understand the mechanism involved since fish were merely detected as they passed the primary array and were not delayed or handled in any way. As noted by Counihan et al. (2006d), the utility of these tests to discern whether independence assumptions have been met is limited by the high capture probabilities. This was true for radio telemetry, and it likely is true for JSATS acoustic telemetry in the JDA and TDA tailwaters. Since detection arrays span the entire river channel, the possibility that this assumption could be violated if downstream detections were influenced by upstream passage routes is minimized, and the lack of handling following initial release of fish also minimizes the risk that upstream detections affect survival (Skalski 1999). However, there may simply be an association relating to unequal detectability and paths of fish or (perhaps more likely) fish may be moving in groups or in clusters relating to local environmental conditions that lead to violation of the independence assumption of Chi-square tests. Small p-values very easily arise when there is non-independence. This needs to be investigated further for non-independence may lead to the model standard errors being too small.

The JDA and TDA releases in spring were used to estimate pool and dam survival for TDA. Our spring estimate of 92.8% (95% CI = 90.2, 95.4%) was 1% to 2% higher than a 2004 estimate and the same as a 2005 estimate based upon radio telemetry studies for two years with similar spill configurations to those used in 2006. Radio telemetry studies estimated project survival at 86.6% (95% CI = 84.3, 88.9%) for 2004 (Counihan et al. 2006a) and at 89.2% (95% CI = 86.4, 92.0%) in 2005 (Counihan et al. 2006b). Most fish pass through the spillway at TDA, and spillway survival ran 94% to 95% with an average 95% CI that bracketed our project survival estimates according to PIT tag studies conducted in 1999 and 2000 (Dawley et al. 2000; Absolon et al. 2002).

4.4.4 The Dalles and Bonneville Tailrace Releases

Tailrace releases below TDA were used as controls for TDA project survival estimates, and tailrace releases below BON were used as controls for BON project survival estimates; as such they can be compared to radio telemetry survival estimates for spillway control releases in 2004 and 2005. Our survival estimate for the TDA control release to Array 1T was 98.9% (95% CI =98.3, 99.6); this did not differ from mean radio telemetry estimates of 95.7% (95% CI = 92.4, 99.1) in 2004 (Counihan et al. 2006a). We could not find a reported survival estimate for control fish released in the TDA Tailrace in 2005, but the reported λ of all arrays was 98.7% (Counihan et al. 2006b).

Our survival estimate for BON Tailrace control releases to Array 1B near Rooster Rock State Park was 85.1% (95% CI =82.4, 87.7), and this was significantly lower than radio telemetry estimates of 94.4% (95% CI = 91.3, 97.6) in spring 2004 (for a control release below the B2 JBS outfall - Counihan et al. 2006f) and of about 97.1% in spring 2005 (Counihan et al. 2006g).

4.4.5 Virtual Releases from The Dalles and Bonneville Forebays

Acoustic and radio dam-survival estimates are not exactly comparable because the former were based on single release models and the latter on paired-release models. However these estimates were the only ones available for comparison, given problems with paired-release models for TDA and BON, as described in Results Section 3.4.7 and discussed in Section 4.4.6 below. Our TDA virtual release estimate of dam and tailwater survival of 94.7% (95% CI = 93.4, 96.1) for the reach from the TDA forebay to Array 1T near Hood River was slightly higher than the radio telemetry dam estimate of 90.6% (95% CI = 89.0, 92.2) for 2004 and did not differ from the 2005 dam survival estimate of 93.3% (95% CI = 94.4, 96.8).

Our BON virtual release estimate of dam and tailwater survival of 91.9% (95% CI =89.1, 94.7) did not differ from the radio telemetry dam-survival estimate of 95.1% (95% CI = 93.7, 96.6) for 2004 based on overlapping 95% CIs but was slightly lower than the 2005 estimate of 96.6% (95% CI = 95.2, 98.0). Of course our estimate was based on a single-release model and theirs was based on a paired release model and that would account for the observed difference. Tailwater mortality is included in the single-release models but not in the paired release models.

4.4.6 The Dalles and Bonneville Project Passage Survivals

Project passage survival for TDA using JDA Tailrace releases as treatment fish and TDA Tailrace fish as control fish was 92.8% (95% CI = 90.3, 95.4). This estimate was 6.2% higher than a TDA Project survival estimate of 86.6% (95% CI = 84.3, 88.9) for 2004 by Counihan et al. (2006a) and similar to a TDA Project estimate of 89.2% (95% CI = 86.4, 92.0) for 2005 (Counihan et al. 2006b).

The Dalles and BON releases were used to estimate BON Project survival, and our initial estimate of 1.0583 (95% CI =1.01126, 1.10534) was high. It was based on the ratio of a single-release estimate for TDA Tailrace fish of 90.0% (95% CI =87.2, 92.9) and a pooled control release (BON Tailrace) estimate of 85.04%. Even if we drop one very low control release estimate of 70.8% (Table 3.9) and recalculate an average control release estimate of 90.9% (95% CI =88.8, 92.9) from the three remaining control estimates, we obtain a revised paired-release project estimate of 99.0%, which still seems high.

The estimates of survival are too low for tailrace-released fish or the estimates of survival for the treatment fish are too high, and the former possibility seems most likely. Survival of radio-tagged control releases below the B2 JBS outfall was 94.7% (95% CI = 91.3, 97.6) in 2004 and a joint probability of detection and survival on at least one of three arrays was 97.1% in 2005; this suggests that survival of acoustically tagged control fish may have been low in 2006. In addition and within the same year, route-specific estimates for yearlings passing through the B2CC and spillway were 94.6% and 94.1%, respectively; these estimates were higher than the 90.9% estimate for the last two control releases and certainly higher than the four-release control estimate of 85%. If we took an average of those estimates (94.4%) as a tailrace survival estimate, we would have generated a paired-release estimate of Project survival of 95.4% (95% CI =89.3, 101.5) for spring 2006. This is very similar to single-release estimates for fish passing the B2CC and the spillway in spring.

Given poor mixing of treatment and control releases in the paired release model for BON, it might be best to assume 100% control release survival and use the single release estimate of 90.9% (95% CI =88.8, 92.9) for project survival (pool and dam). In 2004, a radio telemetry estimate of BON project survival was 90.8% (95% CI = 88.1, 93.7%) during spill to the gas cap at night (Counihan et al. 2006f), which is the condition that prevailed most of spring 2006. In 2005, project survival by radio telemetry was estimated at 92.9% (95% CI = 91.0, 94.9) for a 75 kcfs day and gas-cap-night spill condition. These radio telemetry estimates probably do not differ significantly from our single-release survival estimate of 90% (95% CI =87.2, 92.9), based on overlapping 95% CIs.

4.4.7 Tests of Assumptions

There were no significant trends in detection probabilities or survival through time in spring, so we were able to pool estimates for the season.

Some homogeneity tests were significant because of Chi square test sensitivity to large sample sizes, but we know that treatment and control fish mixed and experienced similar tailwater conditions relative to time of day because median arrival times were within 2 hours of each other and 95% confidence intervals overlapped (Figure 3.16). Differences in arrival times < 2 hours are not biologically significant, although they can be statistically significant. The paired release model for JDA Turbine, Front Roll, and Tailrace releases was the only one designed before the 2006 study began.

There were significant departures from mixing for pairings of JDA Tailrace and TDA Tailrace Releases and for pairings of TDA and BON Tailrace releases, primarily because these pairings were made post hoc without benefit of planning to synchronize timing. Research at the three projects was originally conceived and proposed as separate pilot studies, and post-hoc pairings were our way of trying to get the most from available data. Nevertheless, data from the next reach downstream of the reach from TDA to Array 1T (i.e., from 1T to 2T) suggest that survival processes were stable regardless of differences in the time of passage. Survival and detection estimates for the 1T to 2T reach did not differ significantly for JDA and TDA Tailrace releases, and neither had significant temporal trends in spring. In addition, high river flow throughout spring 2006 resulted in a consistency of discharge among days and among hours that may not occur in an average or low-flow year, and this likely contributed to stability in survival processes. Similarly, survival estimates for TDA and BON Tailrace releases from Array 1B to 2B did not differ from each other and had no seasonal trend, which again suggests that survival processes were stable for the two release groups.

Clearly, inter-dam travel times need to be used to stagger upstream–downstream release times for better prospects of mixing in future studies. The violation of model mixing assumptions for JDA and TDA Tailrace pairs and for TDA and BON Tailrace pairs leaves ample room for improvement. We used time of travel data as a function of river discharge each season (Figures 3.29 and 3.30) to develop equations for predicting appropriate lag times between upstream and downstream releases as a function of river discharge. In the future, researchers can use equations in Figures 3.31 through 3.35 as a starting place to predict appropriate lag times from forecasts of river discharge. Data on travel times from years with a lower range of discharge also should be consulted to increase the appropriateness of lag estimates for normal to low water years. River discharge was higher than average throughout spring and the first half of summer.

Survival models assume that upstream and downstream detections did not affect estimates of detection or survival, and we applied Burnham et al. (1987) Test 2 and Test 3 to evaluate that assumption. Two out of the three JDA releases had significant ($P < 0.10$) Burnham et al. (1987) Test 2 results (Appendix D, Table D.1), but none of the tests was significant for the JDA, TDA, or BON Tailrace releases (Appendix D, Tables D.2 and D.3). None of the Burnham et al. (1987) Test 3 results were significant for any of the release groups tested (Appendix D, Tables D.4-D.6). This was not surprising because there was no physical mechanism like recapture or re-handling associated with detections to affect downstream detection performance. Counihan et al. (2002a) noted that the utility of these tests seemed to be affected by high capture probabilities at radio telemetry arrays, and if true, that would also be the case for tests on pooled data in this study. For the Intake 9C release, pooled data had a highly significant Test 2 ($P = 0.0001$), but the Chi square test statistic was only significant in one of six tests (16.7%) that could be calculated (83.3% were not significant). The other release with a significant Test 2 for pooled releases was the JDA Tailrace where only three of eight releases could be calculated of those, two were not significant and one was significant.

It is no longer clear that the Burnham et al. (1987) test of goodness-of-fit is ever relevant to radio- or acoustic-tag studies where recaptures are not physical. The high detection rates and lack of mechanism for model violations appear to make the violations artifacts of previous technologies. Other possible explanations for violations of assumptions are only reasonable if the explanations are plausible. There is no evidence that water depth or schooling are affecting hydroacoustic-detection histories.

4.4.8 Survival through Successive Reaches

In spring, a plot of survival from point of release to each array but the last in the study area indicated that most losses occurred in reaches with dams rather than in reaches between dams (Figures 3.17 and 3.24). Cumulative survival plots are a good way to summarize single-release model results. Between-dam reach survivals from JDA to TDA and TDA to BON were among the highest observed in this study. Smolts released from the LGR Tailrace had the lowest survival of all released smolts with a survival rate of 37% but only because these fish had to pass through five dams before reaching the primary array at JDA and a total of seven dams by the time they left the last array below BON with a survival rate of 37%. However, the average dam and tailwater survival to Array 1J (10.2%) was similar to estimates observed for other releases in this study and in previous survival studies on the lower river, as mentioned in Section 4.4.2 above. Only 68% of fish released in the JDA turbine intake survived to reach the BON secondary array. The other two JDA releases had survivals ranging from 70% to 75% by the time the smolts reached the final arrays. The TDA Tailrace-released smolts had the highest survival rates in spring, with 90% reaching the BON secondary array. The BON Tailrace-released smolts had a lower survival rate of 81% at the BON secondary array for unknown reasons. This result was surprising since fish released below BON did not have to travel through any dams. However, all smolts released below BON were released through the BON JBS. Early in the season, large numbers of predatory birds were observed sitting on the outfall tubes of the JBS actively feeding on smolts exiting the JBS. Steps were taken to remedy this by releasing tagged smolts at night when predatory birds were not actively feeding.

4.4.9 Bonneville Route-Specific Survival (Pooled Releases)

Regrouping fish as they passed through the BON spillway, B2 JBS, and B2CC regardless of release location was the only way to obtain enough detections to make these route-specific survival estimates and even then sample sizes were low.

4.4.9.1 Spillway, B2 JBS, and B2CC

We could not distinguish between survival rates of yearlings passing the B2CC, B2 JBS, and spillway because of low precision of estimates associated with small sample sizes. The estimate for the B2 JBS of 89.3% (95% CI =73.0, 105.6) did not differ from estimates for the B2CC of 94.6% (95% CI =84.6, 104.6) or from the spillway estimate of 94.1% (95% CI =87.1, 101.1), according to overlapping 95% CIs. The highest survival estimates for the B2CC and spillway did not differ from the BON project estimate of 89%, for the same reason.

We compared acoustic telemetry estimates with radio telemetry estimates reported by Counihan et al. 2006f and 2006g and found no significant differences, mostly due to poor precision in our estimates, which were based upon low numbers of detected fish (42-134). Spill was lower in spring 2004 and 2005 than it was in spring 2006, but radio telemetry survival estimates of 91.0% (95% CI = 88.8, 93.2) in 2004 and of 93.0% (95% CI = 91.2, 94.7) in 2005 did not differ significantly from our estimate for the spillway or from each other. If we divide the 2006 single-release model estimate for the B2 JBS (89.3%) by 90.5%, which is the average survival for the last two BON Tailrace releases that were concurrent with our releases, we get a paired-release point estimate of 98.7%. This paired-release estimate is between the 97% estimate for 2004 and the 100% estimate for 2005 based on radio telemetry. Radio telemetry studies in 2004 and 2005 produced paired release survival estimates of 102% each year, and that would not differ significantly from either our single release estimate of 94.6% (95% CI =84.6, 104.6) or a paired release estimate of 104.5%.

4.4.9.2 Spillway by Time of Day

Spillway survival during the daytime hours (96%) did seem to be slightly higher than a nighttime estimate of 88%, but completely overlapping 95% CIs indicate that this difference probably was not significant. Spill was consistently high (to gas cap) 24 h per day, so diel shifts in spill would not have been a major driving factor in spring 2006. This was not the case in 2004 or 2005 when radio telemetry studies were conducted and river flow was low enough to provide day and night differences in spill.

4.5 Detection and Survival of Subyearling Chinook Salmon in Summer

4.5.1 Tag-Life Study Correction

As in spring, no tag-life correction was needed or used for the summer survival study of subyearling Chinook salmon because examination of the tag-life curve and arrival distributions of fish to downstream detection arrays (Appendix E) indicated that the vast majority of fish arrived before the time of first tag failure. Only three releases show any need for tag-life correction, and these had tag-life probabilities > 99.9%, which made a correction inconsequential because it would only inflate the variance and would not change point estimates.

4.5.2 Little Goose Tailrace Releases

A significant decline in survival estimates during summer suggests that many fall subyearling Chinook salmon stopped migrating or died before reaching the beginning of our study area below JDA. The possibility of residualization in upstream areas is supported by results of the Lower Monumental Fall Chinook Behavioral Study (Cook et al. 2007). Throughout that study period, 44% (N = 852) of the study fish did not pass downstream of Lower Monumental Reservoir even though detection probabilities of seven acoustic arrays downstream of the LGS Tailrace were unchanged throughout the season. The majority (N = 647; 76%) of the fish that ceased downstream migration did so in the stratified portion of the reservoir and upstream of Lower Monumental Dam, and most of the fish that stopped in the isothermal zone were never detected at any of the acoustic telemetry arrays (N = 170; 20% of the fish that did not emigrate from the reservoir). Researchers attribute the loss of these fish to predation near the release site because this was supported by mobile tracking data. Regardless of residualization, if most fish were ultimately lost, then the apparent downward trend in survival may be real.

Because of the reduction in apparent survival, data from replicate releases should not be pooled, but analyzed separately to properly characterize the between-release variability (Figure 4.1). Interestingly, the difference in survival between successive primary arrays in our study area also decreased significantly, indicating that residualization or mortality continued within our study area.

4.5.3 John Day Tailrace Releases

Releases from the JDA Tailrace in summer were designed to establish single-release detection and survival probabilities and, for the limited time that releases were made (five releases between June 16 and June 27), that was accomplished. Detection and survival estimates to Array 1J were consistently high, ranging from 98% to 100%. We could not find comparable estimates in radio telemetry reports, so we made an estimate for the reach from the JDA Tailrace to Array 3J, which is similar to the pool estimates for the 2004 and 2005 TDA survival studies (Counihan et al. 2006a and b). The TDA "pool" estimate for this study was 95.7% (95% CI =93.3, 98.1), and this was slightly higher than a summer 2004 estimate of 91.1% (95% CI =89.6, 92.7) based upon releases through July 21 of that year (Counihan et al. 2006a). However, it was very similar to a summer 2005 estimate of 94.7% (95% CI =93.6, 95.9). Our last survival estimate for subyearlings traveling from JDA to Array 3J near the TDA forebay was the lowest in summer 2006 at 89.0% (95% CI =82.9, 95.2), and it did not differ from either JDA Tailwater estimates by radio telemetry.

We had originally planned for 10 releases lasting until July 13, but releases were stopped on June 27 to increase the size of releases below TDA when the spill pattern was to shift to a Bi-op pattern of about 75,000 cfs day spill and gas-cap spill at night. Curtailing releases likely prevented us from detecting a trend of decreasing survival for these releases in summer, something that we did observe for LGS, TDA, and BON releases, which ran until mid July (Figure 3.27).

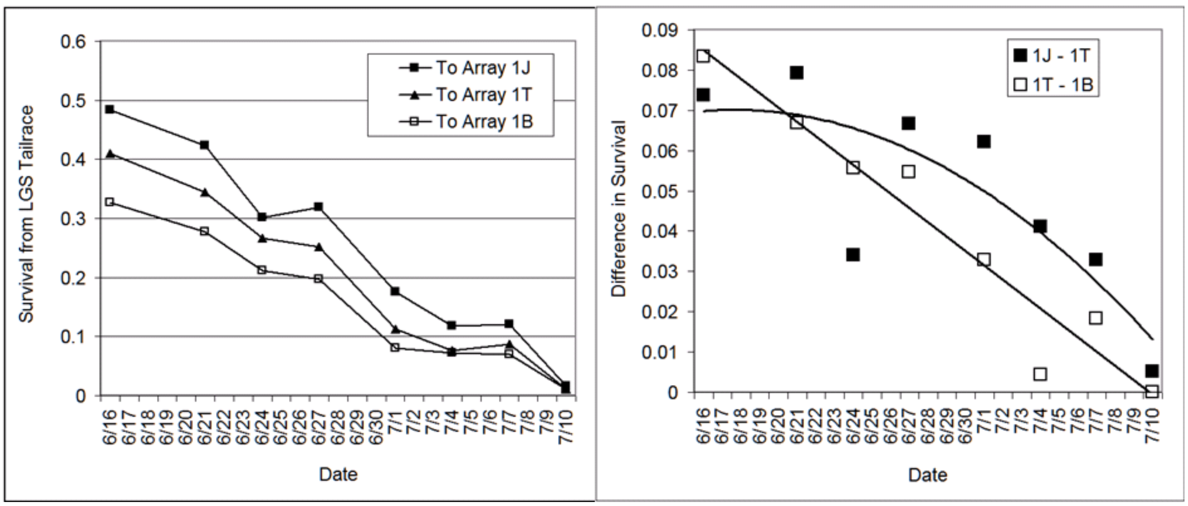


Figure 4.1. Apparent Survival of Subyearling Chinook Salmon Released from Lower Goose Tailrace in Summer Down to Primary Arrays in the JDA, TDA, and BON Tailwaters (Left) and Differences in Survival Between Successive Primary Arrays (Right).

4.5.4 The Dalles and Bonneville Tailrace Releases

Survival of TDA Tailrace releases of subyearlings in the BON pool declined moderately as summer progressed, a fact that could be hidden by summer pooled and arithmetic mean estimates of 97% in Table 3.27. We calculated estimates for TDA Tailrace fish down to Array 3T in the BON forebay and found that apparent survival declined significantly during summer so that an average estimate would depend upon the length of the summer release season (Figure 4.2). The last release was on July 13 in 2006, July 20 in 2004, and July 17 in 2005.

Subyearlings released from the BON Tailrace in 2006 also exhibited a trend of apparently decreasing survival during summer (Figure 4.3), although this trend was not as pronounced as it was for the BON pool upstream. We could not find survival estimates for controls released into the BON Tailrace in 2004 and 2005 radio telemetry reports (Counihan et al. 2006f and g), but combined probabilities of those fish surviving and being detected on at least one of three arrays was 94.7% to 94.8% in 2004 and 95% in 2005. Survival probabilities should have been slightly higher than those combined probabilities, and this would put them within the range of survival estimates depicted for 2006 (Figure 4.3).

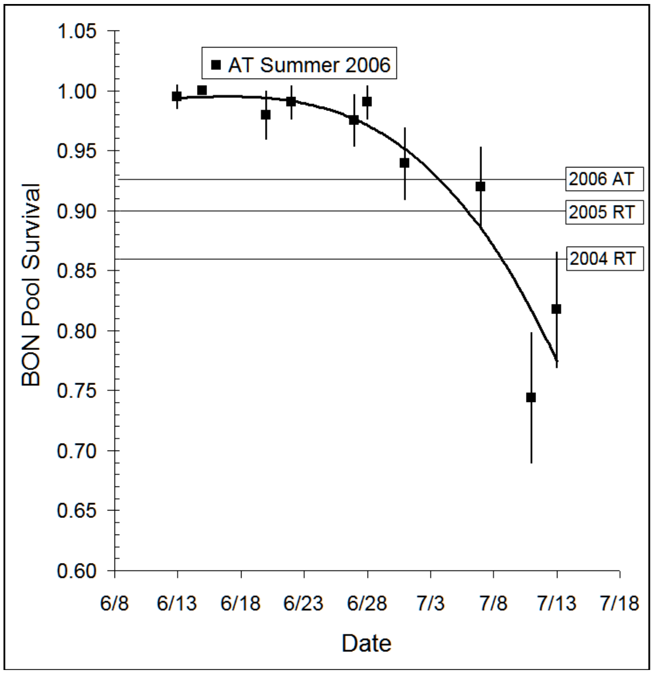


Figure 4.2. Apparent Survival of Subyearling Chinook Salmon Released from the TDA Tailrace in Summer Down to Array 3T just above BON. Vertical bars are 95% CIs. Horizontal lines show means for this study (2006 AT) and for the 2004 and 2005 radio telemetry (RT) studies (after Counihan et al. 2006a and b).

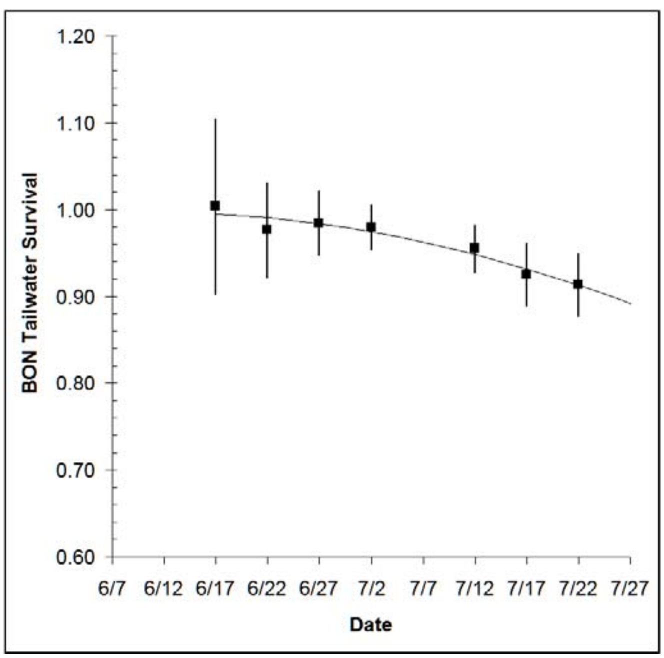


Figure 4.3. Apparent Survival of Subyearling Chinook Salmon Released from the BON Tailrace in Summer Down to Array 1B. Vertical bars are 95% CIs.

4.5.5 Virtual Release from The Dalles and Bonneville Forebays

Releases into the JDA Tailrace ended on June 27, and therefore trends in virtual survival estimates for TDA did not exhibit an apparent summer decline as observed elsewhere. Subyearlings clearly suffered significant losses in passing TDA as the summer estimate was 86.3% (95% CI =82.3, 90.4). If we divide this estimate by 97% (a TDA control release estimate) we get a paired-release estimate of 89.0% (95% CI = 84.5, 93.5), which is slightly higher than a TDA Dam survival estimate of 81.7% (95% CI = 79.5, 83.9) in 2004 (Counihan et al. 2006a) and similar to an estimate of 90.0% (95% CI = 88.1, 91.8) in 2005 (Counihan et al. 2006b).

Virtual survival estimates for BON in summer declined significantly after June 22, 2006 (Figure 4.4) and therefore the estimates cannot be pooled or averaged without obscuring important trends in apparent survival (residualization or survival). Point estimates of BON survival based on paired-release radio telemetry estimates in 2004 and 2005 are illustrated as lines in Figure 4.4, and both point estimates fall within the range of JSATS estimates for summer 2006.

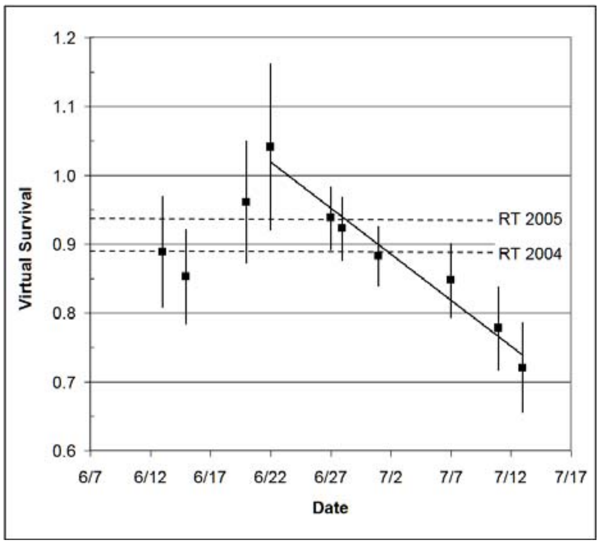


Figure 4.4. Apparent Survival of Subyearling Chinook Salmon Regrouped at Array 3T above BON. Vertical bars are 95% CIs. Horizontal lines show means for the 2004 and 2005 radio telemetry (RT) studies (after Counihan et al. 2006f and g).

4.5.6 The Dalles and Bonneville Project Passage Survivals

4.5.6.1 The Dalles Project

We compared our project survival estimates based upon concurrent treatment and control releases, which ended before the decline in survival began in 2006, and compared them with project survival estimates reported by Counihan et al. 2006a and 2006b. Our estimates for the TDA project for summer 2006 of 82.9% (95% CI =78.6, 87.2) based on all releases and of 85.2% (95% CI =82.8, 87.7) based on concurrent releases were higher than the radio telemetry estimate of 69.4% (95% CI = 66.7, 72.0) for 2004 (Counihan et al. 2006a) but similar to an estimate of 85.2% (95% CI = 82.4, 88.0) for 2005 (Counihan et al. 2006b).

There was ample opportunity for seasonal survival trends to have made the 2004 radio-telemetry estimate lower than our estimate and that of the 2005 radio-telemetry study. Our JDA releases ended prematurely on June 27 before a seasonal decline in survival, whereas the 2005 study released fish there through July 17, and the 2004 study, with the lowest point estimate of project survival, released fish through July 28. Spill-bay survival estimates from Counihan et al. (2006a, Appendix 8) show a clear trend of decreasing survival after about July 12 and this trend would reduce the point estimate for TDA project survival to something lower than observed in 2005 and 2006 (Figure 4.5). We could not recalculate the 2004 point estimate for project survival for a shorter season because survival estimates were not reported for individual releases. However, in Counihan et al. (2006a, Figure 11) shows a seasonal decline in dam survival based upon eight-day increments that suggests that shortening the 2004 release season by eight days would have increased the 2004 point estimate at least 10%.

4.5.6.2 Bonneville Project

Our 2006 survival estimate for JSATS-tagged fish of 83.7% (95% CI =80.8, 86.7) based on concurrent releases below TDA and BON was higher than the 2004 project survival estimate for radio-tagged fish (76.8%; 95% CI = 74.7, 78.8) but very close to the 2005 radio telemetry estimate of 84.4%. The 2004 study started releasing fish on June 20 and ended on July 20, which was about a week later than our summer schedule, and, given trends in summer survival in 2004 (Figure 4.5), may account for differences between our BON project estimate for 2006 and the radio-telemetry estimate in 2004.

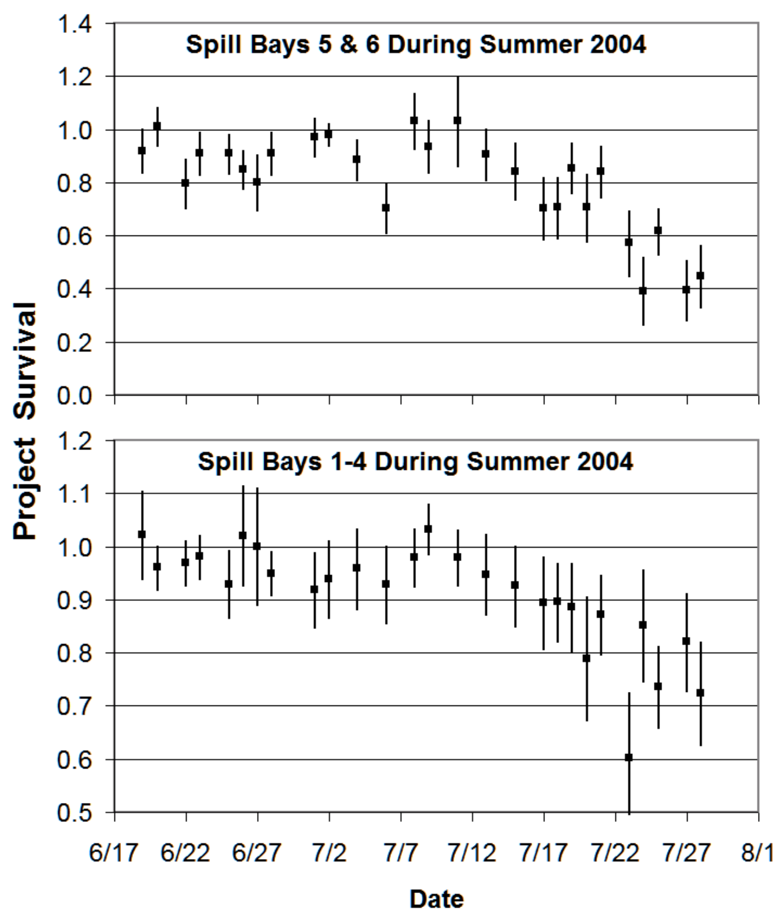


Figure 4.5. Apparent Survival of Subyearling Chinook Salmon Released above TDA Spill Bays in Summer 2004. Vertical bars are standard errors. Data were from Appendix 8 in Counihan et al. 2006a).

4.5.7 Tests of Assumptions

Mixing violations for post-hoc pairings of JDA and TDA releases may not have been as detrimental as goodness-of-fit-tests indicated, although we acknowledge that mixing could be improved. The JDA and TDA tailrace releases used to estimate project survival at TDA showed significant ($P < 0.001$) departures from mixing in summer, primarily because releases after June 27 in the TDA Tailrace had no treatment counterparts. These mixing violations raised concerns about interpreting paired-release project survival models for TDA, so we recomputed estimates using only data acquired during the period of concurrent releases, and the resulting survival estimate of 82.9% (95% CI =78.6, 87.2) did not differ significantly from the estimate based on all releases (85.2%; 95% CI =82.8, 87.7). Hourly time-of-arrival data indicated that the slowest and fastest fish from the JDA or TDA groups could arrive any hour of the day, but there was a clear 4-h difference in mean arrival time that may have affected survival conditions. Post hoc paired-release estimates were our attempt to extract as much information as possible from the JDA and TDA releases. Future studies could use the regression equation (Figure 3.35) to calculate a lag between upstream and downstream release times to assure mixing of treatment and control fish in the common tailwater reach below TDA. Travel times from other years should be considered as well because 2006 was a high-water year.

The BON Project survival estimate of 83.7% for concurrent releases is considered reliable because subyearlings from the TDA and BON Tailraces traversed the BON Tailwater at about the same time of day, even though all release data indicated significant differences in arrival distributions. However, the point estimate is not particularly meaningful given the significant decrease in survival during summer. Mixing violations resulted primarily from non-concurrent releases of two control groups and one treatment group, but even after we dropped those releases, the revised survival estimate of 83.7% (95% CI =80.8, 86.7) did not differ from the original estimate of 84.9% (95% CI =80.4, 89.5). For the concurrent releases, time of arrival data indicated that the average arrival hour at Array 1B for TDA Tailrace releases was 1040 hours ($\widehat{SE} = 6$ hours), and for BON releases, it was 0913 hours ($\widehat{SE} = 2.2$ hours).

None of the calculable Burnham et al. (1987) Test 2 results were significant, and only one Test 3 result was significant. It indicated that the capture history to Array 2T had an effect on detection at Array 1B. There is no physical mechanism for such an effect, but very high detection probabilities on upstream arrays (Pool estimate = 99.1% to 100%, see Table 3.27) relative to a lower probability of 81.5% for Array 1B may have produced a false-positive result. When we ran the Test 3 on 10 individual releases, only one was significant, out of the four that were calculable. With high detection probabilities, the utility of these tests may be questionable.

4.5.8 Survival through Successive Reaches

Survival estimates for summer, as in spring, were estimated from release location to the final array and showed that the most significant decreases were in reaches that included passage through a dam (TDA or BON; Figure 3.25). Mortality for non-dam reaches usually was < 5%. The decline in survival of JDA-released subyearlings in the reach including TDA was three times greater than that observed in spring for yearlings. The TDA release showed similar results for passage through BON with a 13% decrease in survival from TDA3 to BON1. This decline was double that experienced by yearlings in spring.

Possible reasons for a steeper decline in survival in summer include lower flows, higher water temperatures and associated increases in thermal and disease stress, smaller fish size in general and relative to tag size, and residualization of subyearlings in the TDA Tailwater. The fact that losses for non-dam reaches are much lower than for reaches with dams suggests that residualization is not a dominant factor causing losses in the lower river. Smaller size and lower energy reserves likely make subyearlings more susceptible to death than yearlings. For fish of the lengths that we tagged in summer (> 95 mm), the tag-effects study showed minimal tagging mortality, although it was higher than that observed for yearlings (Rich Brown, PNNL, Personal Communication).

4.5.9 Bonneville Route-Specific Survival (Pooled Releases)

4.5.9.1 Spillway, B2 JBS, and B2CC

There were few surprises in the point estimates of survival for the B2CC, B2 JBS, and spillway in summer. Survival at the spillway decreased almost 15% in summer relative to a 5% drop in spring, but the summer estimates for the B2CC and B2 JBS did not differ from spring estimates. Based upon non-overlap of 95% confidence intervals, the B2CC estimate of 95.24% (95% CI =89.09, 101.4) could be significantly different from a 85.77% (95% CI =82.48, 89.07) estimate for the spillway, but the B2CC estimate did not differ from the B2 JBS estimate of 90.7% (95% CI =84.6, 96.8) and the B2 JBS estimate did not differ from that of the spillway, mostly because of poor precision associated with a small number of detected fish (91 at the B2CC, 189 at the B2 JBS, and 706 at the spillway).

4.5.9.2 Spillway Survival by Condition

Our comparison of subyearling survival during three different spill conditions in summer was confounded by an independent decline in survival as summer progressed and the chronological order of three successive spill conditions. The earliest spill condition through June 25 happened to be 24-h spill to the gas cap, and it had the highest survival (96.0%; 95% CI = 88.7, 103.4). The next condition was 24-h ≤80,000 cfs spill, which occurred from June 26 through about July 5. It was associated with a lower, although not significantly lower, survival estimate (87.8%; 95% CI = 82.6, 93.0) than the first 24-h high spill condition. The third spill condition was Bi-op spill of 75,000 cfs during the day and spill to the gas cap at night. It lasted through the end of the summer releases and not surprisingly was associated with a significantly lower survival of 78.3% (95% CI =73.1, 83.5) that probably would have occurred regardless of the spill treatment.

There are several comparisons of results that reinforce our conclusion that survival trends for BON spillway-passed subyearlings were not related to spill condition but to date within summer. First, survival estimates for the 24-h gas-cap spill condition and the 24-h low-spill condition did not differ significantly, probably because both occurred before a summer decline in survival was obvious. Second, survival estimates associated with 75,000 cfs spill during the day and gas-cap spill at night did not differ significantly and were low (75.82-79.99%) because they occurred in mid to late summer when survival was low. In short, subyearlings that migrate in early summer had better survival than those migrating in later summer, regardless of spill condition at BON.

If there is a desire to test different spill conditions in summer, the confounding effect of decreasing survival through time must be considered and eliminated from the experimental design. We recommend confining tests of spill conditions to early summer periods or late summer periods to avoid confounding results.

4.6 Comparison of Estimates Using Preferred vs. As-Planned Arrays

In spring and summer, there were no differences in survival statistics calculated from “preferred” and “as planned” arrays, either because estimates were identical (7 of 17 in spring and 8 of 10 in summer) or because pairs of estimates had overlapping standard deviations. Therefore, future studies should maximize return on investment by using the arrays described at the end of Section 4.3 above whenever multiple projects are being studied.

4.7 Travel Time and Rate

Travel times and rates were primarily a function of river discharge, particularly when discharge was above 250,000 cfs (Figure 4.6), as it was in spring and early summer. Relations between travel time and discharge were much weaker when river discharge was < 250,000 cfs, a level that first appeared after June 26 and continued throughout summer 2006. This period coincided with declining survival estimates associated with increased mortality or residualization of subyearlings. Travel times were slower in summer than they were in spring, particularly at downstream locations (Figure 4.7). On average, subyearlings released at JDA took 10 hours longer than yearlings to make it from the first array below JDA to the last array below BON. For TDA Tailrace releases, subyearlings took an average of 5 hours longer than yearlings to reach the last array below BON.

Travel times were useful for identifying delays at dams when specific routes could be identified. Median egress times for yearlings released at three locations at JDA were shortest for tailrace-released fish (0.8 h) because they had the shortest distance to travel, longer for fish released into the Turbine 9 front roll (1.2 h), and longest for fish released into the Turbine Intake 9c (1.3 h) turbine. Egress times did not differ between turbine- and front-roll releases. Egress times were significantly and inversely correlated with river discharge, so that egress time was about one hour longer for fish released at minimum discharge (311,000 cfs) than it was for fish released at maximum discharge (387,000 cfs).

The time it took fish to traverse the BON forebay until they were detected passing the dam was much longer for fish using the B2 JBS than for other routes, probably because of holding delays in gatewell slots. Passage times were 4.5 to 21.6 times longer for B2 JBS-passed fish than for fish passing the B2CC or spillway. Delays are not desirable in late summer when survival estimates appear to decline significantly over time.

4.8 Using Time of Travel to Lag Paired Releases in Future Studies

Travel times were useful for deriving predictors of lag times between paired releases as a function of discharge (Figures 3.30 through 3.35) for future studies. We recommend the use of those equations for determining appropriate lag times to assure mixing in a common downstream reach.

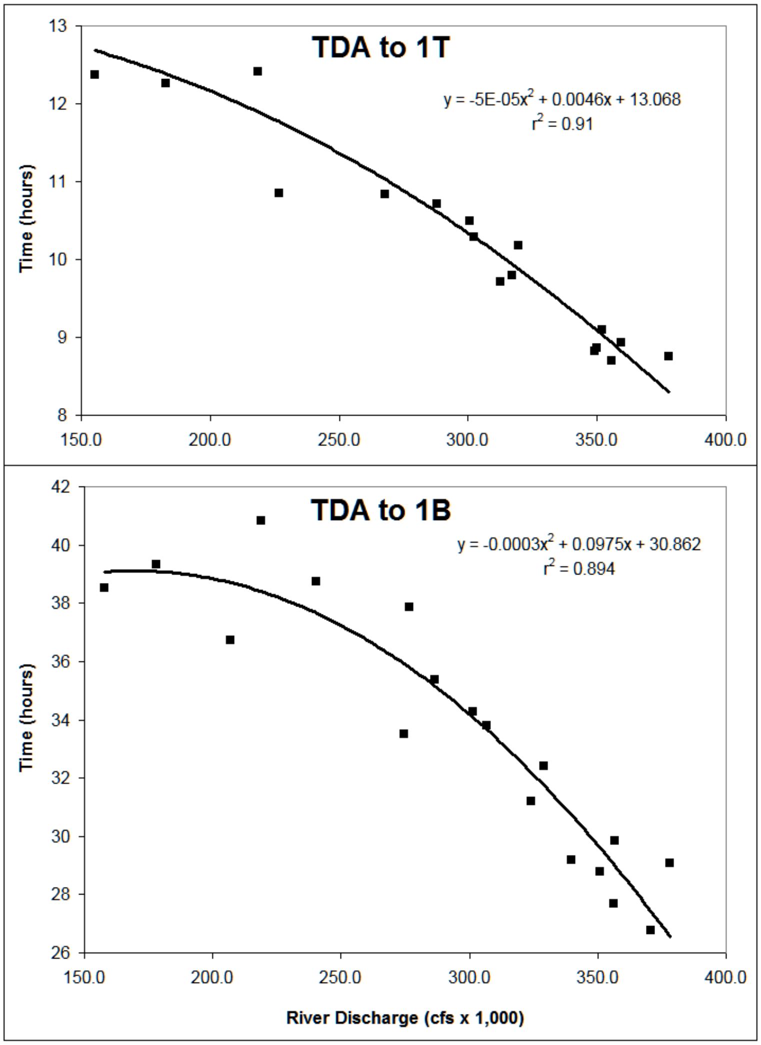


Figure 4.6. Travel Time as a Function of River Discharge for the River Reach from TDA to Array 1T near Hood River and from TDA to Array 1B near Rooster Rock State Park below BON

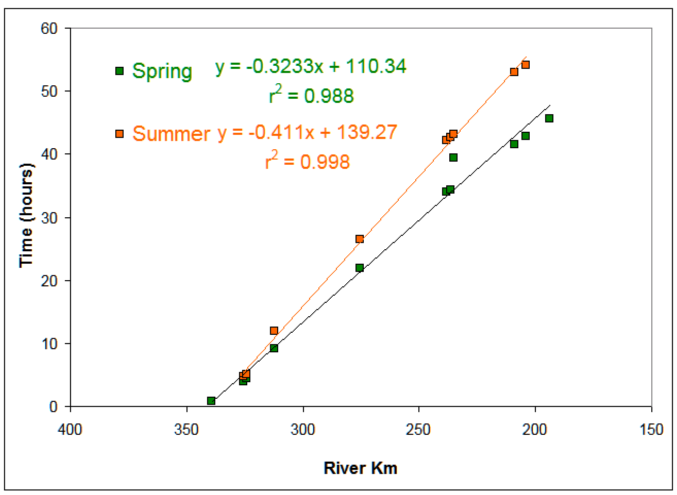


Figure 4.7. Travel Time in Spring and Summer as a Function of River Kilometer

4.9 Diel Distribution

Fish regrouped at Array 3T in the BON forebay from all upstream releases and passed the dam at all hours of the day, because diel distributions of arrival from TDA and JDA Tailrace release locations complimented one another. Most TDA Tailrace-released fish arrived during hours when arrivals from the JDA Tailrace releases were low (compare Figures 3.36 and 3.37). This serendipitous and broad representation of hours would not have occurred if we had carefully lagged JDA and TDA Tailrace releases to maximize mixing in those releases in the TDA Tailwater. Arrival and passage times may have an effect on survival of fish passing BON, but we may not have detected it because most daytime-passed fish arrived from TDA Tailrace releases while most night-passed fish arrived from further upstream at JDA. When time of arrival is related to release location and most fish from day and night periods have different passage histories, diel effects on survival could be confounded.

4.10 Cross Channel Distribution

One of the advantages of acoustic telemetry is that cross-channel distributions can be compiled to learn more about how juvenile salmonids migrate through river channel cross sections. Radio telemetry can detect passing fish but usually does not provide distribution data without a special effort like that described by Hansel et al. (2005 and 2007) to sample approach patterns in the TDA forebay.

A majority of fish were detected away from shore each season, and there was little evidence that subyearlings preferred to migrate near shore instead of in the middle of the river in summer (Figure 3.39). Only two of nine lateral distribution plots showed any skew toward shore in summer. The most reliable evidence came from primary arrays in each tailwater (1J, 1T, and 1B) because they each had five or six autonomous nodes. Distribution data from arrays with three nodes were less informative because it was possible that some detections on the center node could have come from tagged fish passing on either side of the river if the tag was simultaneously detected on two nodes. Simultaneous detection was common for arrays in the JDA and TDA tailwaters but was rare on the three arrays in the BON Tailwater.

We worried a lot about tagged fish migrating around islands and avoiding detection in the BON Tailwater, but the percentage of detections on nodes sampling side channels was low in two of three locations. Those nodes with low detection percentages included Node 1 on Array 1B, which was on a shallow flat downstream of the Sand Island side channel, and Node 4 on Array 2B, which was located downstream of a Washington side channel created by Miller Island. High detection percentages on Node 4 of Array 3B located at the upstream opening to Camas Slough formed by Lady Island made it the only exception. The Camas Slough entrance is located on an outside bend across from the mouth of the Sandy River and was not far from the navigation channel, but clearly this site must be monitored for an array to be successful at Lady Island. In contrast, Node 4 below the Reed Island side channel was on an inside bend. Node 1 below the Sand Island side channel was over a large shallow mud flat on the south shore of a straight stretch of river.

The four autonomous nodes and five fixed nodes were deployed at the BON spillway for the last week of spring and all of the summer monitoring season, and these receivers showed a skew in the percent of detections toward the south end of the spillway (Figure 3.40). Only 1% of all tags detected at the spillway were detected on the most northern receivers. The distribution of detections suggests passage locations but does not provide unequivocal evidence. A southerly skew in observed acoustic detections is consistent with the distribution of juvenile salmonid passage at the BON spillway based upon previous studies (Ploskey et al. 2006).

4.11 Physical Factors Affecting Array Detection Probabilities

We examined the frequency of detections on one or more nodes within each array to assess receiver coverage and to help explain observed detection probabilities of arrays described previously. Obviously, simultaneous detections on two or more nodes indicates that detection fields overlapped, and this situation is highly preferred over a predominance of detections on a single node. Arrays with very high detection probabilities had a majority of detections on 2 to 5 nodes, and this was the case for five of nine arrays (1J, 3J, 1T, 2T, and 3T). About 70% of detections at Array 2J were on single nodes, but only two nodes were functional in spring. Detection probabilities for JDA-released fish on Array 2J averaged 88% in spring and 96.8% in summer when three nodes were functional. The percent of multiple-node detections on this array for 2006 would have been higher than 30% had three nodes been functional each season.

The BON Tailwater arrays, which had the lowest detection probabilities (mean = 67.6% in spring and 80.2% in summer), received 80% or more detections on a single node (Figure 3.42). Array 1B had 16% multiple node detections, showing that contributing factors of node density and bathymetry played a role in the poor performance of this array. The maximum depth of Array 1B was 50 ft and distance across the river was around 1,100 ft.; therefore, spacing of nodes was much greater than at Array 1T. Array 2B and 3B performed similarly in spring with only 9% detections on multiple nodes. Both of these arrays had three nodes covering a 650-m transect across the river and a backwater node separate from the main transect. Array 2B had a node that was on the north side of Reed Island to detect tagged fish exiting the side channel and Array 3B had a node out the mouth of the Washougal River to detect tagged fish entering the Camas Slough. Separate nodes for sampling side channels would not allow for simultaneous detections on the side channel node and other nodes in the main channel, but multiple node detections should have occurred on the other three nodes.

The 2006 single- and multi-node detection results indicate that the best location for an array is at a cross section that is deep and narrow and the worst location is one with extensive shallows, uneven bathymetry, and islands that limit sound propagation and maximize multi-path signals. Primary factors affecting array performance include the shape (depth and width) of the river cross section and node density. In 2006, multiple detections were more common at upstream locations that tended to be deeper and narrower than locations below BON, where finding narrow cross sections without bars, islands, and side channels was difficult.

Examination of scatter plots of detection probability regressed on physical variables provided some useful recommendations for deploying acoustic receivers. The ultimate measure of array performance is detection probability, but it is not always clear what physical factors affect detection probabilities. Our examination of correlations of observed average detection probabilities with several physical factors (Table 3.59; Figure 3.41) led us to recommend the following to provide a reasonable chance of achieving detection probabilities > 80% in future studies.

1. Arrays should be located at the narrowest and deepest (mean depth > 14 m) cross sections available, after allowing enough travel distance to avoid detecting dead fish on an array. There was a significant negative correlation between detection probability and river width and a positive correlation between the probability and mean depth.
2. We recommend deploying enough autonomous nodes to keep inter-nodal distances < 150 m, so that node densities are at least six per km of river width.
3. Offshore distances to the first node on either side of the river should not exceed 100 m.

Limiting offshore distances to 50 m and inter-node distances to 100 m (i.e., node density $\approx$ 10 / km) would provide completely overlapping coverage so that the loss of any single node would not diminish detection probability. The loss of two adjacent nodes would only leave a small breach in coverage. An example approaching such a deployment was Array 1T in the TDA Tailwater. This array had 82% of detections occurring on multiple nodes because the width of the river at this array location was only 500 m and five nodes were deployed there, so that the inter-node spacing with five nodes was 100 m. The offshore distance was about 100 m, which is double the 50 m recommended for overlapping coverage. The depth of the river in this location ranged from 35 ft to 120 ft. TDA2 and TDA3 performed similarly in that around 80% of detections were multiple node detections.

4.12 Data Gaps

We tried to deploy nodes with overlapping coverage to minimize impacts of node failure or loss but did so without benefit of an extensive data set on range of detection. In short, we used node densities and inter-nodal distances based upon experience with detections on previous estuary arrays, and we were limited by the number of nodes available in 2006. Each year and season can have very different factors that result in malfunction, loss, or damage.

In spring, there were multiple factors that resulted in data loss. First, higher-than-average spring flows caused an increase in the amount of debris in the water to collide with and damage fragile hydrophones or snag rigging and drag entire assemblies downstream. Second, high water in spring 2006 delayed recovery of many of the first round of deployments for about three weeks because we used tagline canisters. In the initial deployment, tagline canisters were used to allow recovery of anchors and reduce costs; however, the combination of taglines, high pool elevations, and high flow caused serious recovery problems. Depending upon river depth, nodes rigged with tag-line canisters and 250 ft of line surfaced for only 10-40 seconds after acoustic triggering of the release mechanism before submerging again. Dragging for re-submerged nodes was a very time consuming and potentially dangerous process. Also, with the limited amount of time nodes were at the surface, nodes could be damaged during a speedy approach by the recovery boat. If not dragged up, nodes were suspended below the surface and vulnerable to commercial vessels. This second problem was solved in late spring with the removal of all taglines and switching to disposable anchors.

The version of nodes deployed in 2006 provided no indication of whether they were acquiring data when sealed and ready for deployment. The 2007 version will have light emitting diodes to provide that indication, which will be a great improvement. We recommend having future nodes transmit a coded signal every 15-30 seconds to remotely indicate the node's status to researchers in a nearby boat. The codes might include the status of batteries, data-storage space, and data acquisition. With this capability, researchers could visit the nodes twice a week, once to check on performance without having to retrieve each node, and a second time, to download data.

The number of data gaps was lower in summer than in spring, but new problems arose. As water levels started to decline, especially below BON, one node was hit by a boat and destroyed, and two other nodes had to be removed due to low water levels. We had more problems with commercial fisherman snagging nodes, damaging node tips, and dragging nodes downstream. Talking with commercial fisherman and ultimately moving two arrays slightly helped decrease the probability of data loss, but it did not resolve the problem. The insufficiency of spare nodes became apparent in early summer when four nodes from various parts of the river went out and no spare nodes were available to replace them. Therefore, we removed the BON tertiary array and those nodes were used to fill holes in other arrays.

After 3 weeks, we were able to borrow enough spare nodes from the Estuary Survival Study to redeploy the BON tertiary array, but by then half of the summer season was over. Until node losses can be accurately forecasted, we recommend that researchers plan to have one spare node for every four that will be deployed.

4.13 Survival and Dam Operations, Rate of Travel, Water Temperature

Significant positive correlations of survival probabilities with travel rates of some releases in spring and with travel rate and discharge in summer make sense based upon some published information (Raymond 1964; Sims and Ossiander 1981; Cada 1997). Most researchers agree that there may be a weak positive correlation between travel rate and survival, although variability is high and sometimes correlations are not significant (e.g., Bickford and Skalski 2000). We were reassured by significant positive correlations of survival with rate of travel for all three JDA releases in spring and for the JDA Tailrace release of subyearlings in summer. Explained variation ranged from 21% to 50%. However, we were puzzled why the same correlations were not observed for TDA Tailrace releases in spring or summer. It also is strange that discharge, which is a strong correlate with travel time (Zabel and Anderson 1997), was not also consistently correlated with survival whenever we found significant correlations of survival with travel rate.

The strong decline in survival of subyearlings in summer would make correlations with discharge and temperature very likely, but it is not indicative of cause and effect. During the first half of summer, discharge was above the last 10-year average and temperature was about average, but during the second half of summer, the opposite was true (discharge was well below average and forebay temperatures were above average – see Figure 3.1). Loss of fish to residualization (reverse smoltification) in summer could produce spurious correlations of apparent survival with discharge and water temperatures, simply because there is a usually a downward trend in discharge and an upward trend in water temperature at that time. Sorting out cause and effect would require more information than is available from this study. One might accept that forebay water temperature could have a negative impact on survival in summer, as observed for both JDA and TDA releases, but it is more difficult to imagine a temperature effect in spring, as observed for TDA Tailrace releases.

4.14 Required Sample Sizes

We used detection and survival estimates from this study to estimate one-half 95% CIs as a function of sample size for all reported releases and model designs and tabulated those results so that readers could look up required sample sizes needed to obtain a desired 95% CI, assuming similar detection and survival estimates to those observed in 2006. These tables should be useful for conducting power analyses for future studies that have a specific study design in mind. There is a one-to-one correspondence between the release-recapture study design, the desired level of precision, and the required sample size to achieve that precision, and calculations can only be performed within the context of a specific study design and a specified level of precision.

In addition to the relation between precision and sample size, performance of survival arrays and resulting detection probabilities have a significant impact on precision, and this relationship should not be ignored when estimating the number of tags needed for future studies. We have discussed in some detail the tradeoff between tagging more fish and deploying more nodes in Section 4.3 above. Our recommendation is to make certain that arrays are populated fully or even overpopulated with receivers to ensure high detection probabilities before buying more tags to increase precision, because tags will be more costly than receivers until detection probabilities exceed about 0.7 (Figure 4.8). Above a 70% detection probability, researchers will see little improvement in precision from increasing detection probabilities alone, unless survival also increases. See Section 4.11 above for a discussion of array performance and recommendations on populating arrays to ensure adequate detection probabilities.

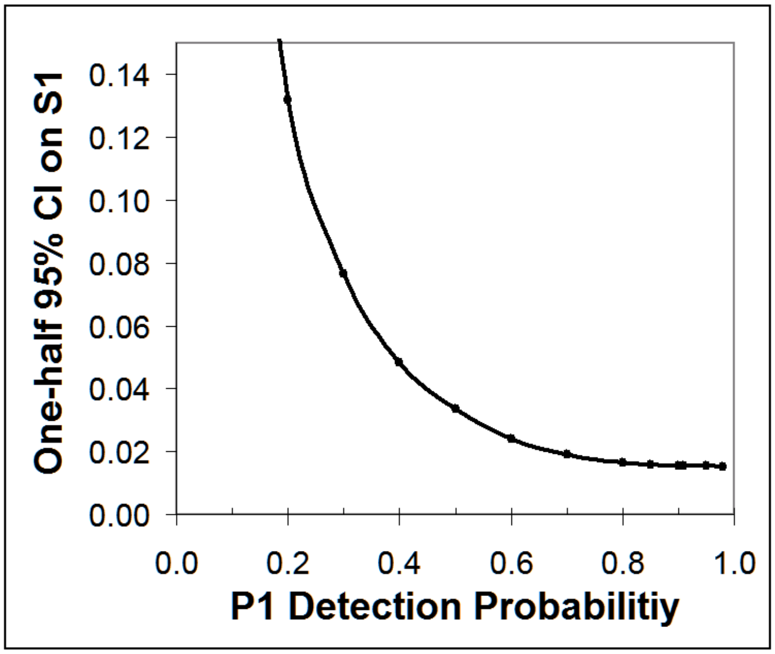


Figure 4.8. One-half 95% CI on Survival to a Primary Array (S1) as a Function of the Detection Probability to the Same Array (P1). The relation assumes R0=1,500; S1=0.9; S2=0.97; P2=P1; and S*P=P2*S2, where R0 is the number of fish tagged and released; S1 is survival to Array 1; S2 is survival to Array 2, P2 is detection probability to Array 2, and S*P is the product of survival and detection to Array 3.

5.0 Recommendations

1. We recommend placing additional emphasis on finding smaller yearlings to fully represent these length classes in the sample of tagged fish. We suspect that they tend to be under-represented because they are less visible to collectors. Checking length frequencies of SMF and tagged fish as the season progresses would help.
2. We had several recommendations for future tag-life studies and tag activations:
   a. Systematically sample tags as they are activated for survival studies.
   b. Record tag lot number as well as tag codes when fish are tagged, so that specific tag-life corrections can be made in the case of tag-manufacturing problems.
   c. Record date and time to the nearest minute that each tag is activated for the tag-life study or JSATS survival studies. This could be accomplished by using a data-logging device when tag activations are verified with a hydrophone. The date and time settings are critical and should be checked regularly.
3. In years when funding is tight and survival is being studied at JDA, TDA, and BON, savings can be obtained by deploying one array above JDA, one below JDA, two below TDA, and three below BON. A JDA forebay array would serve to estimate survival to JDA and could allow for a virtual release for JDA. A single JDA Tailwater array located near the TDA forebay would serve as a primary survival array and as a TDA forebay array for forming a virtual release for TDA. The two arrays below TDA would be located near the Bingen Marina to split the long TDA tailwater into two long segments, and the second array near the BON forebay would serve as a secondary array and to provide a virtual release for BON.
4. If there is a desire to test different spill conditions in summer, the confounding effect of decreasing survival through time must be considered and eliminated from the experimental design. We recommend confining tests of spill conditions to early summer periods or late summer periods to avoid a confounding effect.
5. We recommend that lag times between the upstream and downstream releases of a pair be reevaluated for future studies based upon anticipated river discharge. The equations derived in this study for estimating an appropriate lag time to ensure adequate mixing in a common downstream reach of paired releases often were related to river discharge and represent a good starting place. However, consideration of travel-time data from other years with lower river discharge should increase the robustness of estimates.
6. Our examination of correlations of observed average detection probabilities with several physical factors (Figure 3.40) led us to recommend the following to provide a reasonable chance of achieving detection probabilities > 80% in future studies.
   a. Arrays should be located at the narrowest and deepest (mean depth > 14 m) cross sections available, after allowing enough travel distance to avoid detecting dead fish on an array. There was a significant negative correlation between detection probability and river width and a positive correlation between the probability and mean depth.
   b. We recommend deploying enough autonomous nodes to keep inter-nodal distances < 150 m, so that node densities are at least six per km of river width.
   c. Offshore distances to the first node on either side of the river should not exceed 100 m.

7. We recommend making certain that arrays are populated fully or even overpopulated with receivers to ensure high detection probabilities before buying more tags to increase precision. The latter approach will usually be more costly than the former until detection probabilities are high.

8. We recommend having future nodes transmit a coded signal every 15-30 seconds to remotely indicate the node's status to researchers in a nearby boat. The codes might include the status of batteries, data-storage space, and data acquisition. With this capability, researchers could visit the nodes twice a week, once to check on performance without having to retrieve each node, and a second time to download data. A more sophisticated setup might include an underwater hydrophone cabled to a radio- or satellite-uplink buoy so that coded acoustic signals from all nodes could be transmitted to a real-time monitoring web site on the Internet.

9. Until node losses can be accurately forecasted, we recommend that researchers plan to have one spare node for every four that will be deployed.

6.0 References

Absolon, R. F., E. M. Dawley, B. P. Sandford, J. W. Ferguson, and D. A. Bregeon. 2002. *Relative Survival of Juvenile Salmon Passing through the Spillway of The Dalles Dam, 1997-2000*. Report of Research by the Northwest Fisheries Science Center, National Marine Fisheries Service for the U. S. Army Corps of Engineer, Portland District, Portland, Oregon.

Bickford, S. H. and J. R. Skalski. 2000. "Reanalysis and interpretation of 25 years of Snake-Columbia River juvenile salmonid survival studies*."* *North American Journal of Fisheries Management*. 20:53-68.

Brett, J.R. 1952. "Temperature Tolerance in Young Pacific Salmon, Genus Oncorhynchus." *Journal of the Fisheries Research Board of Canada*. 9: 265-323.

Burnham, K.P., D.R Anderson, G.C. White, C. Brownie, and K.H. Pollock. 1987. "Design and analysis methods for fish survival estimates based on release-recapture*." American Fisheries Society Monograph* No. 5.

Cada, G. F., M.D. Deacon, S.V. Mitz, and M.S. Bevelhimer. 1997. Effects of water velocity on the survival of downstream-migrating juvenile salmon and steelhead: A review with emphasis on the Columbia River Basin. *Reviews in Fisheries Science* 5(2):131-183.

Cash, K.M., D.M. Faber, T.W. Hatton, E.C. Jones, R.J. Magie, N.M. Swyers, R.K. Burns, M.D. Sholtis, S.A. Zimmerman, J.S. Hughes, T.L. Gilbride, N.S. Adams, and D.W. Rondorf. 2005. *Three-dimensional behavior and passage of juvenile Salmonids at The Dalles Dam, 2004.* Final Report by U.S. Geological Survey and Pacific Northwest National Laboratory to the U.S. Army Corps of Engineers, Portland, Oregon.

Cobleigh, M. M. 2003. *Stress, Growth and Survival of Juvenile Chinook Salmon*. MS Thesis, University of Washington, Seattle, Washington.

Conover, W. J. 1980. *Practical Nonparametric Statistics*. Wiley & Sons, New York.

Cook CB, GA McMichael, JA Vucelick, B Dibrani, EE Hockersmith, CA Duberstein, ID Welch, BJ Bellgraph, CA McKinstry, P Titzler, RR Kirkham, and MD Bleich. 2007. *Lower Monumental Reservoir Juvenile Fall Chinook Salmon Behavior Studies* . PNWD-3800, Battelle-Pacific Northwest Division, Richland, Washington.

Counihan, T.D., J.H. Petersen, N.S. Adams, R.S. Shively, and H.C. Hansel. 2002a. *Feasibility of Extracting Survival Information from Radio-Telemetry Studies at the John Day Dam*, 1999. Annual Report prepared by the U.S. Geological Survey, Cook, Washington, for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Counihan, T. D., J. H. Petersen, and K. J. Felton. 2002b. *Survival Estimates of Migrant Juvenile Salmonids in the Columbia River from John Day Dam through Bonneville Dam using Radio-Telemetry, 2000*. Annual report prepared by the U.S. Geological Survey, Cook, Washington, for the U.S. Army Corps of Engineers, Portland, Oregon.

Counihan, T.D., G.S. Holmberg, and J.H. Petersen. 2003. *Survival Estimates of Migrant Juvenile Salmonids through Bonneville Dam Using Radio-Telemetry, 2002*. Annual Report prepared by the U.S. Geological Survey, Cook, Washington, for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Counihan, T.D., A.L. Puls, C.E. Walker, J.M. Hardiman, and G.S. Holmberg. 2006a. *Survival Estimates of Migrant Juvenile Salmonids through The Dalles Dam Using Radiotelemetry, 2004.* Final Report of Research prepared by the U.S. Geological Survey, Cook, Washington, for the U.S. Army Corps of Engineers, Portland, Oregon.

Counihan, T.D., A.L. Puls, C.E. Walker, J.M. Hardiman, and G.S. Holmberg. 2006b. *Survival Estimates of Migrant Juvenile Salmonids through The Dalles Dam Using Radiotelemetry, 2005.* Final Report of Research prepared by the U.S. Geological Survey, Cook, Washington, for the U.S. Army Corps of Engineers, Portland, Oregon.

Counihan, T.D., G.S. Holmberg, C.E. Walker, and J.M. Hardiman. 2006c. *Survival Estimates of Migrant Juvenile Salmonids through The Dalles Dam using Radiotelemetry, 2002.* Final Report of Research prepared by the U.S. Geological Survey, Cook, Washington, for the U.S. Army Corps of Engineers, Portland, Oregon.

Counihan, T. D., G. S. Holmberg, and J. H. Peterson. 2006d. *Survival Estimates of Migrant Juvenile Salmonids in the Columbia River through John Day Dam using Radio Telemetry, 2002.* Annual Report by the U.S. Geological Survey, Columbia River Research Laboratory, Cook, Washington, for the U.S. Army Engineer District, Portland, Oregon.

Counihan, T. D., G. S. Holmberg, C. E. Walker, and J. M. Hardiman. 2006e. *Survival Estimates of Migrant Juvenile Salmonids in the Columbia River through John Day Dam using Radio-Telemetry, 2003.* Annual Report by the U.S. Geological Survey, Columbia River Research Laboratory, Cook, Washington, for the U.S. Army Engineer District, Portland, Oregon.

Counihan, T. D., J. Hardiman, C. Walker, A. Puls, and G. Holmberg. 2006f. *Survival Estimates of Migrant Juvenile Salmonids through Bonneville Dam using Radio Telemetry, 2004*. Annual Report by the U.S. Geological Survey, Columbia River Research Laboratory, Cook, Washington, for the U.S. Army Engineer District, Portland, Oregon.

Counihan, T. D., J. Hardiman, C. Walker, A. Puls, and G. Holmberg. 2006g. *Survival Estimates of Migrant Juvenile Salmonids through Bonneville Dam using Radio Telemetry, 2005*. Annual Report by the U.S. Geological Survey, Columbia River Research Laboratory, Cook, Washington, for the U.S. Army Engineer District, Portland, Oregon.

Efron, B., and R. J. Tibshirani. 1993. *An Introduction to the Bootstrap*. Chapman & Hall, New York.

Faber, D.M., M.A. Weiland, R.A. Moursund, and T.J. Carlson. 2001. *Evaluation of the Fish Passage Effectiveness of the Bonneville I Prototype Surface Collector using Three-Dimensional Ultrasonic Fish Tracking,* PNNL-13526, Prepared for U.S. Army Corps of Engineer District, Portland, Oregon by Pacific Northwest National Laboratory, Richland, Washington.

Dawley, E.M., L.G. Gilbreath, R.F. Absolon, B.P. Sandford, and J.W. Ferguson. 2000. *Relative Survival of Juvenile Salmon Passing through the Spillway and the Ice and Trash Sluiceway of The Dalles Dam, 1998.* Report of Research by the Northwest Fisheries Science Center, National Marine Fisheries Service for the U.S. Army Engineer District, Portland, Oregon.

Efron, B., and R. J. Tibshirani. 1993. *An Introduction to the Bootstrap*. Chapman & Hall, New York.

Hansel, H.C., J.W. Beeman, S.D. Juhnke, P.V. Haner, and L.L. Dingmon. 2005. *Estimates of Fish-, Spill- and Sluiceway Efficiencies of Radio-Tagged Juvenile Chinook Salmon during Spring and Summer at The Dalles Dam in 2004.* Annual Report of Research to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Hansel, H. C. , S. D. Juhnke, P. V. Haner, L.L. Dingmon, and J. W. Beeman. 2007. *Estimates of Fish-, Spill-, and Sluiceway-Passage Efficiencies of Radio-Tagged Juvenile Chinook Salmon during Spring and Summer at The Dalles Dam in 2005.* Draft final report of research. Prepared by the U.S. Geological Survey for the U.S. Corps of Engineers, Portland, Oregon.

Hockersmith, E. E., R. S. Brown, and T. L. Liedtke. 2007. *Comparative Performance of Acoustic-tagged and PIT-tagged Juvenile Salmonids*. Draft Report prepared for the U.S. Army Corps of Engineer District, Portland, Oregon, USA.

Johnson, G. E., J. Beeman, I. Duran, and A. Puls. 2007. *Synthesis of Juvenile Salmonid Passage Studies at The Dalles Dam, Volume II, 2001-2005*. Draft Technical Report by the Pacific Northwest National Laboratory, Richland, Washington, for the U.S. Army Corps of Engineers District, Portland, Oregon.

McComas, R. L., J. W. Ferguson, S. G. Smith, G. A. McMichael, and T. J. Carlson. 2004. A study to estimate salmonid survival through the Columbia River Estuary using acoustic tags. Abstract in the *2004 Anadromous Fish Evaluation Program*, U. S. Army Corps of Engineer District, Portland, Oregon.

McComas, R. L., J. W. Feguson, S. G. Smith, G. A. McMichael, T. J. Carlson, J. A. Vucelick, and K. D. Ham. 2005. A study to estimate salmonid survival through the Columbia River Estuary using Acoustic Tags.2005. Abstract in the *2005 Anadromous Fish Evaluation Program*, U. S. Army Corps of Engineer District, Portland, Oregon, USA.

McComas, R. L., L. Gilbreath, Eric Hockersmith, and S. G. Smith, G. A. McMichael, T. J. Carlson, J. A. Vucelick, and K. D. Ham. 2006. A study to estimate salmonid survival through the Columbia River Estuary using Acoustic Tags, 2006. Abstract in the *2006 Anadromous Fish Evaluation Program,* U. S. Army Corps of Engineer District, Portland, Oregon, USA.

Ploskey, G. R. and T. J. Carlson. 2004. *Comparison of Blade-Strike Modeling Results with Empirical Data.* Technical Report PNNL-14603 to the U. S. Department of Energy Hydropower Program.

Ploskey, G. R., G. E. Johnson, A. E. Giorgi, R. L. Johnson, J. R. Stevenson, *Synthesis of Biological Research on Juvenile Fish Passage and Survival at Bonneville Dam through 2005.* Draft Technical Report by the Pacific Northwest National Laboratory, Richland, Washington, for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Peven, C., A. Giorgi, J. Skalski, M. Langeslay, A. Grassell, S.G. Smith, T. Counihan, R. Perry, and S. Bickford. 2005. *Guidelines and Recommended Protocols for Conducting, Analyzing, and Reporting Juvenile Salmonid Survival Studies in the Columbia River Basin.* Published electronically; available in PDF electronic format from chuckp@chelanpud.org**.**

Raymond, H. L. 1964. *Effects of Dams on the Upstream Migration Rates and Timing of Columbia River Salmonids.* Report for Fish Passage Research Program of the Bureau of Commercial Fisheries, Northwest Fisheries Science Center, Seattle, Washington.

Robson, D. S., and H. A. Regier. 1964. "Sample size in Petersen mark-recapture experiments." *Transactions of the American Fisheries Society* 93:215-226.

Seber, G. A. F. 1982. *The Estimation of Animal Abundance.* MacMillan, New York.

Sims, C. W., and F. Ossiander. 1981. *Migrations of Juvenile Chinook Salmon and Steelhead in the Snake River, from 1973 to 1979, a Research Summary.* Report prepared by the National Marine Fisheries Service for the U.S. Army Corps of Engineers, Portland, Oregon.

Skalski, J. R., R. L. Townsend, T. W. Steig, J. W. Horchik, G. W. Tritt, and A. Grassell. 2003a. *Estimation of Rock Island Project Passage Survival of Yearling Chinook Salmon Smolts in 2003 Using Acoustic and PIT-Tag Release-Recapture Methods*. Report prepared by the University of Washington, School of Aquatic and Fishery Sciences, for the Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Skalski, J. R., R. L. Townsend, T. W. Steig, J. W. Horchik, G. W. Tritt, and R. D. McDonald. 2003b. *Estimation of Survival of Yearling Chinook Salmon Smolts at the Rock Island Dam, Pool, and Project in 2002 Using Acoustic and PIT-Tag Release-Recapture Methods*. Report prepared by the University of Washington, School of Aquatic and Fishery Sciences, for the Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffmann. 1998. "Use of PIT-tags to estimate survival of migrating juvenile salmonids in the Snake and Columbia Rivers." *Canadian Journal of Fisheries and Aquatic Sciences* 55:1484-1493.

Skalski, J.R. 1999. *Statistical Methods to Extract Survival Information from the John Day and The Dalles Dams Radiotag Studies*. Report prepared by the University of Washington, School of Aquatic and Fishery Sciences, for the U.S. Army Corps of Engineers, Portland, Oregon.

Tiffan, K.F., D.W. Rondorf, and P.G. Wagner. 2000. "Physiological development and migratory behavior of subyearling chinook salmon in the Columbia river." *North American Journal of Fisheries Management* 20: 28-40.

Townsend, R. L., J. R. Skalski, P. Dillingham, and T. W. Steig. 2006. "Correcting bias in survival estimation resulting from tag failure in acoustic and radiotelemetry studies." *Journal of Agricultural Biology and Environmental Statistics* (in press).

Zabel, R.W. and J.J. Anderson. 1997. A Model of the Travel Time of Migrating Juvenile Salmon, with an Application to Snake River Spring Chinook Salmon. *North American Journal of Fisheries Management* 17(1): 93-100.

Zabel, R. W., T. W. Wagner, J. L. Congleton, S. C. Smith, and L. C. Williams. 2005. Survival and selection of migrating salmon from capture-recapture models with individual traits. *Ecological Applications* 15(4): 1427-1439.

Appendix A

Tables of All Fish Tagging and Release Data

Table A.1. Summary of Tagging Numbers and Statistics by Release Location, and Release Date in Spring

Release Location	Release Date	Number Released	Number Surviving Tagging	Percent Alive	Number Dead	Percent Dead	Number Sacrificed	Percent Sacrificed
JDA Front Roll	05/16/06	55	54	98.2	1	1.8	0	0
JDA Front Roll	05/19/06	60	59	98.3	1	1.7	0	0
JDA Front Roll	05/21/06	60	59	98.3	1	1.7	0	0
JDA Front Roll	05/23/06	70	70	100	0	0	0	0
JDA Front Roll	05/25/06	60	60	100	0	0	0	0
JDA Front Roll	05/27/06	80	80	100	0	0	0	0
JDA Front Roll	06/01/06	60	60	100	0	0	0	0
JDA Front Roll	06/03/06	55	55	100	0	0	0	0
JDA Intake 9C	05/16/06	55	55	100	0	0	0	0
JDA Intake 9C	05/19/06	63	63	100	0	0	0	0
JDA Intake 9C	05/21/06	58	58	100	0	0	0	0
JDA Intake 9C	05/23/06	68	68	100	0	0	0	0
JDA Intake 9C	05/25/06	60	60	100	0	0	0	0
JDA Intake 9C	05/27/06	80	80	100	0	0	0	0
JDA Intake 9C	06/01/06	60	60	100	0	0	0	0
JDA Intake 9C	06/03/06	56	56	100	0	0	0	0
JDA Tailrace	05/16/06	55	54	98.2	1	1.8	0	0
JDA Tailrace	05/19/06	60	60	100	0	0	0	0
JDA Tailrace	05/21/06	60	60	100	0	0	0	0
JDA Tailrace	05/23/06	70	70	100	0	0	0	0
JDA Tailrace	05/25/06	42	41	97.6	0	0	1	2.4
JDA Tailrace	05/27/06	79	77	97.5	1	1.3	1	1.3
JDA Tailrace	06/01/06	80	79	98.8	1	1.3	0	0
JDA Tailrace	06/03/06	54	40	74.1	2	3.7	12	22.2
TDA Tailrace	05/16/06	97	96	99	1	1	0	0
TDA Tailrace	05/19/06	120	120	100	0	0	0	0
TDA Tailrace	05/21/06	120	120	100	0	0	0	0
TDA Tailrace	05/23/06	90	90	100	0	0	0	0
TDA Tailrace	05/25/06	50	48	96	0	0	2	4
TDA Tailrace	05/27/06	89	85	95.5	4	4.5	0	0
TDA Tailrace	06/01/06	67	67	100	0	0	0	0
TDA Tailrace	06/03/06	153	153	100	0	0	0	0
TDA Tailrace	06/05/06	215	199	92.6	2	0.9	13	6
Average						0.597		

Table A.2. Summary of Tagging Numbers and Statistics by Release Location, and Release Date in Summer

Release Location	Release Date	Number Released	Number Surviving Tagging	Percent Alive	Number Dead	Percent Dead	Number Sacrificed	Percent Sacrificed
BON B2CC	Summer	17	0	0	0	0	17	100
BON B2CC	Summer	7	0	0	0	0	7	100
BON B2CC	Summer	6	0	0	0	0	6	100
JDA Tailrace	6/13/2006	50	50	100	0	0	0	0
JDA Tailrace	6/15/2006	50	50	100	0	0	0	0
JDA Tailrace	6/20/2006	50	50	100	0	0	0	0
JDA Tailrace	6/22/2006	50	49	98	1	2	0	0
JDA Tailrace	6/27/2006	100	100	100	0	0	0	0
TDA Tailrace	6/13/2006	200	196	98	4	2	0	0
TDA Tailrace	6/15/2006	200	200	100	0	0	0	0
TDA Tailrace	6/20/2006	200	196	98	4	2	0	0
TDA Tailrace	6/22/2006	200	200	100	0	0	0	0
TDA Tailrace	6/27/2006	200	200	100	0	0	0	0
TDA Tailrace	6/28/2006	200	200	100	0	0	0	0
TDA Tailrace	7/1/2006	250	245	98	3	1.2	0	0
TDA Tailrace	7/7/2006	250	248	99.2	2	0.8	0	0
TDA Tailrace	7/11/2006	250	246	98.4	4	1.6	0	0
TDA Tailrace	7/13/2006	252	246	97.6	6	2.4	0	0
Average						0.667		

Table A.3. Summary of Tagging Numbers and Statistics by Release Location, and Release Date in Summer

Release Location	Season	Number Released	Number Alive	Percent Alive	Number Dead	Percent Dead	Number Sacrificed	Percent Sacrificed
JDA Front Roll	Spring	500	497	99.4	3	0.6	0	0.0
JDA Intake 9C	Spring	500	500	100.0	0	0.0	0	0.0
JDA Tailrace	Spring	500	481	96.2	5	1.0	14	2.8
TDA Tailrace	Spring	1,001	978	97.7	7	0.7	15	1.5
BON B2CC	Summer	30	0	0.0	0	0.0	30	100.0
JDA Tailrace	Summer	300	299	99.7	1	0.3	0	0.0
TDA Tailrace	Summer	2,202	2,177	98.9	23	1.0	0	0.0

Table A.4. List of Appendix A CSV Files on an Accompanying Compact Disc*. Variables in the CSV files are defined in Table A.5 below.

File	Description
Appendix A – Spring Codes.CSV	PIT and Acoustic Tag Codes Released in Spring 2006 by Date, Time, and Location followed by dam operations data
Appendix A – Summer Codes.CSV	PIT and Acoustic Tag Codes Released in Summer 2006 by Date, Time and Location followed by dam operations data

*A compact disc accompanying the report has two files: Appendix A – Spring Codes.CSV and Appendix a – Summer Codes.CSV.

Table A.5. Definitions of Variables in Headings of Appendix A CSV Files on the Accompanying Compact Disc.

Variable	Definition
SEASON	Fish Released season Spring/Summer
ReleaseDate	Fish released date
ReleaseTime	Fish released time
TagCode	PIT tag code
AcousticTagCode	Acoustic Tag Code
ActivationDate	Acoustic Tag Activated date
ForkLength	Fish length
Weight	Fish weight
Mortality	MORT/NO MORT
ReleaseLoc	Fish Release Location
FB	Forebay Elevation, ft above mean sea level
TW	Tailwater Elevation, ft above mean sea level
N_Units	Number of operating turbines
PH1_Q	Powerhouse 1 Discharge (cfs x 1,000)
PH2_Q	Powerhouse 2 Discharge (cfs x 1,000)
Spill_Q	Spillway Discharge (cfs x 1,000)
Total_Q	Total Project Discharge (cfs x 1,000)
T1	Turbine 1 Discharge (cfs x 1,000)
T2	Turbine 2 Discharge (cfs x 1,000)
T3	Turbine 3 Discharge (cfs x 1,000)
T4	Turbine 4 Discharge (cfs x 1,000)
T5	Turbine 5 Discharge (cfs x 1,000)
T6	Turbine 6 Discharge (cfs x 1,000)
T7	Turbine 7 Discharge (cfs x 1,000)
T8	Turbine 8 Discharge (cfs x 1,000)
T9	Turbine 9 Discharge (cfs x 1,000)
T10	Turbine 10 Discharge (cfs x 1,000)
T11	Turbine 11 Discharge (cfs x 1,000)
T12	Turbine 12 Discharge (cfs x 1,000)
T13	Turbine 13 Discharge (cfs x 1,000)
T14	Turbine 14 Discharge (cfs x 1,000)
T15	Turbine 15 Discharge (cfs x 1,000)
T16	Turbine 16 Discharge (cfs x 1,000)
T17	Turbine 17 Discharge (cfs x 1,000)
T18	Turbine 18 Discharge (cfs x 1,000)
T19	Turbine 19 Discharge (cfs x 1,000)
T20	Turbine 20 Discharge (cfs x 1,000)
T21	Turbine 21 Discharge (cfs x 1,000)
T22	Turbine 22 Discharge (cfs x 1,000)
S1	Spill Bay 1
S2	Spill Bay 2
S3	Spill Bay 3
S4	Spill Bay 4
S5	Spill Bay 5
S6	Spill Bay 6
S7	Spill Bay 7

Variable	Definition
S8	Spill Bay 8
S9	Spill Bay 9
S10	Spill Bay 10
S11	Spill Bay 11
S12	Spill Bay 12
S13	Spill Bay 13
S14	Spill Bay 14
S15	Spill Bay 15
S16	Spill Bay 16
S17	Spill Bay 17
S18	Spill Bay 18
S19	Spill Bay 19
S20	Spill Bay 20
S21	Spill Bay 21
S22	Spill Bay 22
S23	Spill Bay 23

Appendix B

Yearling Chinook Salmon Tag-Life Analysis Including Fitted Survivorship Curve and Arrival Time vs. Tag Survivorship Plots

Appendix B

Yearling Chinook Salmon Tag-Life Analysis Including Fitted Survivorship Curve and Arrival Time vs. Tag Survivorship Plots

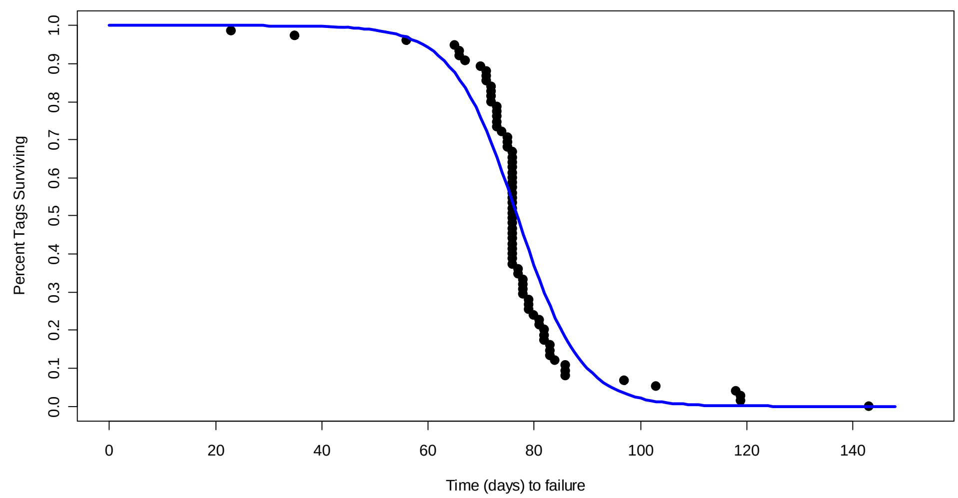


Figure B.1. Estimated Time to Failure for the 10-s Tags Used for Yearling Chinook salmon Released from Lower Granite Dam

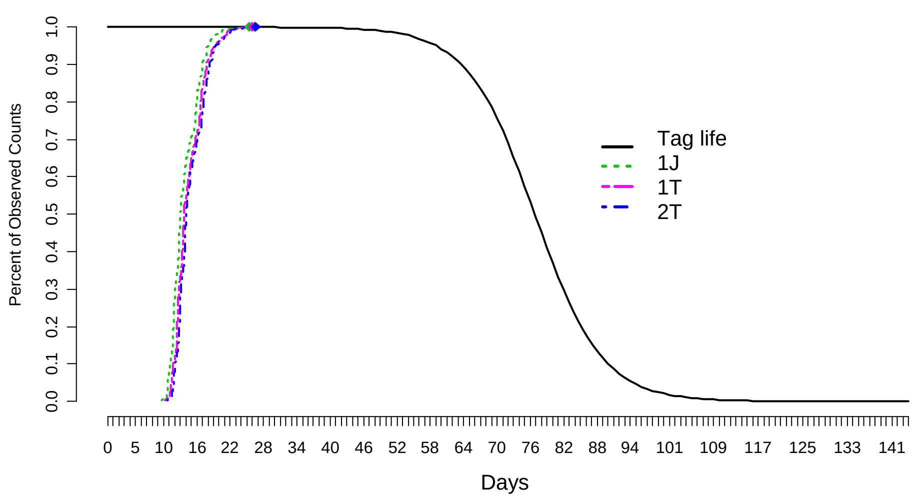


Figure B.2. Cumulative Arrival Time for Releases from John Day Dam to Detection Arrays 1J, 1T, and 2T Versus Tag Life

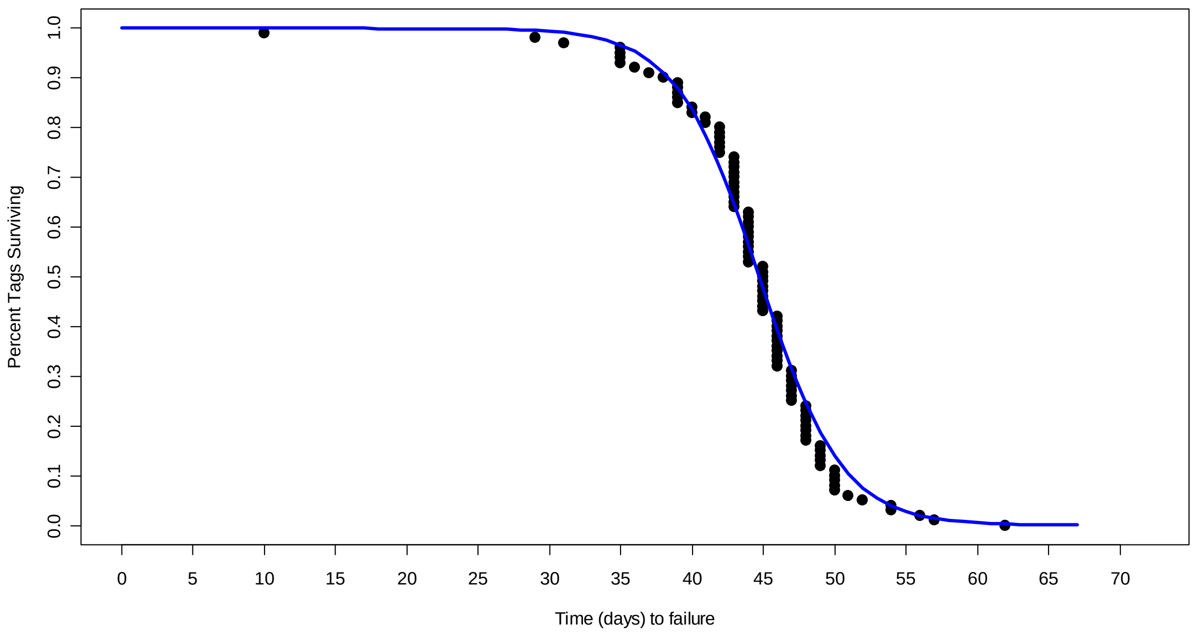
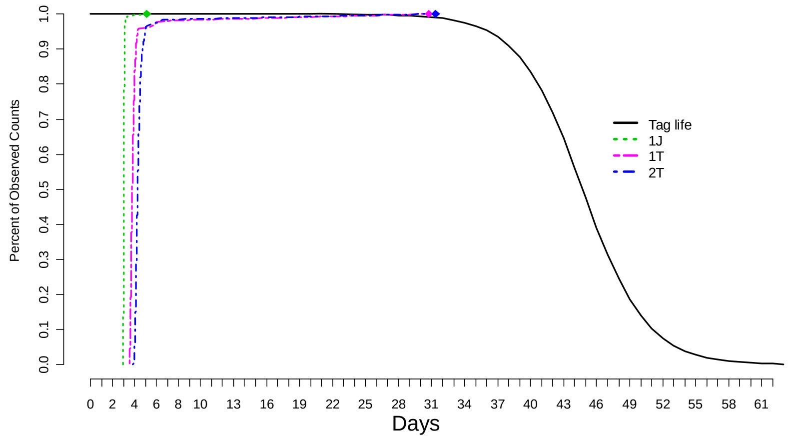
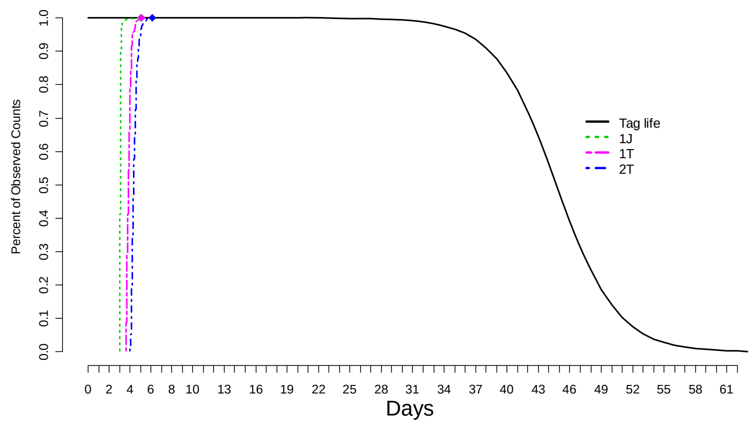


Figure B.3. Estimated Time to Failure for 5-s Tags Used for spring and summer Chinook salmon released from John Day Dam, below Dalles Dam, and below Bonneville Dam.

a. Front Roll



b. Turbine Intake



c. Tailrace

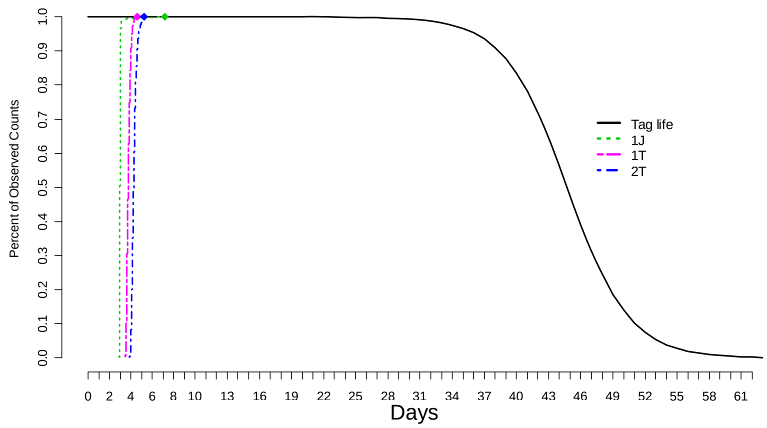


Figure B.4. Cumulative Arrival Time for Releases from John Day Dam to Detection Arrays 1J, 1T, and 2T Versus Tag Life

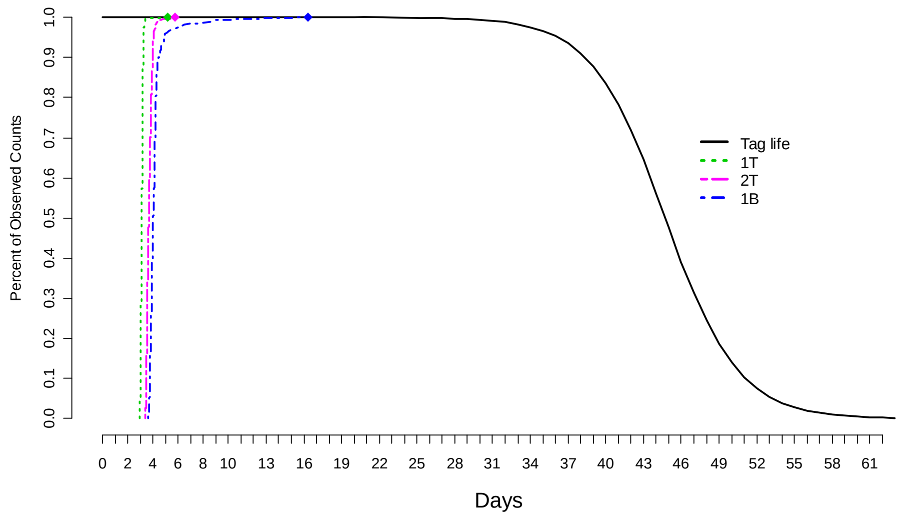


Figure B.5. Cumulative Arrival Time for Releases from The Dalles Tailrace to Detection Arrays 1T, 2T, and 1B Versus Tag Life

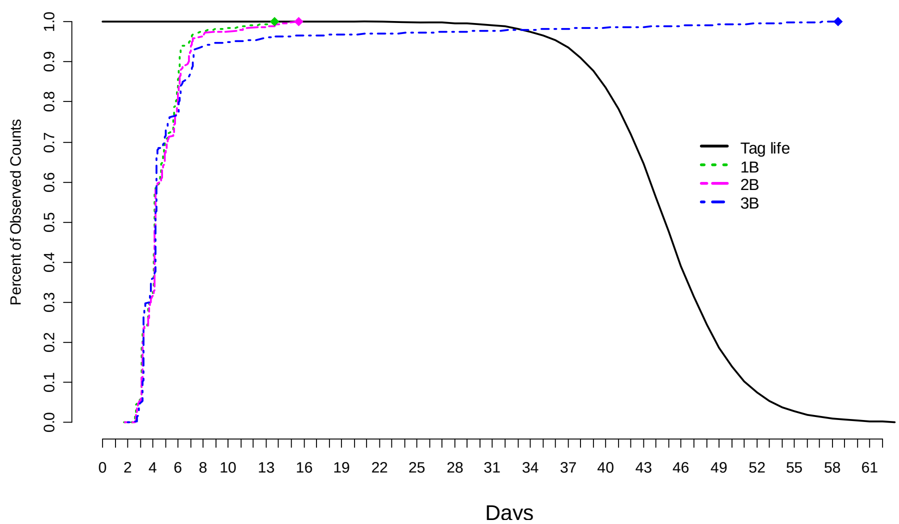


Figure B.6. Cumulative Arrival Time from Bonneville Tailrace to Detection Arrays 1B, 2B, and 3B Versus Tag Life

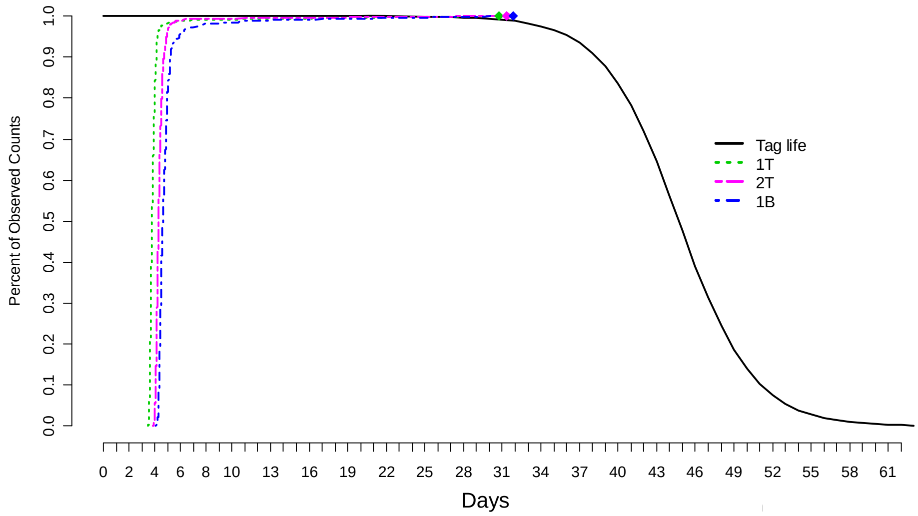


Figure B.7. Cumulative Arrival Time for the Virtual Release Above The Dalles Dam to Downstream Detection Arrays 1T, 2T, and 1B Versus Tag Life

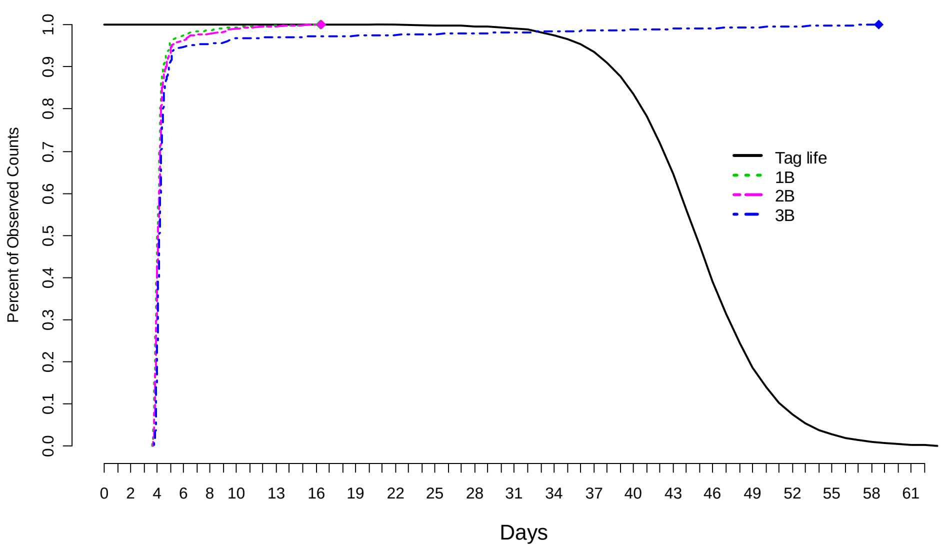


Figure B.8. Cumulative Time for the Virtual Release Above Bonneville Dam to Downstream Detection Arrays 1B, 2B, and 3B Versus Tag Life

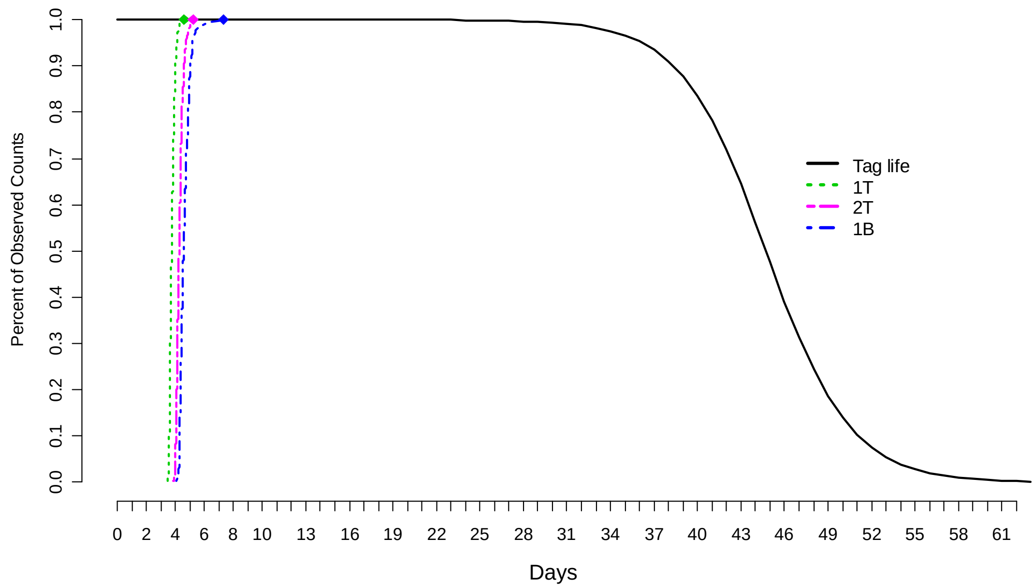


Figure B.9. Cumulative Arrival Time for Releases from John Day Tailrace to Downstream Detection Arrays 1T, 2T, and 1B Versus Tag Life

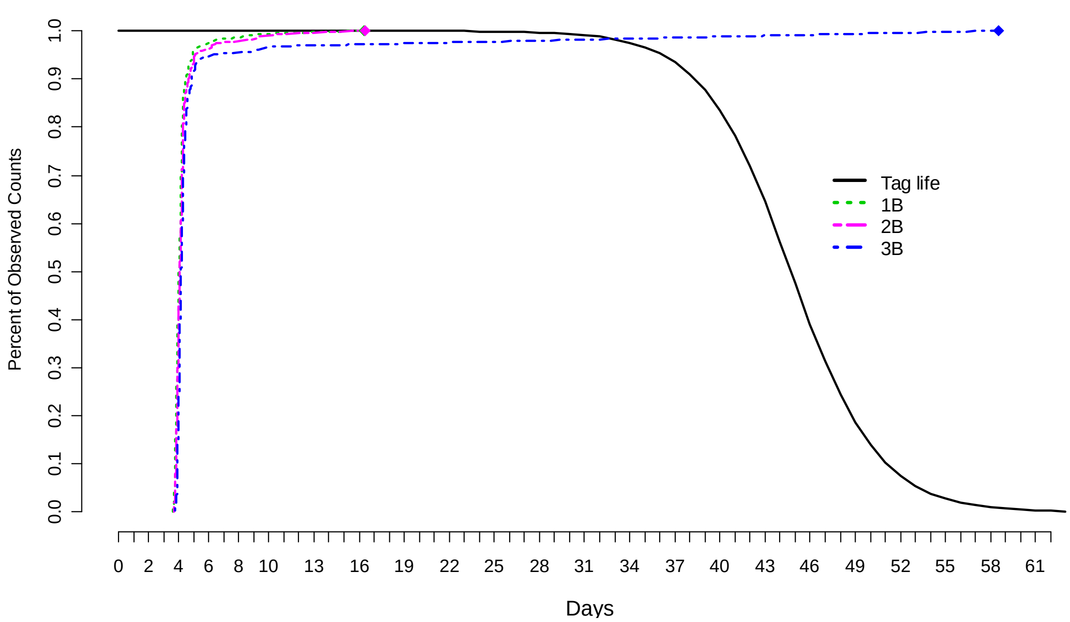


Figure B.10. Cumulative Arrival Time for Releases from The Dalles Tailrace to Downstream Detection Arrays 1B, 2B, and 3B Versus Tag Life

Appendix C

Forward-Sequential Model Selection Results for Acoustic-Tag Release Pairs in the 2006 Acoustic-Tag Survival Studies through John Day, The Dalles, and Bonneville Projects for Yearling Chinook Salmon

Appendix C

Forward-Sequential Model Selection Results for Acoustic-Tag Release Pairs in the 2006 Acoustic-Tag Survival Studies through John Day, The Dalles, and Bonneville Projects for Yearling Chinook Salmon

Table C.1. Forward-Sequential Model Selection Results for John Day Dam Release Pairs for Acoustic-Telemetry Studies[1]

Hypothesis	χ^2	df	P-value
a. Acoustic-tagged Chinook salmon smolts, John Day front roll and tailrace releases.			
$p_1 \mid \underset{\sim}{S}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	1.8667	1	0.1719
$M_{\underset{\sim}{S}_1}$ vs CJS	3.5333	4	0.4728
Conclude Model: $M_{\underset{\sim}{S}_1}$			
b. Acoustic-tagged Chinook salmon smolts, John Day intake 9C and tailrace releases.			
$p_1 \mid \underset{\sim}{S}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	1.9630	1	0.1612
$M_{\underset{\sim}{S}_1}$ vs CJS	3.6257	4	0.4590
Conclude Model: $M_{\underset{\sim}{S}_1}$			
c. Acoustic-tagged Chinook salmon smolts, John Day intake 9C and front roll releases.			
$p_1 \mid \underset{\sim}{S}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	7.4426	1	0.0064
$S_2 \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	0.0569	4	0.8115
$M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1}$ vs CJS	0.5564	3	0.9063
Conclude Model: $M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1}$			

[1] *Note:* Model fit to the data are indicated by a "~" when the parameters were treated as a vector (i.e., different between releases within a pair). The notation indicates which parameter was tested for homogeneity, given (i.e., "$\mid$") the specification of the other model parameters.

Table C.2. Forward-Sequential Model Selection Results for The Dalles Project Release Pairs for Acoustic-Tagged Studies. Acoustic-tagged Chinook salmon smolts released from John Day and The Dalles Dam tailraces.

Hypothesis	χ^2	df	P-value
$p_1 \mid \underset{\sim}{S}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	13.0480	1	0.0003
$S_2 \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	1.6251	1	0.2024
$M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1}$ vs CJS	3.5583	3	0.3133
Conclude Model: $M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1}$			

Table C.3. Forward-Sequential Model Selection Results for Bonneville Project Release Pairs for Acoustic-Tagged Studies. Acoustic-tagged Chinook salmon smolts released from The Dalles and Bonneville Dam tailraces.

Hypothesis	χ^2	df	P-value
$p_1 \mid \underset{\sim}{S}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	27.4017	1	< 0.0001
$S_2 \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{p}_2, \underset{\sim}{\lambda}$	1.6764	1	0.1954
$M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1}$ vs CJS	16.7258	3	0.0008
$p_2 \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{S}_2, \underset{\sim}{\lambda}$	13.6243	1	0.0002
$\lambda \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2$ vs CJS	0.0246	1	0.8754
Conclude Model: $M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{S}_2, \underset{\sim}{p}_2}$			

Appendix D

Tests of Mixing and Goodness-of-Fit for Yearling Chinook Salmon Release Groups

Appendix D

Tests of Mixing and Goodness-of-Fit for Yearling Chinook Salmon Release Groups

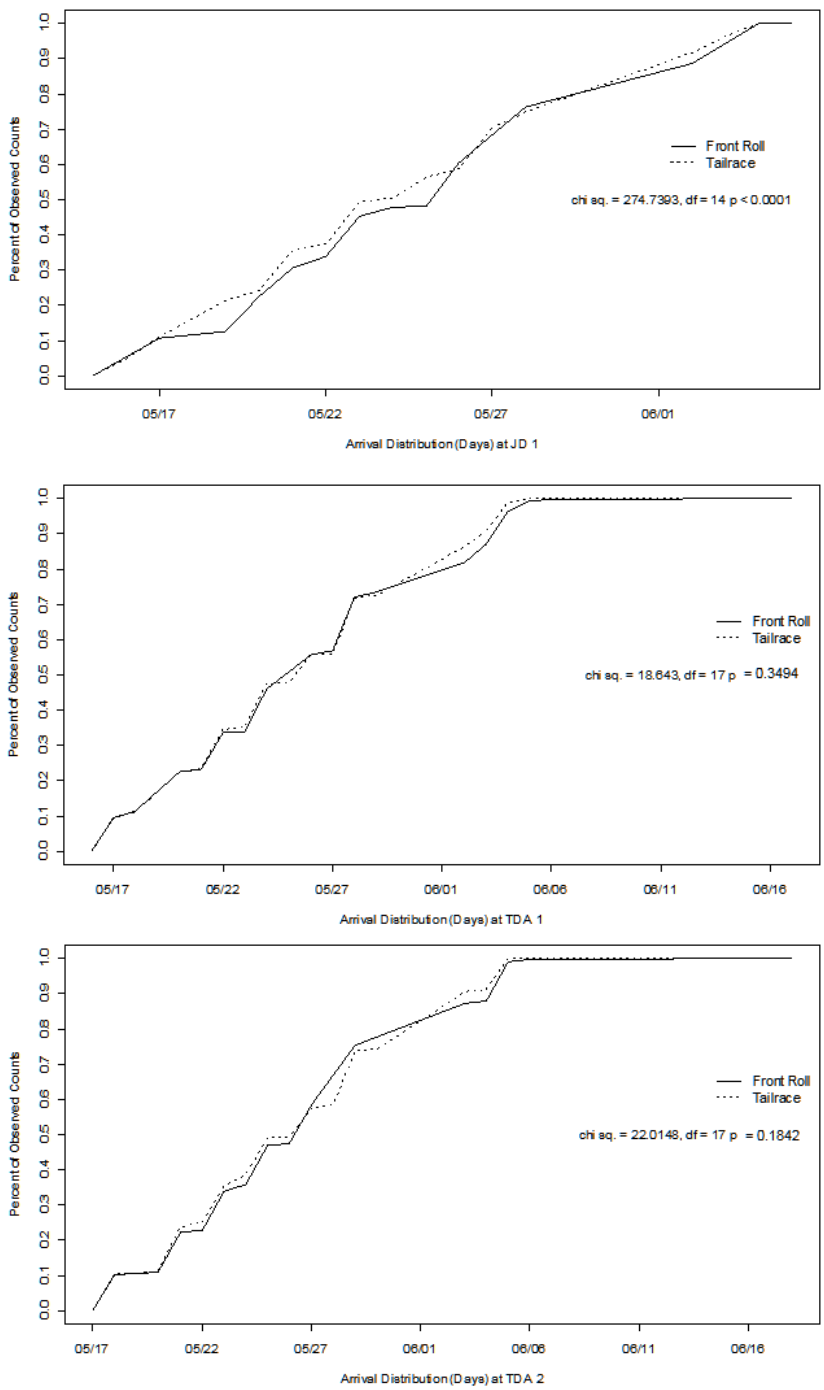


Figure D.1. Cumulative Arrival Distributions of the John Day Front Roll and Tailrace Releases to Detection Arrays 1J, 1T, and 2T

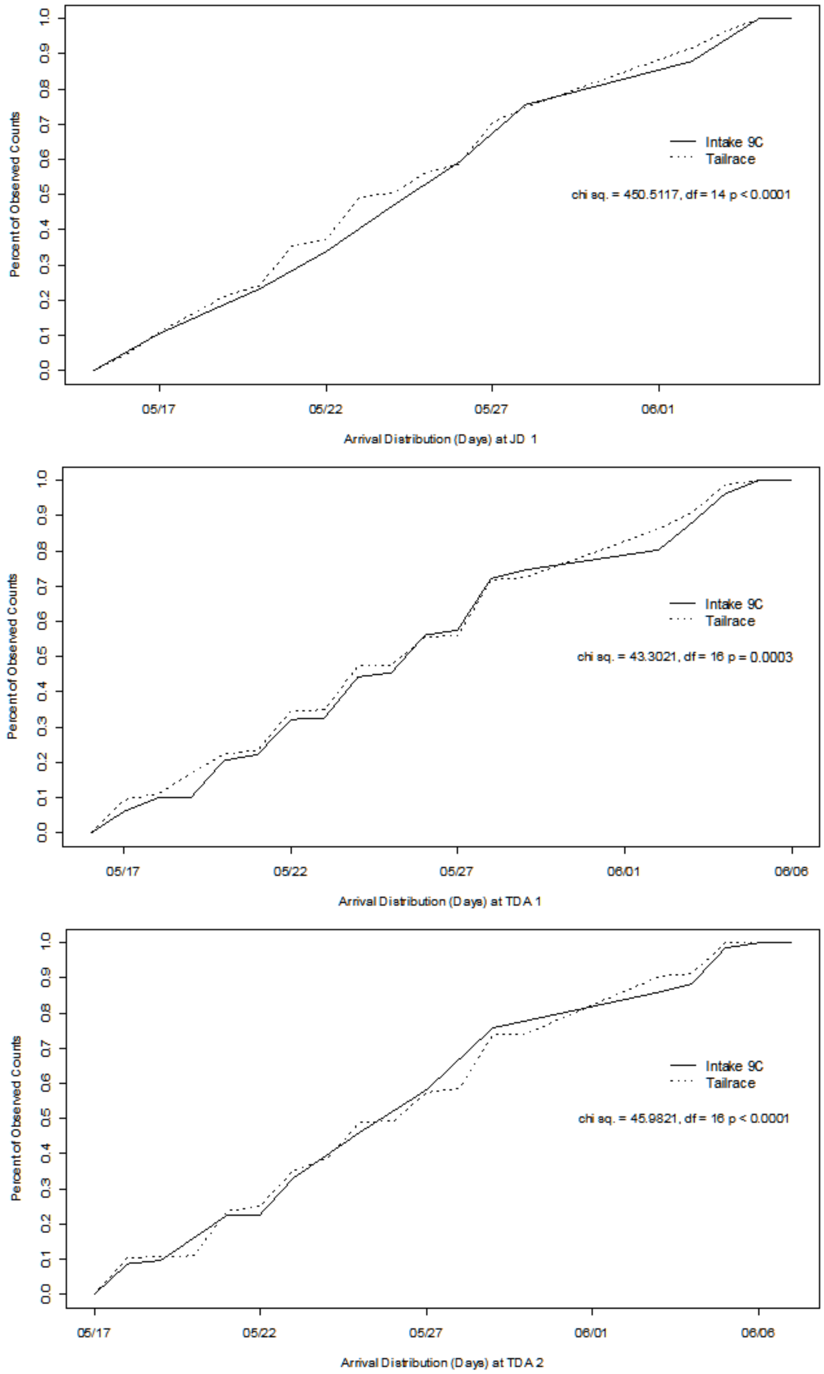


Figure D.2. Cumulative arrival distributions of John Day turbine intake 9C and tailrace releases to detection arrays 1J, 1T, and 2T

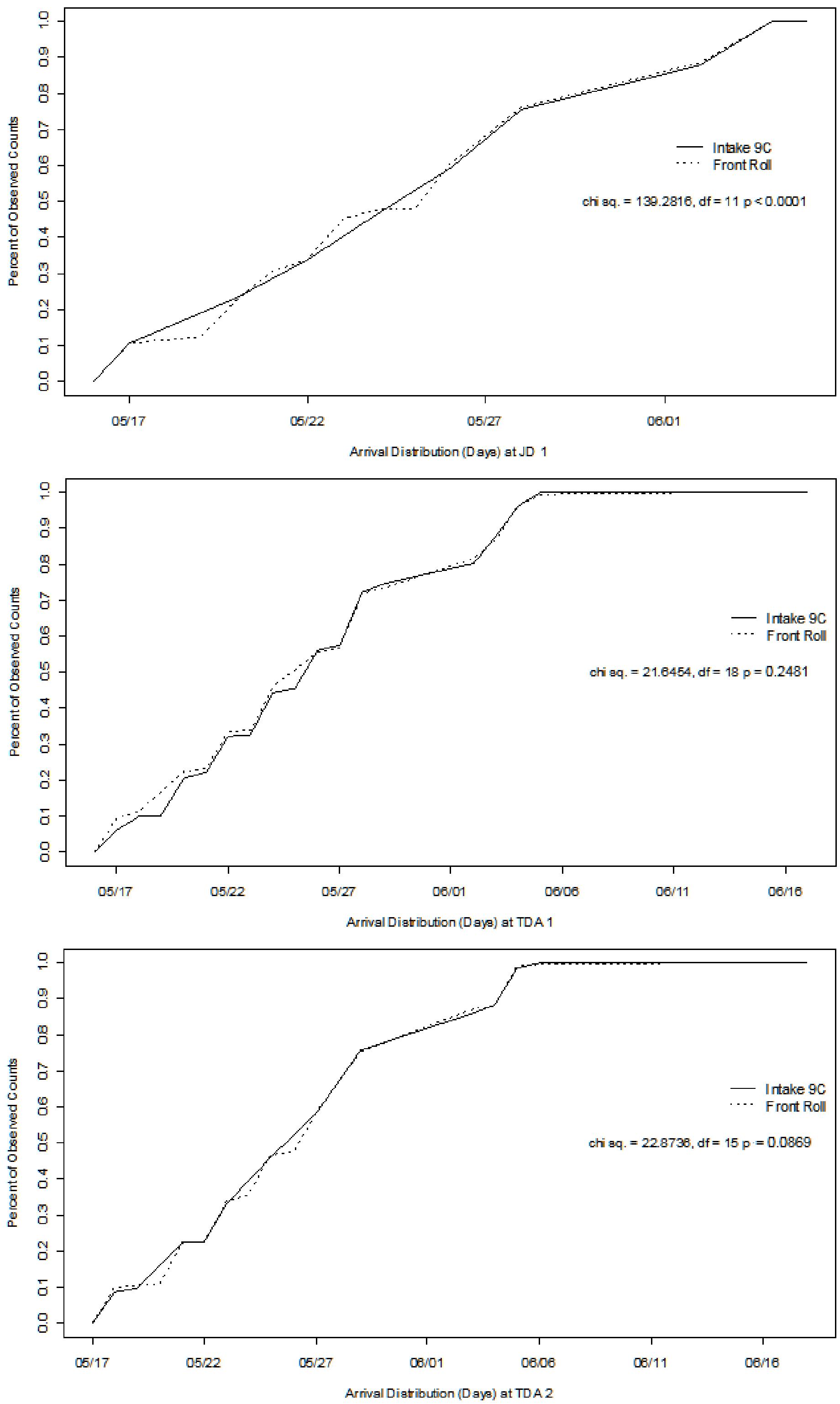


Figure D.3. Cumulative Arrival Distributions for the John Day Turbine Intake and Front Roll Releases to Detection Arrays 1J, 1T, and 2T

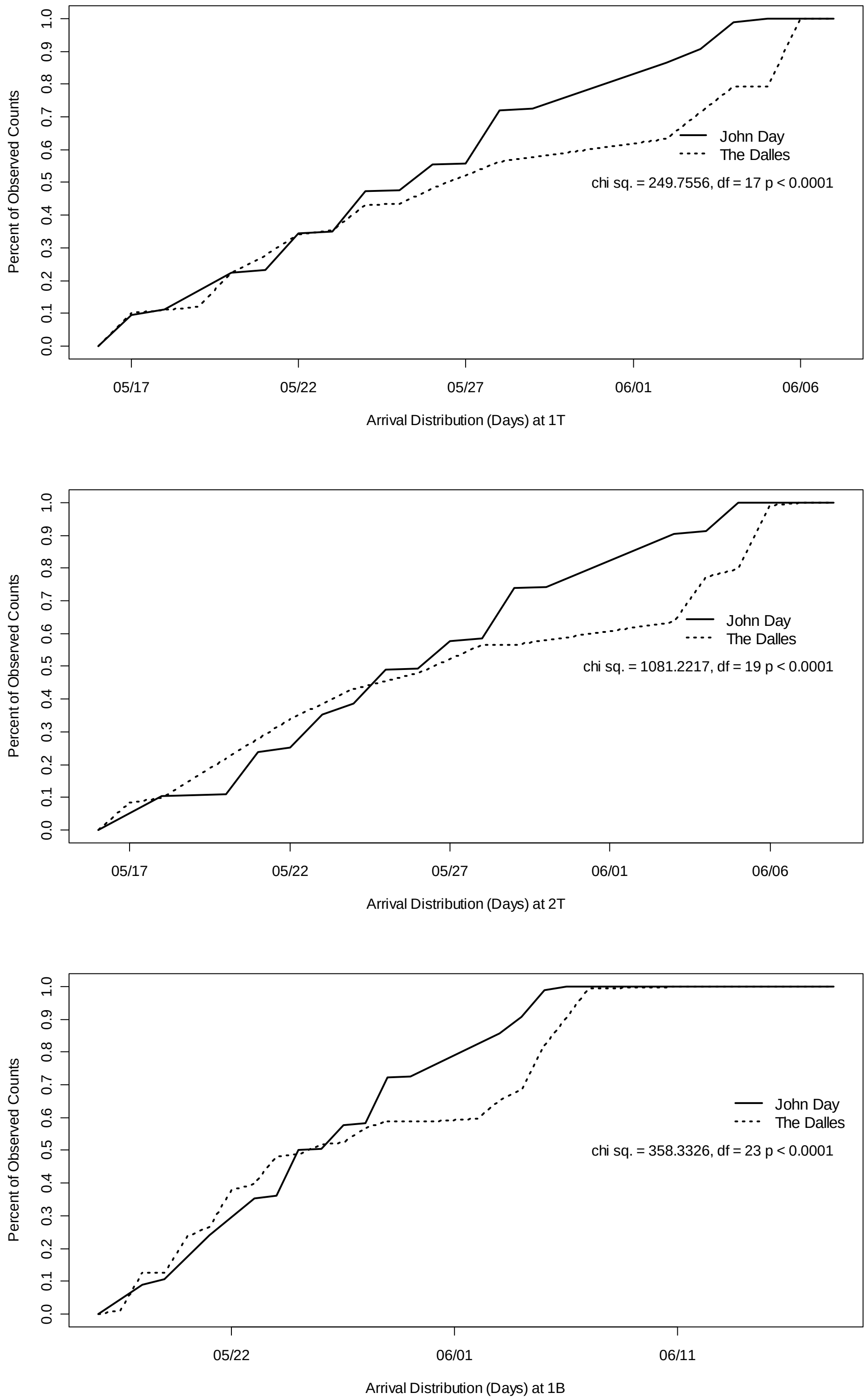


Figure D.4. Cumulative Arrival Distributions for John Day and The Dalles Tailrace Releases to Detection Arrays 1T, 2T, and 1B

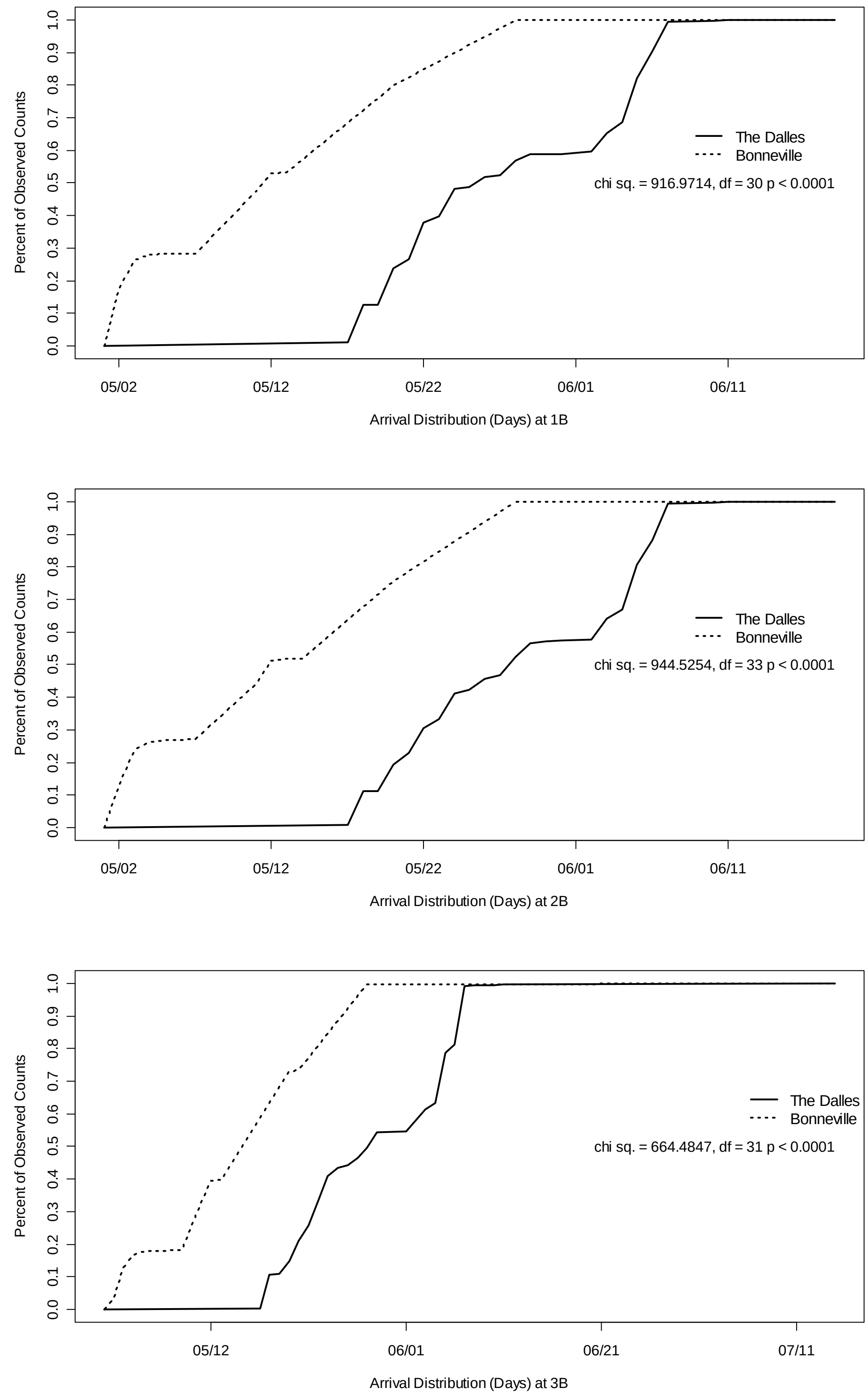


Figure D.5. Cumulative arrival distributions for The Dalles and Bonneville tailrace releases to detection arrays 1B, 2B, and 3B

Table D.1. Burnham Test 2.2 for John Day Dam single releases. This procedure tests the assumption of whether detections at John Day primary array affect downstream survival and/or detection

Release Site	Test 2.2		χ_1^2	*P*-value
	Detection Site			
	1T	2T		
JD Front Roll	4	1		
1J array	412	36	0.0226	0.8804
JD Intake 9C	10	6		
1J array	366	26	16.2186	0.0001
JD Tailrace	7	3		
1J array	405	26	5.6534	0.0174

Table D.2. Burnham Test 2.2 for The Dalles Project single releases. This procedure tests the assumption of whether detections at The Dalles primary array affect downstream survival and/or detection.

Release Site	Test 2.2		χ_1^2	*P*-value
	Detection Site			
	2T	1B		
John Day tailrace	29	0		
1T array	405	0	NA	NA
The Dalles tailrace	24	0		
1T array	930	3	2.4676	0.1162

Table D.3. Burnham Test 2.2 for Bonneville Project single releases. This procedure tests the assumption of whether detections at Bonneville primary array affect downstream survival and/or detection

Release Site	Test 2.2		χ_1^2	*P*-value
	Detection Site			
	2B	3B		
The Dalles tailrace	219	45		
B1 array	362	93	1.0317	0.3098
Bonneville tailrace	144	23		
B1 array	470	58	0.7059	0.4008

Table D.4. Burnham et al. (1987) Test 3.1 John Day release groups. This procedure tests whether detection at John Day primary array affect downstream detection histories

Release Group	Capture History at 2T	Capture History to 1T		χ_1^2	***P*-value**
		101	111		
Front Roll	1	4	404		
	0	0	8	2.3956	0.1217
Intake 9C	1	10	356		
	0	0	10	0.2174	0.6411
Tailrace	1	7	398		
	0	0	7	1.2635	0.2610

Table D.5. Burnham et al. (1987) Test 3.1 The Dalles Project release groups. This procedure tests whether detection at The Dalles primary array affect downstream detection histories.

Release Group	Capture History at 1B	Capture History to 2T		χ_1^2	***P*-value**
		101	111		
John Day	1	12	232		
	0	17	173	2.1726	0.1405
The Dalles	1	12	542		
	0	12	388	0.3625	0.5471

Table D.6. Burnham et al. (1987) Test 3.1 Bonneville Project release groups. This procedure tests whether detection at the Bonneville primary array affect downstream detection histories.

Release Group	Capture History at 3B	Capture History to 2B		χ_1^2	***P*-value**
		101	111		
John Day	1	95	173		
	0	124	189	0.8983	0.3432
The Dalles	1	67	219		
	0	77	251	0.0066	0.9353

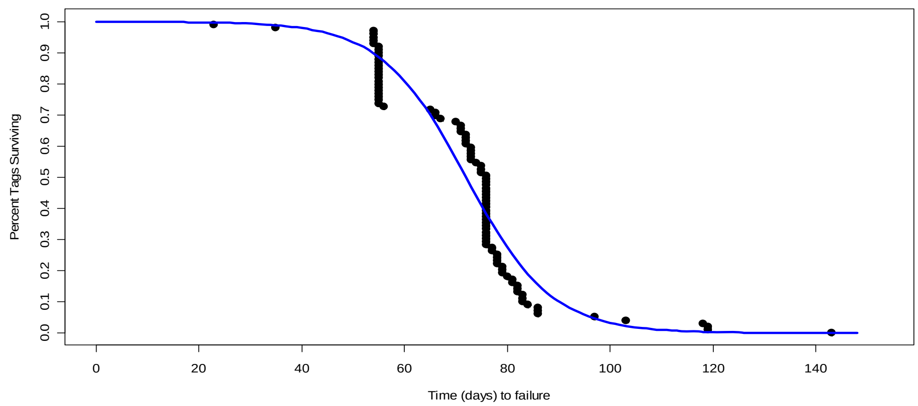
Appendix E

Tag-Life Survivorship Curve and Comparisons of Arrival Distributions Versus Tag Life for Subyearling Chinook Salmon

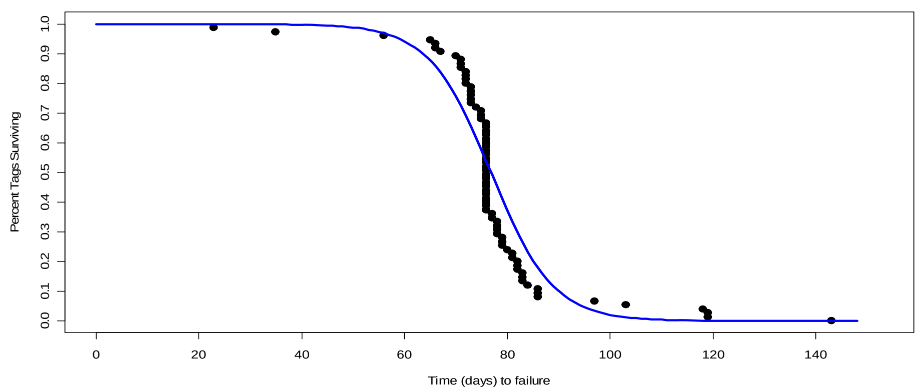
Appendix E

Tag-Life Survivorship Curve and Comparisons of Arrival Distributions Versus Tag Life for Subyearling Chinook Salmon

a. Estimated tag life using all 99 10-s tags.



b. Estimated tag life without the 24 10-s tags activated on July 15 2006



c. Estimated tag life of the 24 10-s tags activated on July 15 2006

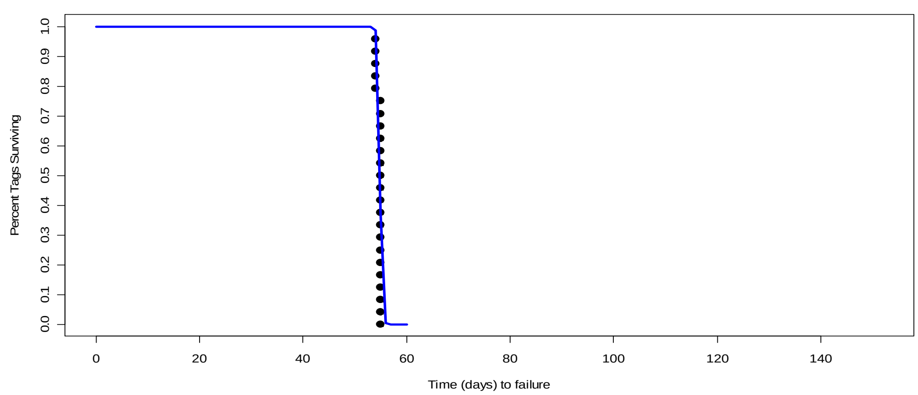


Figure E.1. Estimated Time to Failure for 10-s Tags for Summer Chinook Salmon

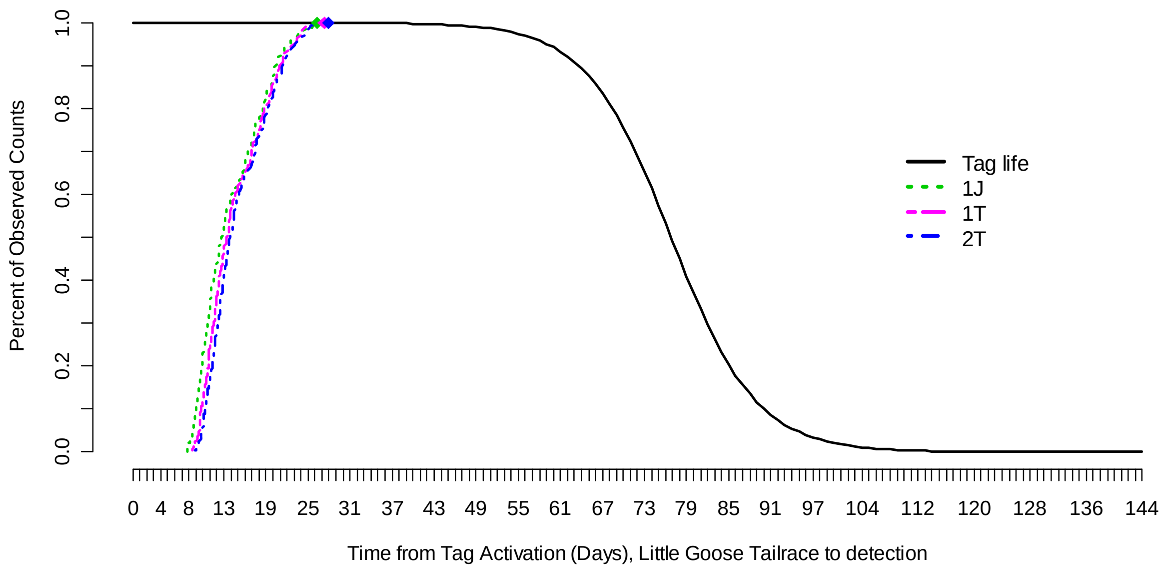


Figure E.2. Cumulative Time, from Time of Activation to Detection from the Little Goose Dam

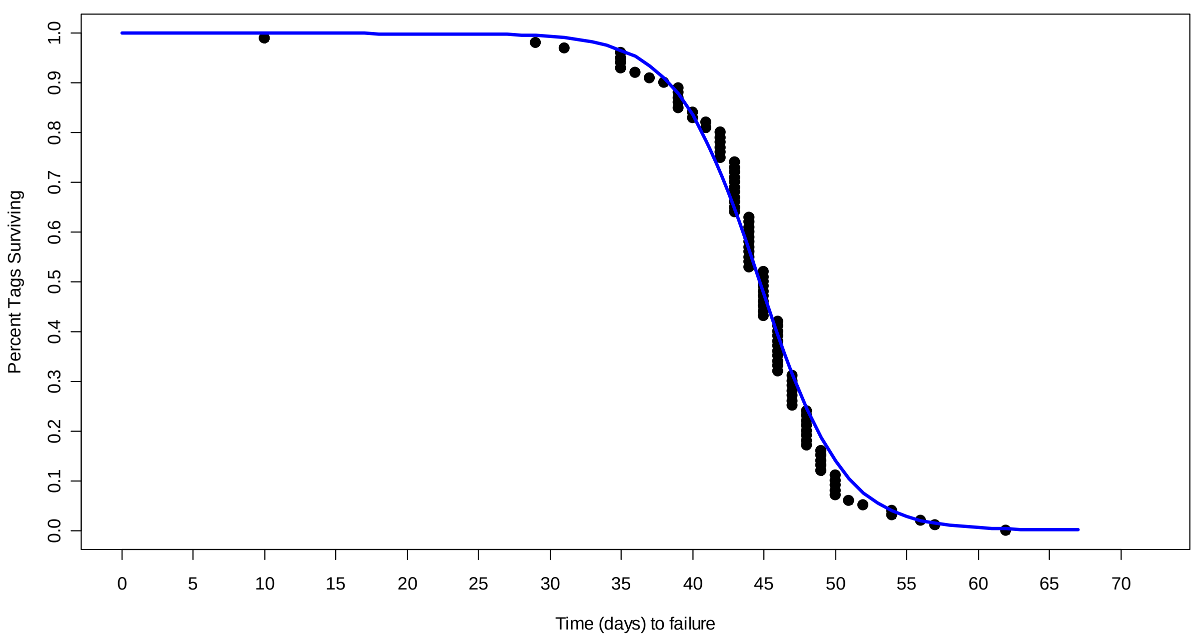


Figure E.3. Estimated Time to Failure for 5-s Tags for Spring and Summer Chinook Salmon Released from John Day Dam and Downstream.

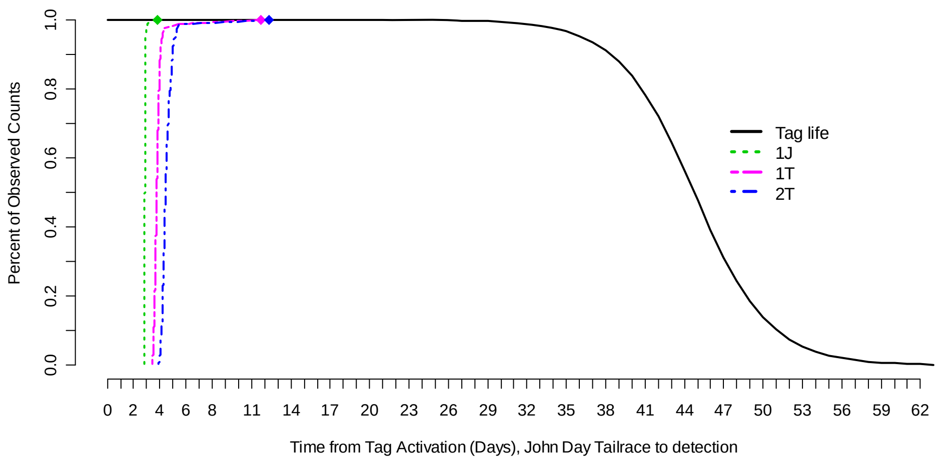


Figure E.4. Cumulative Time, from Time of Activation to Detection, from John Day Dam

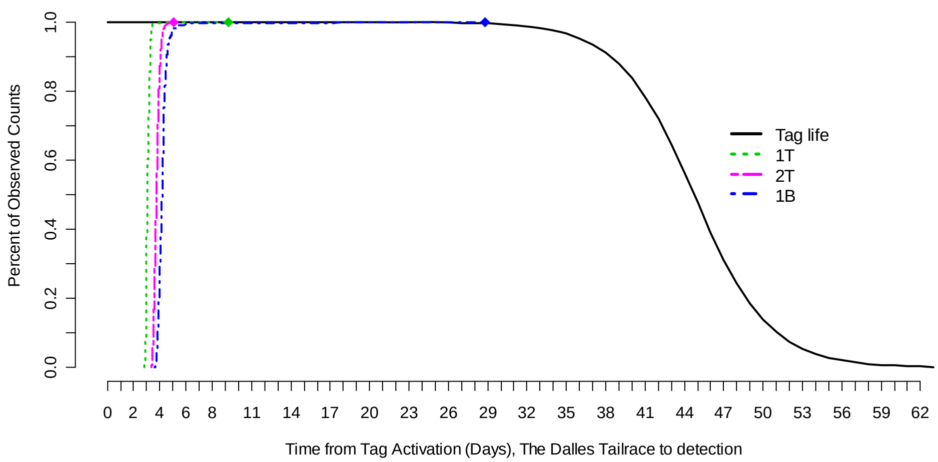


Figure E.5. Cumulative Time, from Time of Activation to Detection, from the Dalles Dam

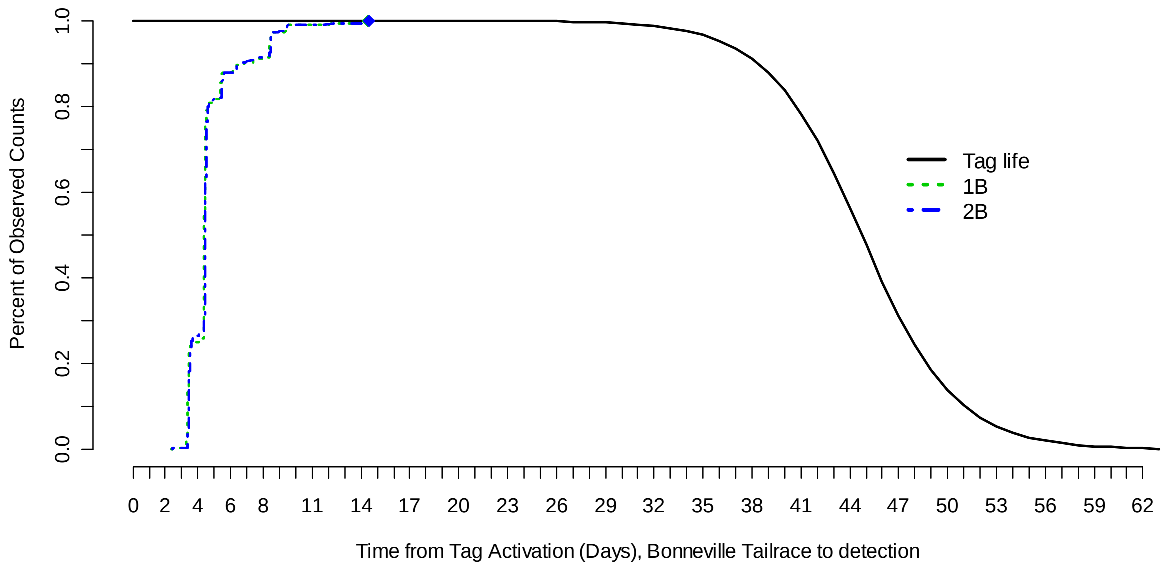


Figure E.6. Cumulative Time, from Time of Activation to Detection, from Bonneville Dam. The 3B Array was Not Operative during the Entire Study

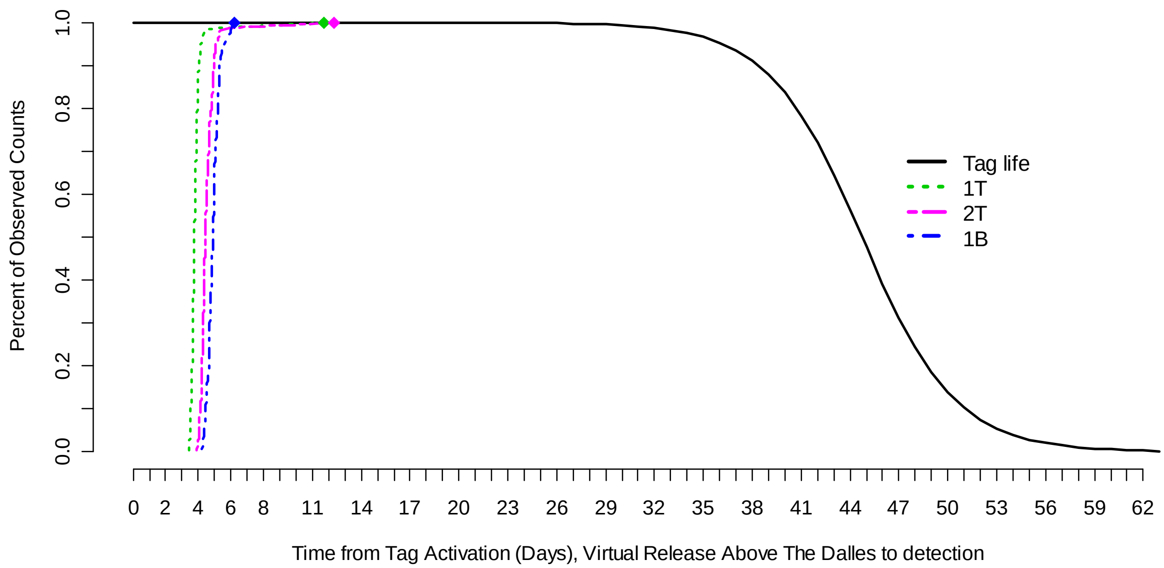


Figure E.7. Cumulative Time, from Time of Activation to Detection, from the Virtual Release above The Dalles Dam

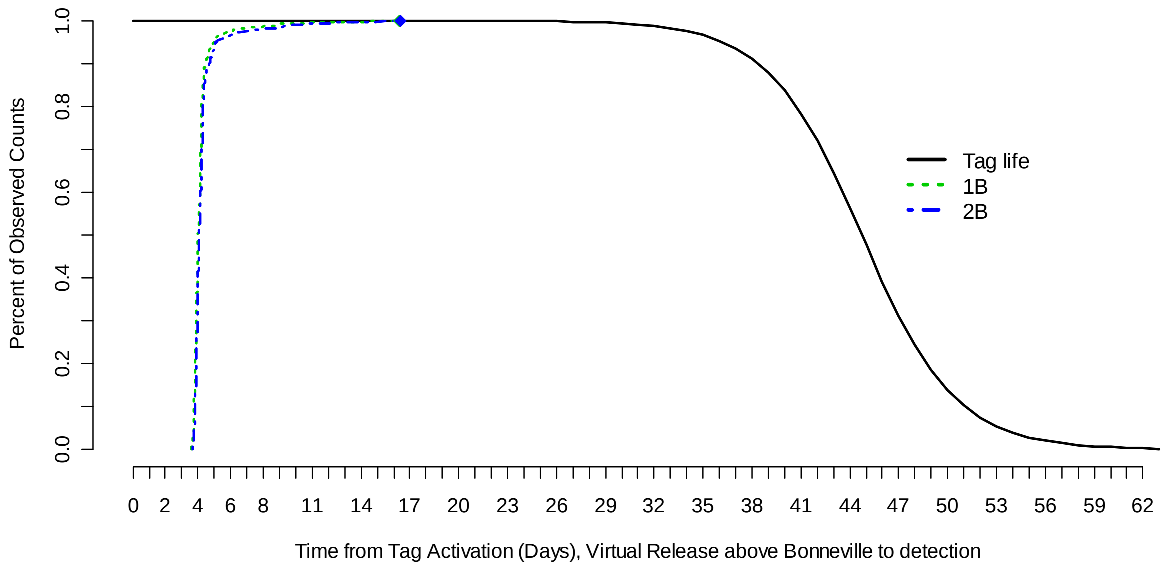


Figure E.8. Cumulative Time, from Time of Activation to Detection, from the Virtual Release above Bonneville Dam

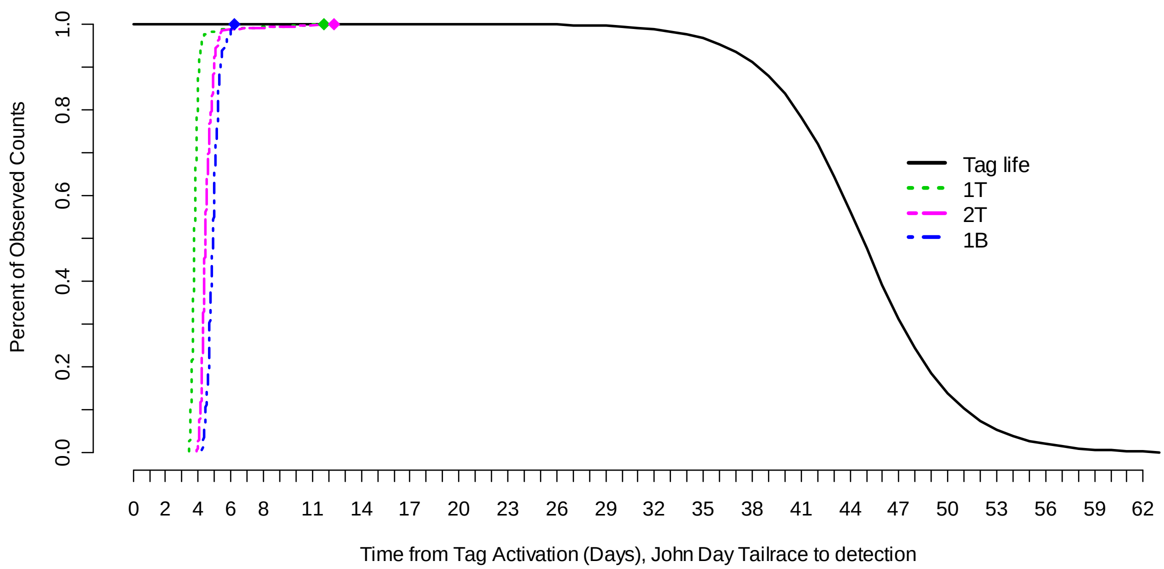


Figure E.9. Cumulative Time, from Time of Activation to Detection, from John Day Tailrace for The Dalles Project Survival

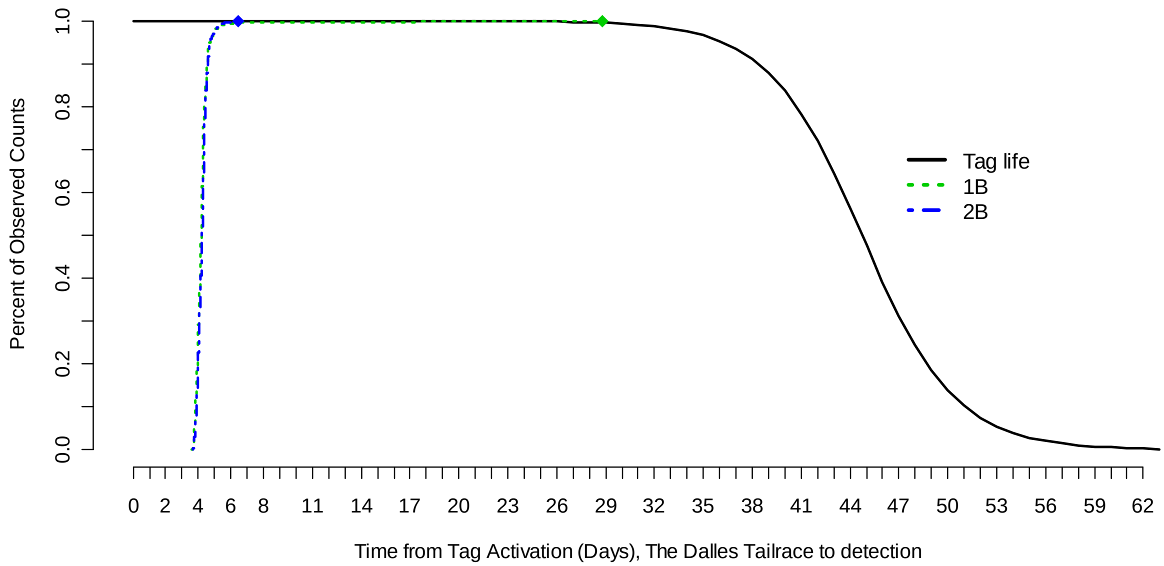


Figure E.10. Cumulative Time, from Time of Activation to Detection, from The Dalles Tailrace for Bonneville Project Survival

Appendix F

Forward-Sequential Model Selection Results for Acoustic-Tag Release Pairs in 2006 Acoustic-Tag Survival Studies through John Day, The Dalles, and Bonneville Projects for Subyearling Chinook Salmon

Appendix F

Forward-Sequential Model Selection Results for Acoustic-Tag Release Pairs in 2006 Acoustic-Tag Survival Studies through John Day, The Dalles, and Bonneville Projects for Subyearling Chinook Salmon

Table F.1. Forward-Sequential Model Selection Results for The Dalles Project Release Pairs for Acoustic-Tag Studies. Acoustic-tagged subyearling smolts released from John Day and The Dalles Dam tailraces.[1] The detection probability (p_2) at The Dalles secondary array (2T) was set to 100% for both release groups

Hypothesis	χ^2	df	P-value
$p_1 \mid \underset{\sim}{S}_1, \underset{\sim}{S}_2, p_2 \underset{\sim}{\lambda}$	0.2514	1	0.6161
$M_{\underset{\sim}{S}_1}$ vs. CJS	16.6102	3	0.0008
$S_2 \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1, p_{2,} \underset{\sim}{\lambda}$	9.4594	1	0.0021
$\lambda \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{S}_2, p_2$	6.8456	1	0.0089
Conclude Model: CJS			

[1] *Note:* Model fit to the data were indicated by a “~” when the parameters were treated as a vector (i.e. different between releases within a pair). The notation indicates which parameter was tested for homogeneity given (i.e. “$\mid$ ”) the specification of the other model parameters.

Table F.2. Forward-Sequential Model Selection Results for Bonneville Project Release Pairs for Acoustic-Tag Studies. Acoustic-tagged Chinook smolts released from The Dalles and Bonneville Dam tailraces

Hypothesis	χ^2	df	P-value
$p_1 \mid \underset{\sim}{S}_1, \underset{\sim}{\lambda}$	0.5002	1	0.4794
$M_{\underset{\sim}{S}_1}$ vs. CJS	42.0555	2	< 0.0001
$\lambda \mid \underset{\sim}{S}_1, \underset{\sim}{p}_1$	41.6343	1	< 0.0001
Conclude Model: $M_{\underset{\sim}{S}_1, \underset{\sim}{p}_1, \underset{\sim}{\lambda}}$			

Appendix G

Tests of Mixing and Goodness of Fit for Subyearling Chinook Salmon Release Groups

Appendix G

Tests of Mixing and Goodness of Fit for Subyearling Chinook Salmon Release Groups

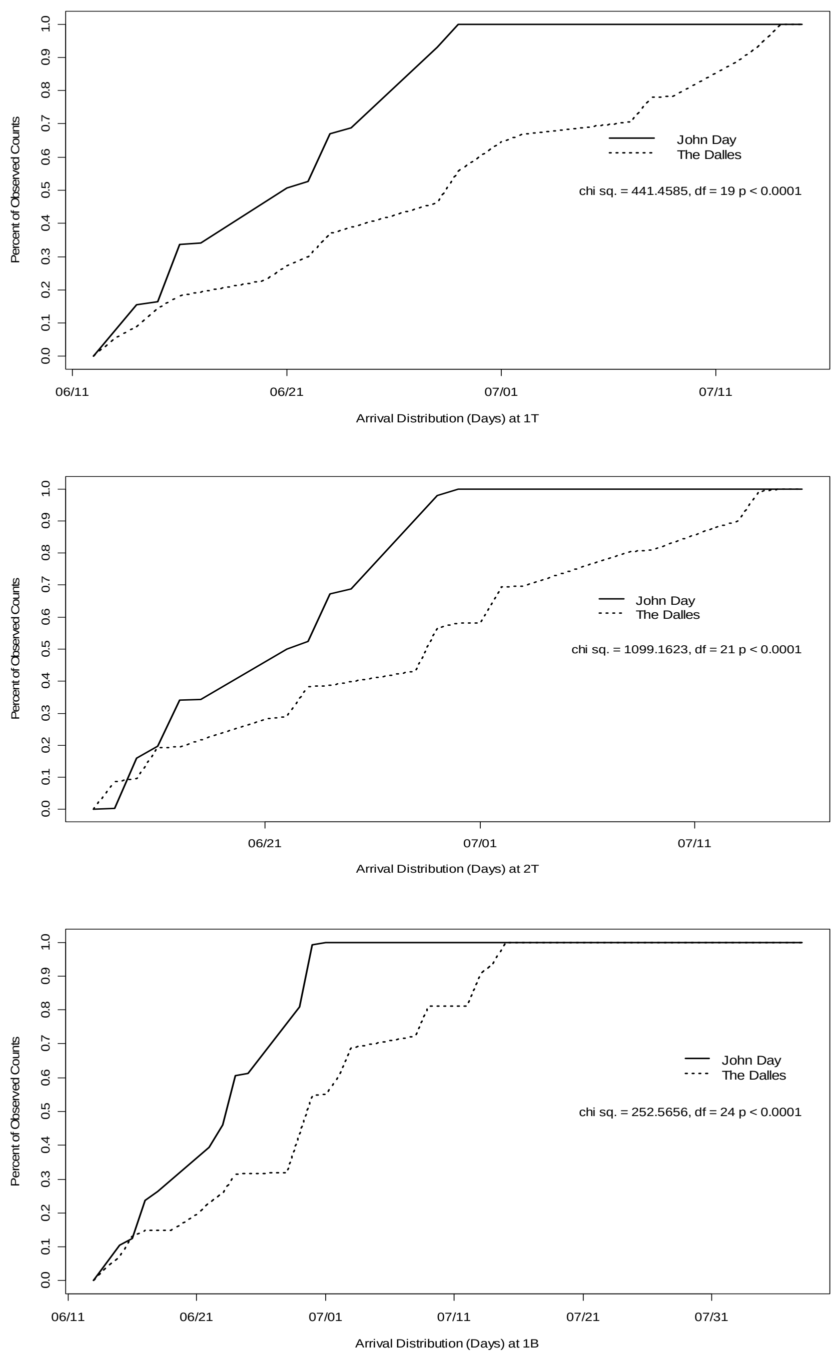


Figure G.1. Estimated Cumulative Arrival Distributions to Detection Arrays, John Day Dam and The Dalles Dam Tailrace Releases

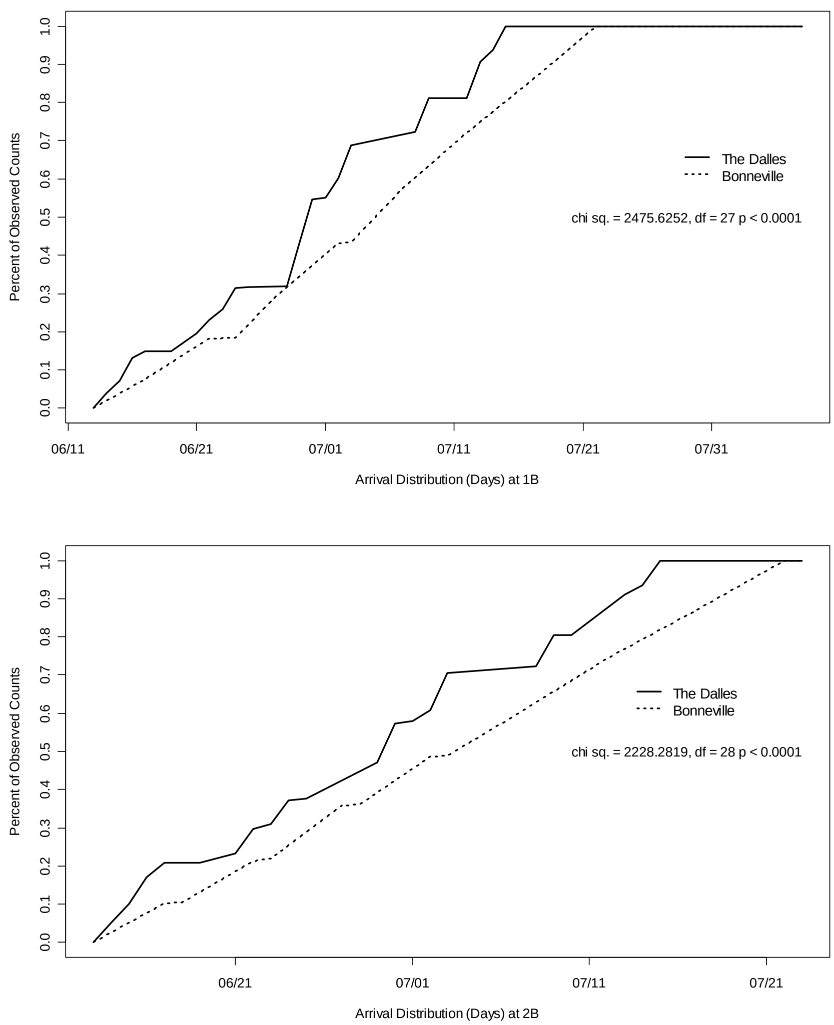


Figure G.2. Estimated Cumulative Arrival Distributions to Detection Arrays, The Dalles Dam and Bonneville Tailrace Releases

Table G.1. Burnham Test 1.T2 and 1.T3 for The Dalles Project Paired Releases. The m_1 are the number of fish detected at that array, z_1 are the number of fish *not detected* at that array, but detected downstream

Release Pair	**The Dalles 1 Array**						**The Dalles 2 Array**				
	Release			χ_1^2	**P-value**		**Release**			χ_1^2	***P*-value**
	History	J.Day	TDA			*History*	J.Day	TDA			
John Day &	$m_{.1}$	243	2093			$m_{.1}$	244	2023			
The Dalles	$z_{.1}$	3	18	0.0488	0.8251	$z_{.1}$	0	0	NA	NA	

Table G.2. Burnham Test 1.T2 for Bonneville Project Paired Releases. The m_1 are the number of fish detected at that array, z_1 are the number of fish *not detected* at that array, but detected downstream

Release Pair	**Bonneville 1 Array**				
	Release			χ_1^2	***P*-value**
	History	TDA	Bonn.		
The Dalles &	$m_{.1}$	1428	1525		
Bonneville	$z_{.1}$	233	265	0.3604	0.5483

Table G.3. Burnham Test 2.2 for The Dalles Project Single Releases. This procedure tests the assumption of whether detections at The Dalles primary array affect downstream survival and/or detection

Release Site	Test 2.2		χ^2_1	***P*-value**
	Detection Site			
	2T	1B		
John Day tailrace	3	0		
TDA 1 array	241	0	NA	NA
The Dalles tailrace	18	0		
TDA 1 array	2005	0	NA	NA

Table G.4. Burnham et al. (1987) Test 3.1 The Dalles Project Release Groups. This procedure tests whether detection at The Dalles primary array affect downstream detection histories

Release Group	Capture History at 1B	Capture History to 2T		χ^2_1	***P*-value**
		101	111		
John Day	1	1	151		
	0	2	90	0.1955	0.6584
The Dalles	1	3	1425		
	0	15	580	22.8816	< 0.0001

Appendix H

Tables of Detection Frequencies and Estimates of Detection and Survival for As-Planned Arrays

Appendix H

Tables of Detection Frequencies and Estimates of Detection and Survival for As-Planned Arrays

Table H.1. Spring Detection History

Season	Release Type	Release Location	Detection History								
			Detected at 1J 2J 3J								
Spring	Single	LGR Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		6-May	60	3	23	5	18	0	8	121	238
		13-May	175	10	75	22	56	2	19	399	758
		Pooled	235	13	98	27	74	2	27	520	996
			Detected at 1T 2T 3T								
Spring	Single	LGR Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		6-May	77	14	2	0	5	4	1	135	238
		13-May	216	65	3	6	16	11	7	434	758
		Pooled	293	79	5	6	21	15	8	569	996
			Detected at 1B 2B 3B								
Spring	Single	LGR Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		6-May	3	4	5	10	7	13	22	174	238
		13-May	9	11	16	21	35	56	55	555	758
		Pooled	12	15	21	31	42	69	77	729	996
			Detected at 1J 2J 3J								
Spring	Single	JDA Front Roll	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	30	0	11	1	4	0	6	2	54
		19-May	42	0	6	0	8	0	2	1	59
		21-May	49	1	2	1	2	0	2	2	59
		23-May	42	0	11	0	13	0	2	2	70
		25-May	45	0	1	0	12	0	2	0	60
		27-May	38	0	6	0	28	0	5	3	80
		1-Jun	49	0	3	1	5	0	2	0	60
		3-Jun	43	0	2	0	10	0	0	0	55
		Pooled	338	1	42	3	82	0	21	10	497
			Detected at 1J 2J 3J								
Spring	Single	JDA Intake 9C	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	28	0	5	1	10	0	2	9	55
		19-May	30	0	6	0	14	0	3	10	63
		21-May	30	0	2	1	12	0	1	12	58
		23-May	39	0	3	1	12	0	1	12	68
		25-May	34	0	7	0	11	0	0	8	60
		27-May	39	2	2	1	22	2	5	7	80
		1-Jun	35	0	4	2	10	0	3	6	60
		3-Jun	37	0	3	0	10	0	1	5	56
		Pooled	272	2	32	6	101	2	16	69	500

Season	**Release Type**	**Release Location**	**Detection History**								
						Detected at 1J 2J 3J					
Spring	Single	JDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	31	0	6	0	11	0	4	2	54
		19-May	48	0	5	0	4	0	2	1	60
		21-May	43	0	7	0	10	0	0	0	60
		23-May	48	1	7	3	5	1	0	5	70
		25-May	27	0	2	0	8	1	1	2	41
		27-May	48	0	8	0	16	0	2	3	77
		1-Jun	58	0	5	0	13	0	1	2	79
		3-Jun	33	0	2	1	3	0	0	1	40
		Pooled	336	1	42	4	70	2	10	16	481
						Detected at 1T 2T 3T					
Spring	Single	JDA Front Roll	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	45	0	1	0	0	0	1	7	54
		19-May	49	6	0	0	0	0	1	3	59
		21-May	45	7	0	0	0	0	0	7	59
		23-May	50	9	0	0	1	0	2	8	70
		25-May	42	7	0	0	0	0	2	9	60
		27-May	67	7	0	0	1	0	0	5	80
		1-Jun	57	1	0	0	0	0	0	2	60
		3-Jun	51	0	0	0	0	0	1	3	55
		Pooled	406	37	1	0	2	0	7	44	497
						Detected at 1T 2T 3T					
Spring	Single	JDA Intake 9C	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	38	0	0	0	0	0	0	17	55
		19-May	44	6	0	0	1	0	1	11	63
		21-May	38	5	0	0	0	0	1	14	58
		23-May	44	6	0	0	1	1	3	13	68
		25-May	45	2	0	0	0	1	1	11	60
		27-May	61	7	0	0	2	0	1	9	80
		1-Jun	49	2	1	0	0	0	0	8	60
		3-Jun	43	2	1	0	0	0	1	9	56
		Pooled	362	30	2	0	4	2	8	92	500
						Detected at 1T 2T 3T					
Spring	Single	JDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	46	0	0	0	0	0	0	8	54
		19-May	48	9	0	0	0	0	2	1	60
		21-May	46	6	0	0	0	0	2	6	60
		23-May	50	7	0	0	1	0	1	11	70
		25-May	34	2	0	0	0	1	0	4	41
		27-May	68	4	0	0	0	0	1	4	77
		1-Jun	74	0	0	0	0	0	1	4	79
		3-Jun	38	0	0	0	0	0	0	2	40
		Pooled	404	28	0	0	1	1	7	40	481

Season	Release Type	Release Location	Detection History								
			Detected at 1B 2B 3B								
Spring	Single	JDA Front Roll	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	10	5	4	3	10	2	7	13	54
		19-May	9	1	2	0	13	7	11	16	59
		21-May	9	4	6	3	8	4	10	15	59
		23-May	11	4	2	2	16	9	3	23	70
		25-May	2	5	5	0	8	6	7	27	60
		27-May	5	5	6	5	15	12	13	19	80
		1-Jun	11	4	4	6	15	5	3	12	60
		3-Jun	3	7	3	0	13	8	8	13	55
		Pooled	60	35	32	19	98	53	62	138	497
			Detected at 1B 2B 3B								
Spring	Single	JDA Intake 9C	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	18	3	1	1	6	2	3	21	55
		19-May	6	2	4	2	17	2	13	17	63
		21-May	9	6	4	4	7	3	4	21	58
		23-May	4	2	3	6	10	5	12	26	68
		25-May	10	2	2	1	12	9	4	20	60
		27-May	6	10	2	5	10	13	12	22	80
		1-Jun	9	4	4	3	12	7	6	15	60
		3-Jun	9	8	2	3	3	11	3	17	56
		Pooled	71	37	22	25	77	52	57	159	500
			Detected at 1B 2B 3B								
Spring	Single	JDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	7	5	4	2	12	8	3	13	54
		19-May	2	4	3	3	13	5	15	15	60
		21-May	8	5	3	0	13	9	5	17	60
		23-May	12	7	4	2	12	4	9	20	70
		25-May	3	7	1	2	7	6	6	9	41
		27-May	10	8	2	2	13	11	10	21	77
		1-Jun	18	11	4	2	12	7	10	15	79
		3-Jun	11	3	0	2	9	4	3	8	40
		Pooled	71	50	21	15	91	54	61	118	481
			Detected at 1T 2T 3T								
Spring	Single	TDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	94	0	0	0	0	0	1	1	96
		19-May	113	2	2	0	0	0	2	1	120
		21-May	108	4	0	0	1	1	1	5	120
		23-May	82	2	0	0	3	1	0	2	90
		25-May	46	1	0	0	0	0	1	0	48
		27-May	75	7	0	0	1	0	1	1	85
		1-Jun	65	2	0	0	0	0	0	0	67
		3-Jun	151	1	1	0	0	0	0	0	153
		5-Jun	191	3	3	0	0	0	1	1	199

		Pooled	925	22	6	0	5	2	7	11	978

Season	Release Type	Release Location	Detection History								
			Detected at 1B 2B 3B								
Spring	Single	TDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	26	6	10	3	27	7	9	8	96
		19-May	18	10	12	2	27	12	21	18	120
		21-May	23	7	14	6	23	10	12	25	120
		23-May	19	8	8	5	13	13	11	13	90
		25-May	5	4	3	2	5	10	6	13	48
		27-May	14	10	4	4	13	24	5	11	85
		1-Jun	10	8	9	6	17	9	1	7	67
		3-Jun	31	19	13	5	32	17	19	17	153
		5-Jun	27	23	20	12	32	22	18	45	199
		Pooled	173	95	93	45	189	124	102	157	978
			Detected at 1B 2B 3B								
Spring	Single	BON Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		2-May	48	10	8	1	88	22	34	28	239
		11-May	66	6	6	1	71	8	14	73	245
		19-May	62	20	31	11	51	13	23	33	244
		27-May	43	31	13	10	41	34	29	43	244
		Pooled	219	67	58	23	251	77	100	177	972
			Detected at 1B 2B 3B								
Spring	Single	BON B2CC	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		Pooled	14	10	9	5	13	8	9	10	78
			Detected at 1B 2B 3B								
Spring	Single	BON B2JBS	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		Pooled	5	3	4	4	7	7	4	8	42
			Detected at 1B 2B 3B								
Spring	Single	BON Spillway	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		Pooled	19	16	16	6	31	16	14	16	134
			Detected at 1T 2T 3T								
Spring	Virtual	JDA	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	35	0	0	0	0	0	0	2	37
		19-May	42	9	0	0	0	0	2	0	53
		21-May	39	5	0	0	0	0	1	5	50
		23-May	46	6	0	0	1	0	1	5	59
		25-May	25	2	0	0	0	0	0	2	29
		27-May	53	1	0	0	0	0	0	2	56
		1-Jun	62	0	0	0	0	0	0	1	63
		3-Jun	35	0	0	0	0	0	0	1	36
		Pooled	337	23	0	0	1	0	4	18	383

Season	**Release Type**	**Release Location**	**Detection History**								
							Detected at 1B 2B 3B				
Spring	Virtual	TDA	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-May	26	6	10	3	27	7	9	6	94
		19-May	18	10	12	2	27	12	21	15	117
		21-May	23	7	14	5	23	10	12	18	112
		23-May	19	8	8	5	13	11	11	9	84
		25-May	5	4	3	2	5	10	6	12	47
		27-May	14	10	4	4	13	23	5	9	82
		1-Jun	10	8	9	6	17	9	1	7	67
		3-Jun	31	19	13	5	32	17	19	17	153
		5-Jun	27	23	20	12	32	22	18	43	197
		Pooled	173	95	93	44	189	121	102	136	953
							Detected at 1T 2T 3T				
Spring	Virtual	JDA	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		Pooled	1212	120	5	2	15	6	22	104	1486
							Detected at 1B 2B 3B				
Spring	Virtual	TDA	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		Pooled	407	235	189	128	500	325	339	500	2623
							Detected at 1T 2T 3T				
Spring	Paired	TDA Dam	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		JDA Tailrace	404	28	0	0	1	1	7	40	481
		TDA Tailrace	925	22	6	0	5	2	7	11	978
							Detected at 1B 2B 3B				
Spring	Paired	BON Dam	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		TDA Tailrace	173	95	93	45	189	124	102	157	978
		BON Tailrace	219	67	58	23	251	77	100	177	972

Table H.2. Spring Detection and Survival Probabilities

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Spring	Single	LGR Release	to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		5/6	0.4943	0.0639	0.9946	0.0670	0.9266	0.0490	0.6923	0.0949	0.7778	0.0906
		5/13	0.4764	0.0359	1.0258	0.0398	0.9000	0.0319	0.6560	0.0555	0.7613	0.0535
		Pooled	0.4807	0.0312	1.0178	0.0343	0.9065	0.0269	0.6649	0.0478	0.7654	0.0461
Spring	Single	LGR Release	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		5/6	0.4337	0.0631	0.9902	0.0231	0.8235	0.0739	0.9785	0.0294	0.9100	0.0561
		5/13	0.4307	0.0355	0.9737	0.0214	0.7413	0.0482	0.9690	0.0200	0.9123	0.0316
		Pooled	0.4312	0.0310	0.9780	0.0169	0.7613	0.0408	0.9713	0.0167	0.9118	0.0274
Spring	Single	LGR Release	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		5/6	0.4353	0.1501	0.8191	0.5071	0.3571	0.1448	0.3182	0.1946	0.2593	0.0561
		5/13	0.3742	0.0612	1.1152	0.3847	0.4054	0.0792	0.3509	0.1239	0.1802	0.0316
		Pooled	0.3866	0.0570	1.0486	0.3156	0.3947	0.0696	0.3418	0.1047	0.1957	0.0274
Spring	Single	JDA Front Roll	to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		5/16	0.9654	0.0508	0.9130	0.0980	0.9783	0.0421	0.7143	0.1366	0.8824	0.1084
		5/19	0.9831	0.0329	0.9852	0.0523	1.0000	0.0000	0.8750	0.0935	0.8400	0.1015
		5/21	0.9674	0.0463	0.9657	0.0498	0.9636	0.0494	0.9434	0.0621	0.9615	0.0523
		5/23	0.9714	0.0390	1.0207	0.0590	1.0000	0.0000	0.7925	0.1092	0.7636	0.1123
		5/25	1.0000	0.0000	0.9711	0.0465	1.0000	0.0000	0.9783	0.0421	0.7895	0.1058
		5/27	0.9625	0.0416	0.9925	0.0784	1.0000	0.0000	0.8636	0.1013	0.5758	0.1192
		6/1	1.0006	0.0014	0.9729	0.0474	0.9828	0.0335	0.9245	0.0711	0.9074	0.0772
		6/3	1.0000	0.0000	1.0085	0.0129	1.0000	0.0000	0.9556	0.0602	0.8113	0.1053
		Pooled	0.9802	0.0123	0.9789	0.0204	0.9914	0.0084	0.8828	0.0321	0.8052	0.0378
Spring	Single	JDA Intake 9C	to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		5/16	0.8372	0.0978	1.0021	0.0794	0.9773	0.0441	0.8235	0.1282	0.7368	0.1399
		5/19	0.8413	0.0902	0.9962	0.0837	1.0000	0.0000	0.8333	0.1217	0.6818	0.1376
		5/21	0.7935	0.1043	1.0039	0.0555	0.9778	0.0431	0.9091	0.0000	0.7143	0.1366
		5/23	0.8238	0.0906	1.0038	0.0439	0.9818	0.0353	0.9070	0.0868	0.7647	0.1164
		5/25	0.8667	0.0860	1.0436	0.0421	1.0000	0.0000	0.8293	0.1152	0.7556	0.1256
		5/27	0.9175	0.0625	0.9504	0.0700	0.9265	0.0621	0.9318	0.0745	0.6308	0.1174
		6/1	0.9020	0.0762	0.9740	0.0731	0.9608	0.0533	0.8537	0.1082	0.7778	0.1215
		6/3	0.9107	0.0747	0.9963	0.0439	1.0000	0.0000	0.9250	0.0815	0.7872	0.1170
		Pooled	0.8628	0.0302	0.9951	0.0227	0.9759	0.0147	0.8782	0.0363	0.7268	0.0449

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Spring	Single	JDA Tailrace	to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		5/16	0.9630	0.0504	0.9640	0.0862	1.0000	0.0000	0.8378	0.1188	0.7381	0.1329
		5/19	0.9833	0.0323	0.9732	0.0474	1.0000	0.0000	0.9057	0.0788	0.9231	0.0725
		5/21	1.0000	0.0000	1.0271	0.0267	1.0000	0.0000	0.8600	0.0962	0.8113	0.1053
		5/23	0.9286	0.0604	1.0188	0.0192	0.9231	0.0649	0.8305	0.0956	0.8909	0.0823
		5/25	0.9519	0.0661	0.9908	0.0582	0.9737	0.0510	0.9310	0.0923	0.7500	0.1415
		5/27	0.9610	0.0433	1.0090	0.0494	1.0000	0.0000	0.8571	0.0917	0.7500	0.1060
		6/1	0.9747	0.0347	1.0016	0.0298	1.0000	0.0000	0.9206	0.0668	0.8169	0.0900
		6/3	0.9750	0.0484	1.0070	0.0112	0.9744	0.0496	0.9167	0.0904	0.9167	0.0904
		Pooled	0.9671	0.0161	0.9993	0.0159	0.9846	0.0114	0.8799	0.0325	0.8240	0.0368
Spring	Single	JDA Front Roll	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		5/16	0.8704	0.0896	0.9787	0.0412	1.0000	0.0000	0.9783	0.0421	1.0000	0.0000
		5/19	0.9512	0.0564	0.9800	0.0388	0.8909	0.0823	1.0000	0.0000	1.0000	0.0000
		5/21	0.8814	0.0825	1.0000	0.0000	0.8654	0.0927	1.0000	0.0000	1.0000	0.0000
		5/23	0.8908	0.0753	0.9623	0.0514	0.8500	0.0904	1.0000	0.0000	0.9833	0.0323
		5/25	0.8556	0.0913	0.9545	0.0615	0.8571	0.0980	1.0000	0.0000	1.0000	0.0000
		5/27	0.9375	0.0531	1.0000	0.0000	0.9067	0.0659	1.0000	0.0000	0.9867	0.0259
		6/1	0.9667	0.0455	1.0000	0.0000	0.9828	0.0335	1.0000	0.0000	1.0000	0.0000
		6/3	0.9455	0.0600	0.9808	0.0372	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		Pooled	0.9127	0.0251	0.9832	0.0123	0.9170	0.0257	0.9977	0.0043	0.9955	0.0063
Spring	Single	JDA Intake 9C	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		5/16	0.6909	0.1221	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		5/19	0.8275	0.0941	0.9783	0.0421	0.8824	0.0884	1.0000	0.0000	0.9804	0.0380
		5/21	0.7609	0.1105	0.9744	0.0496	0.8837	0.0958	1.0000	0.0000	1.0000	0.0000
		5/23	0.8157	0.0947	0.9375	0.0684	0.8654	0.0927	1.0000	0.0000	0.9615	0.0523
		5/25	0.8178	0.0980	0.9783	0.0421	0.9375	0.0684	1.0000	0.0000	0.9792	0.0404
		5/27	0.8889	0.0694	0.9844	0.0304	0.9000	0.0704	1.0000	0.0000	0.9714	0.0390
		6/1	0.8667	0.0860	1.0000	0.0000	0.9615	0.0523	0.9808	0.0372	1.0000	0.0000
		6/3	0.8401	0.0962	0.9778	0.0431	0.9565	0.0590	0.9783	0.0421	1.0000	0.0000
		Pooled	0.8174	0.0341	0.9788	0.0145	0.9200	0.0267	0.9949	0.0071	0.9849	0.0120

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Spring	Single	JDA Tailrace	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		5/16	0.8519	0.0947	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		5/19	0.9896	0.0339	0.9600	0.0543	0.8421	0.0947	1.0000	0.0000	1.0000	0.0000
		5/21	0.9043	0.0766	0.9583	0.0564	0.8846	0.0868	1.0000	0.0000	1.0000	0.0000
		5/23	0.8448	0.0857	0.9808	0.0372	0.8793	0.0839	1.0000	0.0000	0.9828	0.0335
		5/25	0.9024	0.0907	1.0000	0.0000	0.9189	0.0880	1.0000	0.0000	0.9730	0.0523
		5/27	0.9488	0.0496	0.9855	0.0282	0.9444	0.0529	1.0000	0.0000	1.0000	0.0000
		6/1	0.9494	0.0484	0.9867	0.0259	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		6/3	0.9500	0.0676	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		Pooled	0.9179	0.0247	0.9830	0.0125	0.9332	0.0235	1.0000	0.0000	0.9954	0.0065
Spring	Single	JDA Front Roll	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		5/16	0.8133	0.1335	0.9017	0.2140	0.7059	0.1531	0.6818	0.1946	0.5556	0.1874
		5/19	0.7910	0.1364	0.7714	0.2178	0.7500	0.1499	0.8333	0.2109	0.3333	0.1688
		5/21	0.8268	0.1433	0.8673	0.2550	0.6765	0.1572	0.5909	0.2054	0.5200	0.1958
		5/23	0.6936	0.1170	1.0436	0.1942	0.6591	0.1401	0.7895	0.1833	0.3750	0.1499
		5/25	0.6356	0.1695	0.9441	0.4145	0.5769	0.1899	0.5833	0.2789	0.3333	0.2017
		5/27	0.9000	0.1503	1.0792	0.4390	0.5417	0.1409	0.4762	0.2136	0.2703	0.1431
		6/1	0.8250	0.1090	1.1785	0.2652	0.6667	0.1378	0.6000	0.1921	0.4286	0.1639
		6/3	0.8785	0.1668	0.8341	0.2668	0.5588	0.1670	0.7692	0.2291	0.3226	0.1646
		Pooled	0.7926	0.0490	0.9598	0.1002	0.6397	0.0547	0.6507	0.0774	0.3862	0.0608
Spring	Single	JDA Intake 9C	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		5/16	0.6313	0.1323	0.9148	0.1223	0.8065	0.1392	0.9130	0.1152	0.7241	0.1627
		5/19	0.7760	0.1252	0.9665	0.3816	0.8182	0.1315	0.5714	0.2593	0.2963	0.1723
		5/21	0.6828	0.1423	0.9680	0.2195	0.6061	0.1668	0.6522	0.1946	0.6000	0.1921
		5/23	0.7526	0.1829	1.0259	0.5739	0.5667	0.1774	0.4000	0.2479	0.2857	0.1933
		5/25	0.7000	0.1311	0.9821	0.2197	0.6667	0.1541	0.8000	0.2025	0.3636	0.1641
		5/27	0.9583	0.2229	0.7312	0.2464	0.3913	0.1411	0.6957	0.1880	0.4103	0.1544
		6/1	0.8060	0.1301	1.0180	0.2707	0.6410	0.1505	0.6500	0.2091	0.4063	0.1701
		6/3	0.7806	0.1725	0.9177	0.2260	0.3889	0.1592	0.7727	0.1750	0.5484	0.1752
		Pooled	0.7584	0.0521	0.8969	0.0866	0.5986	0.0570	0.6968	0.0723	0.4557	0.0635

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Spring	Single	JDA Tailrace	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		5/16	0.7955	0.1280	1.1174	0.2846	0.6053	0.1554	0.6667	0.2178	0.3750	0.1678
		5/19	0.9167	0.1936	0.8727	0.4692	0.6000	0.1752	0.5000	0.2828	0.2500	0.1733
		5/21	0.7653	0.1321	0.9382	0.2109	0.6316	0.1535	0.8125	0.1913	0.3714	0.1601
		5/23	0.7740	0.1262	0.8500	0.1809	0.6829	0.1425	0.7600	0.1674	0.5429	0.1650
		5/25	0.9800	0.2648	0.7441	0.2920	0.4231	0.1899	0.7692	0.2291	0.4348	0.2027
		5/27	0.8364	0.1445	0.7971	0.1909	0.5435	0.1439	0.8182	0.1611	0.4286	0.1497
		6/1	0.8846	0.1113	0.8290	0.1433	0.6296	0.1288	0.8286	0.1249	0.6042	0.1384
		6/3	0.8338	0.1368	0.9253	0.1695	0.6897	0.1684	0.8750	0.1621	0.5185	0.1886
		Pooled	0.8371	0.0504	0.8571	0.0749	0.6060	0.0551	0.7707	0.0659	0.4549	0.0598
Spring	Single	TDA Tailrace	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		5/16	0.9896	0.0204	0.9895	0.0206	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		5/19	0.9920	0.0163	0.9829	0.0235	0.9829	0.0235	0.9829	0.0235	1.0000	0.0000
		5/21	0.9587	0.0359	0.9909	0.0176	0.9561	0.0376	1.0000	0.0000	0.9825	0.0241
		5/23	0.9778	0.0304	1.0000	0.0000	0.9659	0.0378	1.0000	0.0000	0.9545	0.0435
		5/25	1.0005	0.0012	0.9787	0.0412	0.9787	0.0412	1.0000	0.0000	1.0000	0.0000
		5/27	0.9892	0.0229	0.9872	0.0249	0.9277	0.0557	1.0000	0.0000	0.9880	0.0235
		6/1	1.0000	0.0000	1.0000	0.0000	0.9701	0.0408	1.0000	0.0000	1.0000	0.0000
		6/3	1.0000	0.0000	1.0000	0.0000	0.9935	0.0127	0.9935	0.0127	1.0000	0.0000
		6/5	0.9951	0.0098	0.9949	0.0100	0.9848	0.0171	0.9848	0.0171	1.0000	0.0000
		Pooled	0.9889	0.0067	0.9926	0.0055	0.9760	0.0096	0.9937	0.0051	0.9927	0.0055
Spring	Single	TDA Tailrace	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		5/16	0.9405	0.0600	1.0280	0.1390	0.7975	0.0886	0.7111	0.1325	0.4848	0.1205
		5/19	0.9237	0.0827	0.9067	0.1709	0.7037	0.0994	0.6667	0.1425	0.4179	0.1182
		5/21	0.8300	0.0809	1.0542	0.1758	0.7229	0.0962	0.6000	0.1358	0.4762	0.1233
		5/23	0.9350	0.0986	0.9331	0.1723	0.6061	0.1178	0.6750	0.1452	0.5094	0.1347
		5/25	0.8830	0.2201	0.8808	0.3512	0.4483	0.1809	0.6429	0.2511	0.3750	0.1936
		5/27	0.9427	0.1043	1.0150	0.1844	0.4493	0.1174	0.7500	0.1499	0.3934	0.1225
		6/1	0.9051	0.0764	1.3303	0.2750	0.6102	0.1245	0.5455	0.1699	0.4091	0.1452
		6/3	0.9559	0.0655	0.9206	0.1160	0.6496	0.0864	0.7353	0.1049	0.5051	0.0984
		6/5	0.8391	0.0725	1.0214	0.1403	0.5809	0.0829	0.6098	0.1056	0.4808	0.0960
		Pooled	0.9000	0.0286	1.0000	0.0564	0.6328	0.0353	0.6601	0.0461	0.4613	0.0406

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Spring	Single	BON Tailrace	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		5/2	0.9154	0.0451	0.8870	0.0843	0.8136	0.0574	0.8657	0.0817	0.3452	0.0719
		5/11	0.7080	0.0580	0.9551	0.0584	0.9051	0.0457	0.9114	0.0627	0.4768	0.0796
		5/19	0.8936	0.0466	1.0126	0.0882	0.7660	0.0606	0.6613	0.0833	0.5616	0.0806
		5/27	0.9157	0.0674	0.8742	0.0984	0.5640	0.0741	0.7629	0.0847	0.4966	0.0804
		Pooled	0.8504	0.0265	0.9531	0.0435	0.7597	0.0318	0.7793	0.0423	0.4658	0.0394
Spring	Single	BON B2CC	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		Pooled	0.9455	0.1000	0.9661	0.1876	0.6102	0.1245	0.6316	0.1535	0.5333	0.1458
Spring	Single	BON B2JBS	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		Pooled	0.8929	0.1631	1.1733	0.4694	0.5333	0.1786	0.5000	0.2450	0.3636	0.2011
Spring	Single	BON Spillway	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		Pooled	0.9408	0.0700	1.0594	0.1717	0.6346	0.0925	0.6140	0.1264	0.4268	0.1070
Spring	Virtual	JDA	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		5/16	0.9459	0.0729	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		5/19	1.0081	0.0123	0.9545	0.0615	0.8235	0.1047	1.0000	0.0000	1.0000	0.0000
		5/21	0.9026	0.0835	0.9750	0.0484	0.8864	0.0937	1.0000	0.0000	1.0000	0.0000
		5/23	0.9174	0.0713	0.9792	0.0404	0.8868	0.0853	1.0000	0.0000	0.9811	0.0367
		5/25	0.9310	0.0923	1.0000	0.0000	0.9259	0.0988	1.0000	0.0000	1.0000	0.0000
		5/27	0.9643	0.0486	1.0000	0.0000	0.9815	0.0359	1.0000	0.0000	1.0000	0.0000
		6/1	0.9841	0.0308	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		6/3	0.9722	0.0537	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		Pooled	0.9537	0.0212	0.9883	0.0114	0.9363	0.0253	1.0000	0.0000	0.9972	0.0055
Spring	Virtual	TDA	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		5/16	0.9605	0.0545	1.0280	0.1390	0.7975	0.0886	0.7111	0.1325	0.4848	0.1205
		5/19	0.9474	0.0804	0.9067	0.1709	0.7037	0.0994	0.6667	0.1425	0.4179	0.1182
		5/21	0.8786	0.0766	1.0457	0.1723	0.7317	0.0958	0.6122	0.1364	0.4762	0.1233
		5/23	0.9714	0.0927	0.9259	0.1690	0.6250	0.1186	0.6750	0.1452	0.5294	0.1370
		5/25	0.9018	0.2217	0.8808	0.3512	0.4483	0.1809	0.6429	0.2511	0.3750	0.1936
		5/27	0.9630	0.1017	1.0131	0.1833	0.4559	0.1184	0.7500	0.1499	0.4000	0.1239
		6/1	0.9051	0.0764	1.3303	0.2750	0.6102	0.1245	0.5455	0.1699	0.4091	0.1452
		6/3	0.9559	0.0655	0.9206	0.1160	0.6496	0.0864	0.7353	0.1049	0.5051	0.0984
		6/5	0.8477	0.0723	1.0214	0.1403	0.5809	0.0829	0.6098	0.1056	0.4808	0.0960
		Pooled	0.9185	0.0278	0.9979	0.0563	0.6364	0.0353	0.6617	0.0461	0.4637	0.0406

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Spring	Virtual	JDA	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		Pooled	0.9316	0.0129	0.9825	0.0073	0.9059	0.0155	0.9948	0.0039	0.9845	0.0067
Spring	Virtual	TDA	to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		Pooled	0.8905	0.0200	0.9382	0.0368	0.6143	0.0225	0.6694	0.0298	0.4376	0.0255
Spring	Paired		to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		JDA Front Roll	0.9803	0.0123	0.9888	0.0129	0.9881	0.0071	0.8814	0.0229	0.8145	0.0265
		JDA Tailrace	0.9671	0.0161								
Spring	Paired		to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		JDA Intake 9C	0.8626	0.0302	0.9978	0.0131	0.9805	0.0092	0.8786	0.0241	0.7251	0.0435
		JDA Tailrace	0.9672	0.0161							0.8250	0.0361
Spring	Paired		to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		JDA Intake 9C	0.8626	0.0302	0.9853	0.0149	0.9841	0.0082	0.8816	0.0239	0.7322	0.0431
		JDA Front Roll	0.9803	0.0123							0.8016	0.0378
Spring	Paired		to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		JDA Tailrace	0.9175	0.0247	0.9830	0.0125	0.9332	0.0120	1.0000	0.0000	0.9954	0.0065
		TDA Tailrace	0.9890	0.0067	0.9926	0.0055	0.9750	0.0050	0.9937	0.0051	0.9927	0.0055
Spring	Paired		to 1B	95% CL	1B to 2B	95% CL	1B	95% CL	2B	95% CL	λ to 3B	95% CL
		TDA Tailrace	0.9000	0.0286	1.0000	0.0564	0.6328	0.0353	0.6601	0.0461	0.4613	0.0406
		BON Tailrace	0.8504	0.0265	0.9531	0.0435	0.7597	0.0318	0.7793	0.0423	0.4658	0.0394

Season	Release Type		$\hat{S}\ (\widehat{s.e.})$	95% CL
Spring	Paired			
		JDA Front Roll to Tailrace	1.0136	0.0414
		JDA Intake 9C to Tailrace	0.8919	0.0676
		JDA Intake 9C to Front Roll	0.8798	0.0641
		TDA Project	0.9277	0.0504
		BON Project	1.0583	0.0923

Table H.3. Summer Detection History

Season	Release Type	Release Location	Detection Histories								
			Detected at 1J 2J 3J								
Summer	Single	LGS Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-Jun	85	2	5	0	2	0	0	101	195
		21-Jun	74	2	4	1	2	0	0	112	195
		24-Jun	52	5	0	0	1	0	0	137	195
		27-Jun	51	4	1	1	5	0	0	133	195
		1-Jul	27	3	2	1	2	1	0	159	195
		4-Jul	21	0	0	0	2	0	0	172	195
		7-Jul	20	1	0	0	2	0	0	171	194
		10-Jul	3	0	0	0	0	0	0	189	192
		14-Jul	0	0	0	0	0	0	0	198	198
		18-Jul	0	0	0	0	0	0	0	195	195
		Pooled	333	17	12	3	16	1	0	1567	1949
			Detected at 1T 2T 3T								
Summer	Single	LGS Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		16-Jun	78	0	0	0	0	0	2	115	195
		21-Jun	64	1	0	0	0	0	2	128	195
		24-Jun	51	0	0	0	0	0	1	143	195
		27-Jun	45	1	0	0	0	0	3	146	195
		1-Jul	20	0	0	0	0	0	2	173	195
		4-Jul	14	0	0	0	0	0	1	180	195
		7-Jul	16	0	0	0	0	0	1	177	194
		10-Jul	2	0	0	0	0	0	0	190	192
		14-Jul	0	0	0	0	0	0	0	198	198
		18-Jul	0	0	0	0	0	0	0	195	195
		Pooled	290	2	0	0	0	0	12	1645	1949
			Detected at 1B 2B								
Summer	Single	LGS Tailrace	1 1	0 1	1 0	0 0					Total
		16-Jun	16	18	14	147					195
		21-Jun	16	11	16	152					195
		24-Jun	21	11	6	157					195
		27-Jun	10	6	14	165					195
		1-Jul	10	2	3	180					195
		4-Jul	7	2	4	182					195
		7-Jul	9	2	2	181					194
		10-Jul	1	1	0	190					192
		14-Jul	0	0	0	198					198
		18-Jul	0	0	0	195					195
		Pooled	90	53	59	1747					1949

Season	**Release Type**	**Release Location**	**Detection Histories**								
							Detected at 1J 2J 3J				
Summer	Single	JDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		13-Jun	43	0	3	0	3	0	1	0	50
		15-Jun	41	0	5	0	3	0	0	1	50
		20-Jun	49	0	0	0	1	0	0	0	50
		22-Jun	48	0	0	1	0	0	0	0	49
		27-Jun	89	0	0	0	10	0	0	1	100
		Pooled	270	0	8	1	17	0	1	2	299
							Detected at 1T 2T 3T				
Summer	Single	JDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		13-Jun	41	1	0	0	0	0	0	8	50
		15-Jun	42	0	0	0	0	0	0	8	50
		20-Jun	45	0	0	0	0	0	1	4	50
		22-Jun	38	2	0	0	0	0	1	8	49
		27-Jun	75	0	0	0	0	0	0	25	100
		Pooled	241	3	0	0	0	0	2	53	299
							Detected at 1B 2B				
Summer	Single	JDA Tailrace	1 1	0 1	1 0	0 0					Total
		13-Jun	15	10	5	20					50
		15-Jun	19	15	1	15					50
		20-Jun	20	6	11	13					50
		22-Jun	14	7	8	20					49
		27-Jun	39	4	20	37					100
		Pooled	107	42	45	105					299
							Detected at 1T 2T 3T				
Summer	Single	TDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		13-Jun	189	6	0	0	0	0	0	1	196
		15-Jun	193	7	0	0	0	0	0	0	200
		20-Jun	188	4	0	0	0	0	2	2	196
		22-Jun	198	0	0	0	0	0	2	0	200
		27-Jun	194	1	0	0	0	0	1	4	200
		28-Jun	198	0	0	0	0	0	0	2	200
		1-Jul	232	0	0	0	0	0	3	12	247
		7-Jul	228	0	0	0	0	0	9	11	248
		11-Jul	183	0	0	0	0	0	41	22	246
		13-Jul	201	0	0	0	1	0	30	14	246
		Pooled	2004	18	0	0	1	0	88	68	2179

Season	**Release Type**	**Release Location**	**Detection Histories**				
					Detected at 1B 2B		
Summer	Single	TDA Tailrace	1 1	0 1	1 0	0 0	Total
		13-Jun	74	53	27	42	196
		15-Jun	88	46	24	42	200
		20-Jun	71	40	47	38	196
		22-Jun	58	40	64	38	200
		27-Jun	111	12	54	23	200
		28-Jun	117	11	50	22	200
		1-Jul	153	6	44	44	247
		7-Jul	113	11	63	61	248
		11-Jul	127	5	10	104	246
		13-Jul	101	9	32	104	246
		Pooled	1013	233	415	518	2179
					Detected at 1B 2B		
Summer	Single	BON Tailrace	1 1	0 1	1 0	0 0	Total
		17-Jun	73	83	42	47	245
		22-Jun	120	54	45	26	245
		27-Jun	140	71	20	14	245
		2-Jul	176	16	44	9	245
		7-Jul	156	11	60	16	243
		12-Jul	205	11	17	12	245
		17-Jul	175	13	35	21	244
		22-Jul	191	6	26	22	245
		Pooled	1236	265	289	167	1957
					Detected at 1B 2B		
Summer	Single	BON B2CC	1 1	0 1	1 0	0 0	Total
		Pooled	57	8	19	7	91
					Detected at 1B 2B		
Summer	Single	BON B2JBS	1 1	0 1	1 0	0 0	Total
		Pooled	93	20	48	28	189
					Detected at 1B 2B		
Summer	Single	BON Spillway	1 1	0 1	1 0	0 0	Total
		Pooled	369	72	143	130	714

Season	**Release Type**	**Release Location**	**Detection Histories**								
						Detected at 1T 2T 3T					
Summer	Virtual	JDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		13-Jun	38	1	0	0	0	0	0	7	46
		15-Jun	39	0	0	0	0	0	0	7	46
		20-Jun	45	0	0	0	0	0	1	3	49
		22-Jun	38	2	0	0	0	0	1	8	49
		27-Jun	75	0	0	0	0	0	0	14	89
		Pooled	235	3	0	0	0	0	2	39	279
						Detected at 1B 2B					
Summer	Virtual	TDA Tailrace	1 1	0 1	1 0	0 0					Total
		13-Jun	74	53	27	41					195
		15-Jun	88	46	24	42					200
		20-Jun	71	40	47	34					192
		22-Jun	58	40	64	36					198
		27-Jun	111	12	54	18					195
		28-Jun	117	11	50	20					198
		1-Jul	153	6	44	29					232
		7-Jul	113	11	63	41					228
		11-Jul	127	5	10	41					183
		13-Jul	101	9	32	59					201
		Pooled	1013	233	415	361					2022
						Detected at 1T 2T 3T					
Summer	Virtual	JDA Tailrace	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		Pooled	527	3	0	0	0	0	13	105	648
						Detected at 1B 2B					
Summer	Virtual	TDA Tailrace	1 1	0 1	1 0	0 0					Total
		Pooled	1250	307	510	491					2558
						Detected at 1T 2T 3T					
Summer	Paired	TDA Dam	1 1 1	0 1 1	1 0 1	0 0 1	1 1 0	0 1 0	1 0 0	0 0 0	Total
		JDA Tailrace	241	3	0	0	0	0	2	53	299
		TDA Tailrace	2004	18	0	0	1	0	88	68	2179
						Detected at 1B 2B					
Summer	Paired	BON Dam	1 1	0 1	1 0	0 0					Total
		TDA Tailrace	1013	233	415	518					2179
		BON Tailrace	1236	265	289	167					1957

Table H.4. Summer Detection and Survival Probabilities

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Summer	Single	LGS Tailrace	to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		16-Jun	0.4821	0.0702	1.0012	0.0020	0.9787	0.0292	0.9457	0.0463	0.9775	0.0308
		21-Jun	0.4256	0.0694	1.0016	0.0025	0.9639	0.0402	0.9383	0.0523	0.9744	0.0351
		24-Jun	0.2974	0.0641	1.0000	0.0000	0.9138	0.0723	1.0000	0.0000	0.9828	0.0335
		27-Jun	0.3179	0.0653	1.0029	0.0049	0.9194	0.0678	0.9649	0.0478	0.9167	0.0700
		1-Jul	0.1846	0.0545	1.0083	0.0133	0.8611	0.1129	0.9091	0.0980	0.9091	0.0980
		4-Jul	0.1179	0.0453	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.9130	0.1152
		7-Jul	0.1186	0.0455	1.0000	0.0000	0.9565	0.0833	1.0000	0.0000	0.9130	0.1152
		10-Jul	0.0156	0.0176	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		14-Jul	******	(******)	******	(******)	******	(******)	******	(******)	******	(******)
		18-Jul	******	(******)	******	(******)	******	(******)	******	(******)	******	(******)
		Pooled	0.1960	0.0176	1.0019	0.0014	0.9450	0.0229	0.9589	0.0204	0.9537	0.0216
Summer	Single	LGS Tailrace	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		16-Jun	0.4103	0.0690	0.9750	0.0343	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		21-Jun	0.3437	0.0666	0.9697	0.0414	0.9846	0.0300	1.0000	0.0000	1.0000	0.0000
		24-Jun	0.2667	0.0621	0.9808	0.0372	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		27-Jun	0.2516	0.0610	0.9375	0.0684	0.9783	0.0421	1.0000	0.0000	1.0000	0.0000
		1-Jul	0.1128	0.0445	0.9091	0.1201	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		4-Jul	0.0769	0.0374	0.9333	0.1262	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		7-Jul	0.0876	0.0398	0.9412	0.1119	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		10-Jul	0.0104	0.0143	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		14-Jul	******	(******)	******	(******)	******	(******)	******	(******)	******	(******)
		18-Jul	******	(******)	******	(******)	******	(******)	******	(******)	******	(******)
		Pooled	0.1560	0.0161	0.9603	0.0220	0.9932	0.0094	1.0000	0.0000	1.0000	0.0000
Summer	Single	LGS Tailrace	to 1B	95% CL			to 1B	95% CL			λ to 2B	95% CL
		16-Jun	0.3269	0.1033			0.4706	0.1678			0.5333	0.1786
		21-Jun	0.2769	0.0878			0.5926	0.1854			0.5000	0.1733
		24-Jun	0.2110	0.0625			0.6563	0.1646			0.7778	0.1568
		27-Jun	0.1969	0.0798			0.6250	0.2372			0.4167	0.1972
		1-Jul	0.0800	0.0394			0.8333	0.2109			0.7692	0.2291
		4-Jul	0.0725	0.0394			0.7778	0.2717			0.6364	0.2842
		7-Jul	0.0693	0.0367			0.8182	0.2279			0.8182	0.2279
		10-Jul	0.0104	0.0143			0.5000	0.6931			1.0000	0.0000
		14-Jul	******	(******)			******	(******)			******	(******)
		18-Jul	******	(******)			******	(******)			******	(******)
		Pooled	0.1215	0.0174			0.6294	0.0792			0.6040	0.0786

Season	**Release Type**	**Release Site**	**Survival Probability**				**Detection Probability**				**Detection and Survival**	
Summer	Single	JDA Tailrace	to 1J	95% CL	1J to 2J	95% CL	1J	95% CL	2J	95% CL	λ to 3J	95% CL
		13-Jun	1.0000	0.0000	0.9842	0.0396	1.0000	0.0000	0.9348	0.0713	0.9348	0.0713
		15-Jun	0.9800	0.0388	1.0075	0.0108	1.0000	0.0000	0.8913	0.0900	0.9318	0.0745
		20-Jun	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.9800	0.0388
		22-Jun	1.0000	0.0000	1.0000	0.0000	0.9796	0.0396	0.9796	0.0396	1.0000	0.0000
		27-Jun	0.9900	0.0194	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.8990	0.0594
		Pooled	0.9933	0.0092	0.9985	0.0069	0.9966	0.0067	0.9677	0.0208	0.9408	0.0272
Summer	Single	JDA Tailrace	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		13-Jun	0.8400	0.1015	1.0000	0.0000	0.9762	0.0461	1.0000	0.0000	1.0000	0.0000
		15-Jun	0.8400	0.1015	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		20-Jun	0.9200	0.0753	0.9783	0.0421	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		22-Jun	0.8378	0.1037	0.9744	0.0496	0.9500	0.0676	1.0000	0.0000	1.0000	0.0000
		27-Jun	0.7500	0.0849	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		Pooled	0.8228	0.0433	0.9918	0.0114	0.9877	0.0139	1.0000	0.0000	1.0000	0.0000
Summer	Single	JDA Tailrace	to 1B	95% CL			to 1B	95% CL			λ to 2B	95% CL
		13-Jun	0.6667	0.1688			0.6000	0.1921			0.7500	0.1897
		15-Jun	0.7158	0.1339			0.5588	0.1670			0.9500	0.0955
		20-Jun	0.8060	0.1492			0.7692	0.1619			0.6452	0.1684
		22-Jun	0.6735	0.1797			0.6667	0.2017			0.6364	0.2011
		27-Jun	0.6505	0.1002			0.9070	0.0868			0.6610	0.1207
		Pooled	0.7079	0.0645			0.7181	0.0723			0.7039	0.0725
Summer	Single	TDA Tailrace	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		13-Jun	0.9949	0.0100	1.0000	0.0000	0.9692	0.0243	1.0000	0.0000	1.0000	0.0000
		15-Jun	1.0000	0.0000	1.0000	0.0000	0.9650	0.0255	1.0000	0.0000	1.0000	0.0000
		20-Jun	0.9900	0.0141	0.9895	0.0145	0.9792	0.0202	1.0000	0.0000	1.0000	0.0000
		22-Jun	1.0000	0.0000	0.9900	0.0137	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		27-Jun	0.9800	0.0194	0.9949	0.0100	0.9949	0.0100	1.0000	0.0000	1.0000	0.0000
		28-Jun	0.9900	0.0137	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		1-Jul	0.9514	0.0269	0.9872	0.0143	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		7-Jul	0.9556	0.0257	0.9620	0.0243	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		11-Jul	0.9106	0.0357	0.8170	0.0506	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		13-Jul	0.9431	0.0290	0.8707	0.0431	1.0000	0.0000	1.0000	0.0000	0.9950	0.0096
		Pooled	0.9692	0.0073	0.9580	0.0086	0.9911	0.0041	1.0000	0.0000	0.9995	0.0010

Season	Release Type	Release Site	Survival Probability		Detection Probability		Detection and Survival	
Summer	Single	TDA Tailrace	to 1B	95% CL	to 1B	95% CL	λ to 2B	95% CL
		13-Jun	0.8844	0.0808	0.5827	0.0858	0.7327	0.0862
		15-Jun	0.8527	0.0690	0.6567	0.0804	0.7857	0.0760
		20-Jun	0.9412	0.0892	0.6396	0.0894	0.6017	0.0884
		22-Jun	1.0307	0.1201	0.5918	0.0972	0.4754	0.0886
		27-Jun	0.9142	0.0494	0.9024	0.0525	0.6727	0.0715
		28-Jun	0.9135	0.0472	0.9141	0.0486	0.7006	0.0694
		1-Jul	0.8288	0.0484	0.9623	0.0296	0.7766	0.0582
		7-Jul	0.7788	0.0576	0.9113	0.0500	0.6420	0.0708
		11-Jul	0.5788	0.0619	0.9621	0.0325	0.9270	0.0435
		13-Jul	0.5888	0.0635	0.9182	0.0512	0.7594	0.0727
		Pooled	0.8061	0.0202	0.8130	0.0216	0.7094	0.0235
Summer	Single	BON Tailrace	to 1B	95% CL	to 1B	95% CL	λ to 2B	95% CL
		17-Jun	1.0031	0.1011	0.4679	0.0782	0.6348	0.0880
		22-Jun	0.9765	0.0543	0.6897	0.0688	0.7273	0.0680
		27-Jun	0.9843	0.0368	0.6635	0.0637	0.8750	0.0512
		2-Jul	0.9796	0.0257	0.9167	0.0390	0.8000	0.0529
		7-Jul	0.9516	0.0337	0.9341	0.0376	0.7222	0.0598
		12-Jul	0.9547	0.0272	0.9491	0.0294	0.9234	0.0349
		17-Jul	0.9246	0.0363	0.9309	0.0363	0.8333	0.0504
		22-Jul	0.9135	0.0361	0.9695	0.0239	0.8802	0.0431
		Pooled	0.9463	0.0139	0.8235	0.0192	0.8105	0.0196
Summer	Single	BON B2CC	to 1B	95% CL	to 1B	95% CL	λ to 2B	95% CL
		Pooled	0.9524	0.0615	0.8769	0.0798	0.7500	0.0974
Summer	Single	BON B2JBS	to 1B	95% CL	to 1B	95% CL	λ to 2B	95% CL
		Pooled	0.9065	0.0613	0.8230	0.0704	0.6596	0.0782
Summer	Single	BON Spillway	to 1B	95% CL	to 1B	95% CL	λ to 2B	95% CL
		Pooled	0.8570	0.0318	0.8367	0.0345	0.7207	0.0388

Season	Release Type	Release Site	Survival Probability				Detection Probability				Detection and Survival	
Summer	Virtual	JDA Tailrace	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		13-Jun	0.8478	0.1039	1.0000	0.0000	0.9744	0.0496	1.0000	0.0000	1.0000	0.0000
		15-Jun	0.8478	0.1039	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		20-Jun	0.9388	0.0670	0.9783	0.0421	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		22-Jun	0.8378	0.1037	0.9744	0.0496	0.9500	0.0676	1.0000	0.0000	1.0000	0.0000
		27-Jun	0.8427	0.0757	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
		Pooled	0.8603	0.0408	0.9916	0.0116	0.9874	0.0141	1.0000	0.0000	1.0000	0.0000
Summer	Virtual	TDA Tailrace	to 1B	95% CL			to 1B	95% CL			λ to 2B	95% CL
		13-Jun	0.8889	0.0808			0.5827	0.0858			0.7327	0.0862
		15-Jun	0.8527	0.0690			0.6567	0.0804			0.7857	0.0760
		20-Jun	0.9608	0.0890			0.6396	0.0894			0.6017	0.0884
		22-Jun	1.0411	0.1205			0.5918	0.0972			0.4754	0.0886
		27-Jun	0.9376	0.0461			0.9024	0.0525			0.6727	0.0715
		28-Jun	0.9227	0.0459			0.9141	0.0486			0.7006	0.0694
		1-Jul	0.8824	0.0433			0.9623	0.0296			0.7766	0.0582
		7-Jul	0.8471	0.0543			0.9113	0.0500			0.6420	0.0708
		11-Jul	0.7781	0.0606			0.9621	0.0325			0.9270	0.0435
		13-Jul	0.7207	0.0651			0.9182	0.0512			0.7594	0.0727
		Pooled	0.8687	0.0192			0.8130	0.0216			0.7094	0.0235
Summer	Virtual	JDA Tailrace	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		Pooled	0.8381	0.0284	0.9759	0.0129	0.9943	0.0065	1.0000	0.0000	1.0000	0.0000
Summer	Virtual	TDA Tailrace	to 1B	95% CL			to 1B	95% CL			λ to 2B	95% CL
		Pooled	0.8570	0.0176			0.8028	0.0198			0.7102	0.0212
Summer	Paired	TDA Dam	to 1T	95% CL	1T to 2T	95% CL	1T	95% CL	2T	95% CL	λ to 3T	95% CL
		JDA Tailrace	0.8228	0.0433	0.9918	0.0114	0.9877	0.0139	1.0000	0.0000	1.0000	0.0000
		TDA Tailrace	0.9692	0.0073	0.9580	0.0086	0.9911	0.0041	1.0000	0.0000	0.9995	0.0010
Summer	Paired	BON Dam	to 1B	95% CL			to 1B	95% CL			λ to 2B	95% CL
		TDA Tailrace	0.8044	0.0196			0.8187	0.0150			0.7108	0.0231
		BON Tailrace	0.9474	0.0139			0.8187	0.0150			0.8096	0.0196

Summer	Paired		$\hat{S}\ (\widehat{s.e.})$	95% CL
		TDA Project	0.8489	0.0884
		BON Project	0.8491	0.0472

Appendix I

Model Estimates of One-Half 95% Confidence Intervals on Detection and Survival Statistics for Yearling Chinook Salmon Based on Single-Release Survival Models for Spring 2006

Appendix I

Model Estimates of One-Half 95% Confidence Intervals on Detection and Survival Statistics for Yearling Chinook Salmon Based on Single-Release Survival Models for Spring 2006

All predicted estimates of 95% confidence intervals (CI) are based upon spring 2006 estimates of survival and detection probabilities, and sample-size estimates associated with a one-half 95% CIs of 2%, 3%, 4%, and 5% on primary array survival (S1) are highlighted when listed.

Table I.1. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Lower Granite Tailrace to Array 1J (S1) and from Array 1J to Array 1T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.056918	0.062406	0.049059	0.087279	0.084064
400	0.049294	0.054037	0.042493	0.075597	0.072814
500	0.044080	0.048334	0.038004	0.067620	0.065131
600	0.040239	0.044120	0.034692	0.061720	0.059447
700	0.037260	0.040846	0.032124	0.057134	0.055037
800	0.034849	0.038220	0.030047	0.053449	0.051489
900	0.032850	0.036025	0.028322	0.050392	0.048549
1000	0.031164	0.034182	0.026872	0.047804	0.046040
1100	0.029714	0.032595	0.025617	0.045590	0.043904
1200	0.028459	0.031203	0.024539	0.043649	0.042042
1300	0.027342	0.029988	0.023579	0.041924	0.040396
1400	0.026342	0.028890	0.022716	0.040415	0.038926
1500	0.025460	0.027910	0.021952	0.039043	0.037593
1600	0.024637	0.027028	0.021246	0.037789	0.036397
1700	0.023912	0.026225	0.020619	0.036672	0.035319
1800	0.023226	0.025480	0.020031	0.035633	0.034320
1900	0.022618	0.024794	0.019502	0.034692	0.033398
2000	0.022050	0.024167	0.019012	0.033810	0.032556
2100	0.021501	0.023579	0.018542	0.032987	0.031772
2200	0.021011	0.023050	0.018110	0.032242	0.031046
2300	0.020560	0.022540	0.017718	0.031517	0.030360
2400	0.020129	0.022070	0.017346	0.030870	0.029733
2500	0.019718	0.021619	0.016993	0.030243	0.029126
2600	0.019326	0.021207	0.016660	0.029655	0.028557
2700	0.018973	0.020796	0.016346	0.029086	0.028028
2800	0.018620	0.020423	0.016052	0.028577	0.027518
3000	0.017993	0.019737	0.015523	0.027597	0.026578

Table I.2. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Lower Granite Tailrace to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.056428	0.030752	0.074382	0.030478	0.050137
400	0.048863	0.026636	0.064406	0.026382	0.043414
500	0.043708	0.023814	0.057604	0.023598	0.038847
600	0.039906	0.021736	0.052587	0.021540	0.035456
700	0.036946	0.020129	0.048686	0.019953	0.032830
800	0.034555	0.018836	0.045550	0.018659	0.030713
900	0.032575	0.017758	0.042944	0.017601	0.028949
1000	0.030909	0.016836	0.040729	0.016680	0.027460
1100	0.029478	0.016052	0.038847	0.015915	0.026186
1200	0.028204	0.015366	0.037181	0.015229	0.025068
1300	0.027107	0.014778	0.035731	0.014641	0.024088
1400	0.026127	0.014230	0.034437	0.014112	0.023206
1500	0.025245	0.013759	0.033261	0.013622	0.022422
1600	0.024441	0.013308	0.032203	0.013191	0.021717
1700	0.023696	0.012916	0.031242	0.012799	0.021070
1800	0.023030	0.012544	0.030360	0.012446	0.020462
1900	0.022422	0.012211	0.029557	0.012113	0.019933
2000	0.021854	0.011917	0.028812	0.011799	0.019424
2100	0.021325	0.011623	0.028106	0.011525	0.018953
2200	0.020835	0.011348	0.027460	0.011250	0.018522
2300	0.020384	0.011113	0.026872	0.010996	0.018110
2400	0.019953	0.010878	0.026303	0.010780	0.017718
2500	0.019541	0.010643	0.025774	0.010564	0.017366
2600	0.019169	0.010447	0.025264	0.010349	0.017032
2700	0.018816	0.010251	0.024794	0.010153	0.016719
2800	0.018463	0.010055	0.024343	0.009976	0.016405
3000	0.017836	0.009722	0.023520	0.009643	0.015856

Table I.3. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Lower Granite Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.104060	0.574910	0.126640	0.190550	0.120600
400	0.090120	0.497880	0.109660	0.165030	0.104450
500	0.080610	0.445350	0.098100	0.147610	0.093430
600	0.073580	0.406520	0.089530	0.134750	0.085280
700	0.068130	0.376400	0.082910	0.124750	0.078970
800	0.063720	0.352060	0.077540	0.116700	0.073850
900	0.060070	0.331930	0.073110	0.110010	0.069640
1000	0.057000	0.314910	0.069360	0.104390	0.066070
1100	0.054350	0.300270	0.066130	0.099530	0.062990
1200	0.052040	0.287450	0.063310	0.095280	0.060310
1300	0.050000	0.276160	0.060840	0.091530	0.057940
1400	0.048180	0.266150	0.058620	0.088220	0.055840
1500	0.046530	0.257090	0.056620	0.085220	0.053940
1600	0.045060	0.248940	0.054840	0.082520	0.052210
1700	0.043710	0.241530	0.053190	0.080070	0.050670
1800	0.042490	0.234710	0.051700	0.077790	0.049240
1900	0.041360	0.228440	0.050310	0.075710	0.047920
2000	0.040300	0.222680	0.049040	0.073810	0.046710
2100	0.039340	0.217340	0.047860	0.072030	0.045590
2200	0.038440	0.212330	0.046770	0.070380	0.044550
2300	0.037590	0.207660	0.045730	0.068840	0.043570
2400	0.036790	0.203250	0.044770	0.067370	0.042650
2500	0.036040	0.199180	0.043860	0.066010	0.041790
2600	0.035360	0.195270	0.043020	0.064720	0.040960
2700	0.034690	0.191630	0.042220	0.063520	0.040200
2800	0.034060	0.188200	0.041450	0.062390	0.039470
2900	0.033480	0.184910	0.040730	0.061290	0.038790
3000	0.032910	0.181790	0.040040	0.060250	0.038140
3100	0.032380	0.178850	0.039400	0.059290	0.037510
3200	0.031870	0.176030	0.038770	0.058350	0.036930
3300	0.031380	0.173340	0.038180	0.057450	0.036360
3400	0.030910	0.170790	0.037610	0.056600	0.035830
3500	0.030460	0.168310	0.037080	0.055780	0.035300
3600	0.030050	0.165970	0.036550	0.055020	0.034810
3700	0.029640	0.163720	0.036060	0.054270	0.034340
3800	0.029240	0.161540	0.035570	0.053550	0.033890
3900	0.028870	0.159470	0.035120	0.052860	0.033460
4000	0.028500	0.157450	0.034670	0.052190	0.033030
4100	0.028150	0.155510	0.034260	0.051550	0.032610
4200	0.027810	0.153680	0.033850	0.050940	0.032240
4300	0.027480	0.151880	0.033460	0.050330	0.031870
4400	0.027170	0.150140	0.033070	0.049760	0.031500
4500	0.026870	0.148430	0.032690	0.049200	0.031140
4600	0.026580	0.146820	0.032340	0.048670	0.030810
4700	0.026280	0.145260	0.031990	0.048140	0.030480
4800	0.026010	0.143730	0.031650	0.047650	0.030140
5000	0.025500	0.140830	0.031030	0.046690	0.029540

Table I.4. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Front Roll to Array 1J (S1) and from Array 1J to Array 1T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.015915	0.026186	0.010800	0.041415	0.048686
400	0.013779	0.022677	0.009349	0.035868	0.042179
500	0.012328	0.020286	0.008350	0.032085	0.037710
600	0.011250	0.018522	0.007624	0.029282	0.034437
700	0.010427	0.017150	0.007056	0.027107	0.031870
800	0.009741	0.016033	0.006605	0.025362	0.029812
900	0.009192	0.015112	0.006233	0.023912	0.028106
1000	0.008722	0.014347	0.005919	0.022677	0.026676
1100	0.008310	0.013681	0.005645	0.021619	0.025421
1200	0.007958	0.013093	0.005390	0.020698	0.024343
1300	0.007644	0.012583	0.005174	0.019894	0.023383
1400	0.007370	0.012113	0.004998	0.019169	0.022540
1500	0.007115	0.011701	0.004822	0.018522	0.021776
1600	0.006899	0.011329	0.004665	0.017934	0.021090
1700	0.006684	0.010996	0.004528	0.017405	0.020462
1800	0.006507	0.010682	0.004410	0.016915	0.019874
1900	0.006331	0.010408	0.004292	0.016464	0.019345
2000	0.006174	0.010133	0.004175	0.016033	0.018855
2100	0.006017	0.009898	0.004077	0.015660	0.018404
2200	0.005880	0.009663	0.003979	0.015288	0.017973
2300	0.005743	0.009447	0.003900	0.014955	0.017581
2400	0.005625	0.009251	0.003822	0.014641	0.017209
2500	0.005508	0.009075	0.003744	0.014347	0.016876
2600	0.005410	0.008898	0.003665	0.014073	0.016542
2700	0.005312	0.008722	0.003606	0.013798	0.016229
2800	0.005214	0.008565	0.003528	0.013563	0.015935
3000	0.005037	0.008271	0.003410	0.013093	0.015406

Table I.5. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Intake to Array 1J (S1) and from Array 1J to Array 1T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.039063	0.029263	0.019051	0.046844	0.058075
400	0.033830	0.025343	0.016503	0.040572	0.050294
500	0.030262	0.022677	0.014759	0.036299	0.044982
600	0.027636	0.020698	0.013465	0.033124	0.041062
700	0.025578	0.019169	0.012466	0.030674	0.038024
800	0.023932	0.017914	0.011662	0.028694	0.035554
900	0.022560	0.016895	0.010996	0.027048	0.033536
1000	0.021403	0.016033	0.010427	0.025656	0.031811
1100	0.020404	0.015288	0.009957	0.024461	0.030321
1200	0.019541	0.014641	0.009526	0.023422	0.029028
1300	0.018777	0.014053	0.009153	0.022501	0.027891
1400	0.018091	0.013544	0.008820	0.021697	0.026891
1500	0.017483	0.013093	0.008526	0.020952	0.025970
1600	0.016915	0.012681	0.008252	0.020286	0.025147
1700	0.016405	0.012289	0.007997	0.019678	0.024402
1800	0.015954	0.011956	0.007781	0.019130	0.023716
1900	0.015523	0.011623	0.007566	0.018620	0.023069
2000	0.015131	0.011329	0.007370	0.018150	0.022481
2100	0.014759	0.011054	0.007193	0.017699	0.021952
2200	0.014426	0.010800	0.007036	0.017307	0.021442
2300	0.014112	0.010564	0.006880	0.016915	0.020972
2400	0.013818	0.010349	0.006742	0.016562	0.020541
2500	0.013544	0.010133	0.006605	0.016229	0.020110
2600	0.013269	0.009937	0.006468	0.015915	0.019718
2700	0.013014	0.009761	0.006350	0.015621	0.019365
2800	0.012799	0.009584	0.006233	0.015327	0.019012
3000	0.012348	0.009251	0.006017	0.014818	0.018365

Table I.6. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Tailrace to Array 1J (S1) and from Array 1J to Array 1T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.020286	0.019992	0.014328	0.041219	0.046726
400	0.017581	0.017307	0.012407	0.035692	0.040474
500	0.015719	0.015484	0.011094	0.031928	0.036201
600	0.014347	0.014132	0.010133	0.029145	0.033046
700	0.013289	0.013093	0.009388	0.026989	0.030596
800	0.012426	0.012250	0.008781	0.025245	0.028616
900	0.011721	0.011544	0.008271	0.023794	0.026989
1000	0.011113	0.010956	0.007840	0.022579	0.025598
1100	0.010604	0.010447	0.007487	0.021521	0.024402
1200	0.010153	0.009996	0.007154	0.020619	0.023363
1300	0.009741	0.009604	0.006880	0.019796	0.022442
1400	0.009388	0.009251	0.006625	0.019090	0.021638
1500	0.009075	0.008938	0.006409	0.018444	0.020894
1600	0.008781	0.008663	0.006213	0.017856	0.020227
1700	0.008526	0.008389	0.006017	0.017326	0.019639
1800	0.008291	0.008154	0.005841	0.016836	0.019071
1900	0.008056	0.007938	0.005684	0.016386	0.018561
2000	0.007860	0.007742	0.005547	0.015974	0.018091
2100	0.007664	0.007546	0.005410	0.015582	0.017660
2200	0.007487	0.007389	0.005292	0.015229	0.017248
2300	0.007330	0.007213	0.005174	0.014896	0.016876
2400	0.007174	0.007076	0.005057	0.014582	0.016523
2500	0.007036	0.006919	0.004959	0.014288	0.016190
2600	0.006899	0.006782	0.004861	0.013994	0.015876
2700	0.006762	0.006664	0.004782	0.013740	0.015582
2800	0.006644	0.006546	0.004684	0.013485	0.015288
3000	0.006409	0.006331	0.004528	0.013034	0.014778

Table I.7. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Front Roll to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.032222	0.015896	0.032948	0.005743	0.007997
400	0.027910	0.013779	0.028538	0.004959	0.006938
500	0.024970	0.012309	0.025519	0.004449	0.006194
600	0.022795	0.011250	0.023304	0.004057	0.005664
700	0.021090	0.010408	0.021580	0.003763	0.005233
800	0.019737	0.009741	0.020188	0.003508	0.004900
900	0.018600	0.009173	0.019032	0.003312	0.004626
1000	0.017660	0.008702	0.018052	0.003136	0.004390
1100	0.016836	0.008310	0.017209	0.002999	0.004175
1200	0.016111	0.007958	0.016484	0.002862	0.003998
1300	0.015484	0.007644	0.015837	0.002764	0.003842
1400	0.014916	0.007370	0.015249	0.002646	0.003704
1500	0.014406	0.007115	0.014739	0.002568	0.003587
1600	0.013955	0.006880	0.014269	0.002489	0.003469
1700	0.013544	0.006684	0.013838	0.002411	0.003371
1800	0.013152	0.006488	0.013446	0.002332	0.003273
1900	0.012799	0.006311	0.013093	0.002274	0.003175
2000	0.012485	0.006154	0.012760	0.002215	0.003097
2100	0.012172	0.006017	0.012466	0.002176	0.003018
2200	0.011897	0.005880	0.012172	0.002117	0.002960
2300	0.011642	0.005743	0.011897	0.002078	0.002881
2400	0.011388	0.005625	0.011642	0.002019	0.002822
2500	0.011172	0.005508	0.011407	0.001980	0.002764
2600	0.010937	0.005410	0.011192	0.001940	0.002724
2700	0.010741	0.005292	0.010976	0.001921	0.002666
2800	0.010545	0.005214	0.010780	0.001882	0.002626
3000	0.010192	0.005037	0.010427	0.001823	0.002528

Table I.8. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Intake to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.043943	0.018836	0.034320	0.009075	0.015464
400	0.038063	0.016307	0.029733	0.007860	0.013387
500	0.034045	0.014582	0.026578	0.007036	0.011976
600	0.031066	0.013308	0.024265	0.006429	0.010937
700	0.028773	0.012328	0.022462	0.005939	0.010133
800	0.026911	0.011525	0.021011	0.005566	0.009467
900	0.025362	0.010878	0.019816	0.005233	0.008938
1000	0.024069	0.010310	0.018796	0.004978	0.008467
1100	0.022952	0.009839	0.017934	0.004743	0.008075
1200	0.021972	0.009408	0.017170	0.004547	0.007742
1300	0.021109	0.009055	0.016484	0.004371	0.007428
1400	0.020345	0.008722	0.015896	0.004194	0.007154
1500	0.019659	0.008428	0.015347	0.004057	0.006919
1600	0.019032	0.008154	0.014857	0.003940	0.006703
1700	0.018463	0.007918	0.014426	0.003822	0.006507
1800	0.017934	0.007683	0.014014	0.003704	0.006311
1900	0.017464	0.007487	0.013642	0.003606	0.006154
2000	0.017013	0.007291	0.013289	0.003508	0.005998
2100	0.016601	0.007115	0.012975	0.003430	0.005841
2200	0.016229	0.006958	0.012681	0.003352	0.005704
2300	0.015876	0.006801	0.012387	0.003273	0.005586
2400	0.015543	0.006664	0.012132	0.003214	0.005468
2500	0.015229	0.006527	0.011897	0.003136	0.005351
2600	0.014935	0.006390	0.011662	0.003077	0.005253
2700	0.014641	0.006272	0.011446	0.003018	0.005155
2800	0.014386	0.006174	0.011231	0.002979	0.005057
3000	0.013896	0.005958	0.010858	0.002881	0.004900

Table I.9. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Tailrace to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.031301	0.015817	0.029753	0.119400	0.008075
400	0.027107	0.013700	0.025754	0.103410	0.006997
500	0.024245	0.012250	0.023030	0.092490	0.006252
600	0.022128	0.011192	0.021031	0.084440	0.005704
700	0.020482	0.010349	0.019463	0.078160	0.005292
800	0.019169	0.009682	0.018208	0.073130	0.004939
900	0.018071	0.009134	0.017170	0.068930	0.004665
1000	0.017150	0.008663	0.016288	0.065410	0.004430
1100	0.016346	0.008252	0.015543	0.062350	0.004214
1200	0.015641	0.007899	0.014876	0.059700	0.004038
1300	0.015033	0.007605	0.014288	0.057370	0.003881
1400	0.014484	0.007330	0.013759	0.055270	0.003744
1500	0.013994	0.007076	0.013308	0.053390	0.003606
1600	0.013544	0.006840	0.012877	0.051700	0.003508
1700	0.013152	0.006644	0.012485	0.050160	0.003391
1800	0.012779	0.006448	0.012152	0.048750	0.003293
1900	0.012446	0.006292	0.011819	0.047450	0.003214
2000	0.012113	0.006135	0.011525	0.046240	0.003136
2100	0.011838	0.005978	0.011250	0.045140	0.003058
2200	0.011564	0.005841	0.010976	0.044100	0.002979
2300	0.011309	0.005704	0.010741	0.043120	0.002920
2400	0.011074	0.005586	0.010525	0.042220	0.002862
2500	0.010839	0.005488	0.010310	0.041360	0.002803
2600	0.010623	0.005370	0.010094	0.040550	0.002744
2700	0.010427	0.005272	0.009918	0.039810	0.002685
2800	0.010251	0.005174	0.009741	0.039080	0.002646
3000	0.009898	0.004998	0.009408	0.037750	0.002548

Table I.10. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Front Roll to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.063014	0.128790	0.070266	0.099529	0.078302
400	0.054566	0.111540	0.060858	0.086201	0.067816
500	0.048804	0.099760	0.054429	0.077106	0.060662
600	0.044551	0.091060	0.049686	0.070384	0.055370
700	0.041238	0.084320	0.046001	0.065150	0.051274
800	0.038592	0.078870	0.043042	0.060956	0.047961
900	0.036378	0.074360	0.040572	0.057467	0.045217
1000	0.034516	0.070540	0.038494	0.054508	0.042885
1100	0.032908	0.067270	0.036691	0.051979	0.040886
1200	0.031497	0.064410	0.035143	0.049764	0.039161
1300	0.030262	0.061880	0.033751	0.047804	0.037612
1400	0.029165	0.059620	0.032536	0.046080	0.036240
1500	0.028185	0.057600	0.031419	0.044512	0.035025
1600	0.027283	0.055760	0.030439	0.043100	0.033908
1700	0.026460	0.054100	0.029518	0.041807	0.032889
1800	0.025715	0.052590	0.028694	0.040631	0.031968
1900	0.025029	0.051180	0.027930	0.039553	0.031125
2000	0.024402	0.049880	0.027224	0.038553	0.030321
2100	0.023814	0.048690	0.026558	0.037612	0.029596
2200	0.023265	0.047570	0.025950	0.036750	0.028910
2300	0.022756	0.046510	0.025382	0.035946	0.028283
2400	0.022285	0.045530	0.024853	0.035182	0.027695
2500	0.021834	0.044610	0.024343	0.034476	0.027126
2600	0.021403	0.043750	0.023873	0.033810	0.026597
2700	0.021011	0.042920	0.023422	0.033183	0.026107
2800	0.020619	0.042160	0.023010	0.032575	0.025637
3000	0.019933	0.040730	0.022226	0.031478	0.024755

Table I.11. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Intake to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.067306	0.111740	0.073598	0.093414	0.081869
400	0.058290	0.096770	0.063739	0.080909	0.070893
500	0.052136	0.086550	0.057016	0.072363	0.063406
600	0.047589	0.079010	0.052038	0.066052	0.057879
700	0.044061	0.073150	0.048177	0.061152	0.053586
800	0.041219	0.068420	0.045080	0.057212	0.050137
900	0.038867	0.064520	0.042493	0.053939	0.047256
1000	0.036868	0.061210	0.040317	0.051176	0.044845
1100	0.035143	0.058350	0.038436	0.048784	0.042748
1200	0.033653	0.055880	0.036809	0.046707	0.040925
1300	0.032340	0.053680	0.035358	0.044884	0.039318
1400	0.031164	0.051720	0.034065	0.043238	0.037887
1500	0.030106	0.049980	0.032908	0.041787	0.036613
1600	0.029145	0.048390	0.031870	0.040454	0.035456
1700	0.028283	0.046940	0.030929	0.039239	0.034398
1800	0.027479	0.045610	0.030047	0.038142	0.033418
1900	0.026754	0.044390	0.029243	0.037122	0.032536
2000	0.026068	0.043280	0.028498	0.036182	0.031713
2100	0.025441	0.042240	0.027812	0.035319	0.030948
2200	0.024853	0.041260	0.027185	0.034496	0.030223
2300	0.024304	0.040360	0.026578	0.033732	0.029557
2400	0.023794	0.039510	0.026029	0.033026	0.028949
2500	0.023324	0.038710	0.025500	0.032360	0.028361
2600	0.022854	0.037970	0.025010	0.031732	0.027812
2700	0.022442	0.037240	0.024539	0.031144	0.027283
2800	0.022030	0.036570	0.024088	0.030576	0.026793
3000	0.021286	0.035340	0.023285	0.029537	0.025892

Table I.12. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.063798	0.094786	0.069796	0.083261	0.075774
400	0.055252	0.082085	0.060446	0.072108	0.065621
500	0.049412	0.073422	0.054057	0.064504	0.058702
600	0.045100	0.067012	0.049353	0.058878	0.053586
700	0.041768	0.062054	0.045688	0.054508	0.049608
800	0.039063	0.058036	0.042728	0.050999	0.046413
900	0.036828	0.054723	0.040298	0.048079	0.043747
1000	0.034947	0.051920	0.038220	0.045609	0.041513
1100	0.033320	0.049490	0.036436	0.043492	0.039572
1200	0.031889	0.047393	0.034888	0.041630	0.037887
1300	0.030654	0.045531	0.033516	0.040004	0.036397
1400	0.029537	0.043884	0.032301	0.038553	0.035084
1500	0.028538	0.042395	0.031203	0.037240	0.033888
1600	0.027616	0.041042	0.030223	0.036064	0.032810
1700	0.026793	0.039808	0.029322	0.034986	0.031830
1800	0.026048	0.038690	0.028498	0.033986	0.030929
1900	0.025343	0.037671	0.027734	0.033085	0.030106
2000	0.024716	0.036711	0.027028	0.032242	0.029341
2100	0.024108	0.035829	0.026382	0.031478	0.028636
2200	0.023559	0.035006	0.025774	0.030752	0.027989
2300	0.023030	0.034241	0.025206	0.030066	0.027362
2400	0.022560	0.033516	0.024676	0.029439	0.026793
2500	0.022089	0.032830	0.024167	0.028851	0.026244
2600	0.021678	0.032203	0.023696	0.028283	0.025735
2700	0.021266	0.031595	0.023265	0.027754	0.025264
2800	0.020874	0.031027	0.022834	0.027264	0.024814
3000	0.020168	0.029968	0.022070	0.026323	0.023971

Table I.13. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the TDA Tailrace to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.011956	0.009898	0.017483	0.009075	0.009761
400	0.010349	0.008585	0.015131	0.007860	0.008448
500	0.009251	0.007664	0.013544	0.007017	0.007546
600	0.008448	0.006997	0.012368	0.006409	0.006899
700	0.007820	0.006488	0.011446	0.005939	0.006390
800	0.007311	0.006056	0.010702	0.005547	0.005978
900	0.006899	0.005723	0.010094	0.005233	0.005625
1000	0.006546	0.005429	0.009584	0.004959	0.005351
1100	0.006252	0.005174	0.009134	0.004743	0.005096
1200	0.005978	0.004959	0.008742	0.004528	0.004880
1300	0.005743	0.004763	0.008389	0.004351	0.004684
1400	0.005527	0.004586	0.008095	0.004194	0.004508
1500	0.005351	0.004430	0.007820	0.004057	0.004371
1600	0.005174	0.004292	0.007566	0.003920	0.004214
1700	0.005018	0.004155	0.007350	0.003802	0.004096
1800	0.004880	0.004038	0.007134	0.003704	0.003979
1900	0.004743	0.003940	0.006938	0.003606	0.003881
2000	0.004626	0.003842	0.006762	0.003508	0.003783
2100	0.004528	0.003744	0.006605	0.003430	0.003685
2200	0.004410	0.003665	0.006448	0.003352	0.003606
2300	0.004312	0.003567	0.006311	0.003273	0.003528
2400	0.004234	0.003508	0.006174	0.003214	0.003450
2500	0.004136	0.003430	0.006056	0.003136	0.003371
2600	0.004057	0.003371	0.005939	0.003077	0.003312
2700	0.003979	0.003293	0.005821	0.003018	0.003254
2800	0.003920	0.003234	0.005723	0.002960	0.003195
3000	0.003783	0.003136	0.005527	0.002862	0.003077

Table I.14. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the TDA Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.051489	0.102020	0.063622	0.083182	0.073186
400	0.044590	0.088340	0.055096	0.072050	0.063386
500	0.039886	0.079030	0.049274	0.064445	0.056683
600	0.036417	0.072130	0.044982	0.058820	0.051744
700	0.033712	0.066780	0.041650	0.054468	0.047902
800	0.031536	0.062470	0.038965	0.050940	0.044825
900	0.029733	0.058900	0.036730	0.048020	0.042258
1000	0.028204	0.055880	0.034849	0.045570	0.040082
1100	0.026891	0.053270	0.033222	0.043453	0.038220
1200	0.025754	0.051000	0.031811	0.041591	0.036593
1300	0.024735	0.049000	0.030556	0.039964	0.035162
1400	0.023834	0.047220	0.029459	0.038514	0.033888
1500	0.023030	0.045630	0.028459	0.037201	0.032732
1600	0.022305	0.044180	0.027538	0.036025	0.031693
1700	0.021638	0.042850	0.026734	0.034947	0.030752
1800	0.021031	0.041650	0.025970	0.033967	0.029870
1900	0.020462	0.040530	0.025284	0.033065	0.029086
2000	0.019933	0.039510	0.024637	0.032222	0.028342
2100	0.019463	0.038550	0.024049	0.031438	0.027656
2200	0.019012	0.037670	0.023500	0.030713	0.027028
2300	0.018600	0.036850	0.022971	0.030047	0.026440
2400	0.018208	0.036060	0.022501	0.029420	0.025872
2500	0.017836	0.035340	0.022030	0.028812	0.025362
2600	0.017483	0.034650	0.021619	0.028263	0.024853
2700	0.017170	0.034010	0.021207	0.027734	0.024402
2800	0.016856	0.033400	0.020815	0.027224	0.023951
3000	0.016288	0.032260	0.020110	0.026303	0.023148

Table I.15. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the BON Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.047765	0.078439	0.057173	0.076381	0.071030
400	0.041376	0.067934	0.049529	0.066150	0.061505
500	0.037005	0.060760	0.044296	0.059153	0.055017
600	0.033771	0.055468	0.040435	0.053998	0.050215
700	0.031262	0.051352	0.037436	0.050000	0.046491
800	0.029243	0.048040	0.035025	0.046766	0.043492
900	0.027577	0.045296	0.033006	0.044100	0.041003
1000	0.026166	0.042963	0.031321	0.041826	0.038906
1100	0.024951	0.040964	0.029870	0.039886	0.037083
1200	0.023892	0.039220	0.028596	0.038181	0.035515
1300	0.022952	0.037691	0.027460	0.036691	0.034124
1400	0.022109	0.036319	0.026460	0.035358	0.032869
1500	0.021364	0.035084	0.025578	0.034163	0.031772
1600	0.020678	0.033967	0.024755	0.033065	0.030752
1700	0.020070	0.032948	0.024030	0.032085	0.029831
1800	0.019502	0.032026	0.023344	0.031184	0.028988
1900	0.018973	0.031164	0.022716	0.030341	0.028224
2000	0.018502	0.030380	0.022148	0.029576	0.027499
2100	0.018052	0.029655	0.021619	0.028871	0.026852
2200	0.017640	0.028969	0.021109	0.028204	0.026225
2300	0.017248	0.028342	0.020658	0.027577	0.025656
2400	0.016895	0.027734	0.020208	0.027009	0.025108
2500	0.016542	0.027166	0.019816	0.026460	0.024598
2600	0.016229	0.026656	0.019424	0.025950	0.024128
2700	0.015915	0.026146	0.019051	0.025460	0.023677
2800	0.015641	0.025676	0.018718	0.025010	0.023246
3000	0.015112	0.024814	0.018091	0.024147	0.022462

Table I.16. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the BON B2CC to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.050921	0.095609	0.063465	0.078204	0.074323
400	0.044100	0.082790	0.054958	0.067738	0.064366
500	0.039455	0.074049	0.049157	0.060584	0.057565
600	0.036005	0.067600	0.044864	0.055292	0.052548
700	0.033340	0.062583	0.041552	0.051195	0.048667
800	0.031184	0.058545	0.038867	0.047883	0.045511
900	0.029400	0.055194	0.036632	0.045158	0.042904
1000	0.027891	0.052371	0.034751	0.042846	0.040709
1100	0.026597	0.049921	0.033144	0.040846	0.038808
1200	0.025460	0.047804	0.031732	0.039102	0.037162
1300	0.024461	0.045923	0.030478	0.037573	0.035711
1400	0.023579	0.044257	0.029380	0.036201	0.034398
1500	0.022775	0.042767	0.028381	0.034966	0.033242
1600	0.022050	0.041395	0.027479	0.033869	0.032183
1700	0.021384	0.040160	0.026656	0.032850	0.031223
1800	0.020796	0.039024	0.025911	0.031928	0.030341
1900	0.020227	0.037985	0.025206	0.031086	0.029537
2000	0.019718	0.037024	0.024578	0.030282	0.028792
2100	0.019247	0.036142	0.023990	0.029557	0.028087
2200	0.018796	0.035300	0.023442	0.028871	0.027440
2300	0.018385	0.034535	0.022912	0.028244	0.026852
2400	0.018012	0.033810	0.022442	0.027656	0.026284
2500	0.017640	0.033124	0.021991	0.027087	0.025754
2600	0.017307	0.032477	0.021560	0.026558	0.025245
2700	0.016974	0.031870	0.021148	0.026068	0.024774
2800	0.016660	0.031301	0.020776	0.025598	0.024324
3000	0.016111	0.030243	0.020070	0.024735	0.023500

Table I.17. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the B2 JBS to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.061054	0.175660	0.066797	0.091669	0.075205
400	0.052861	0.152120	0.057840	0.079400	0.065131
500	0.047295	0.136060	0.051744	0.071011	0.058251
600	0.043159	0.124210	0.047236	0.064817	0.053175
700	0.039964	0.114990	0.043728	0.060015	0.049235
800	0.037377	0.107560	0.040905	0.056134	0.046060
900	0.035241	0.101410	0.038573	0.052920	0.043434
1000	0.033438	0.096220	0.036593	0.050215	0.041199
1100	0.031889	0.091730	0.034888	0.047883	0.039278
1200	0.030517	0.087830	0.033398	0.045844	0.037612
1300	0.029322	0.084380	0.032085	0.044041	0.036123
1400	0.028263	0.081320	0.030929	0.042434	0.034810
1500	0.027303	0.078560	0.029870	0.041003	0.033634
1600	0.026440	0.076070	0.028930	0.039690	0.032575
1700	0.025637	0.073790	0.028067	0.038514	0.031595
1800	0.024931	0.071720	0.027264	0.037436	0.030713
1900	0.024265	0.069800	0.026538	0.036436	0.029890
2000	0.023638	0.068030	0.025872	0.035515	0.029126
2100	0.023069	0.066390	0.025245	0.034653	0.028420
2200	0.022540	0.064860	0.024676	0.033849	0.027773
2300	0.022050	0.063450	0.024128	0.033104	0.027166
2400	0.021580	0.062110	0.023618	0.032418	0.026597
2500	0.021148	0.060860	0.023148	0.031752	0.026048
2600	0.020737	0.059660	0.022697	0.031144	0.025539
2700	0.020345	0.058550	0.022266	0.030556	0.025068
2800	0.019992	0.057510	0.021874	0.030008	0.024618
3000	0.019306	0.055550	0.021129	0.028988	0.023775

Table I.18. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the BON Spillway to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.046746	0.114820	0.061858	0.084456	0.071540
400	0.040474	0.099430	0.053567	0.073147	0.061956
500	0.036201	0.088940	0.047902	0.065425	0.055429
600	0.033046	0.081180	0.043728	0.059721	0.050588
700	0.030596	0.075170	0.040494	0.055292	0.046844
800	0.028616	0.070310	0.037867	0.051724	0.043806
900	0.026989	0.066290	0.035711	0.048765	0.041317
1000	0.025598	0.062900	0.033869	0.046256	0.039180
1100	0.024402	0.059960	0.032301	0.044120	0.037358
1200	0.023363	0.057410	0.030929	0.042238	0.035770
1300	0.022462	0.055150	0.029714	0.040572	0.034378
1400	0.021638	0.053160	0.028636	0.039102	0.033124
1500	0.020894	0.051350	0.027656	0.037769	0.032007
1600	0.020247	0.049730	0.026774	0.036574	0.030988
1700	0.019639	0.048240	0.025990	0.035476	0.030047
1800	0.019090	0.046880	0.025245	0.034476	0.029204
1900	0.018581	0.045630	0.024578	0.033555	0.028440
2000	0.018110	0.044470	0.023951	0.032712	0.027714
2100	0.017660	0.043390	0.023383	0.031928	0.027048
2200	0.017268	0.042390	0.022834	0.031184	0.026421
2300	0.016876	0.041470	0.022344	0.030498	0.025833
2400	0.016523	0.040590	0.021874	0.029870	0.025304
2500	0.016190	0.039770	0.021423	0.029263	0.024794
2600	0.015876	0.039000	0.021011	0.028694	0.024304
2700	0.015582	0.038280	0.020619	0.028146	0.023853
2800	0.015308	0.037590	0.020247	0.027656	0.023422
3000	0.014778	0.036320	0.019561	0.026715	0.022618

Appendix J

Model Estimates of One-Half 95% Confidence Intervals on Detection and Survival Statistics for Yearling Chinook Salmon Based on Paired-Release Survival Models for Spring 2006

Appendix J

Model Estimates of One-Half 95% Confidence Intervals on Detection and Survival Statistics for Yearling Chinook Salmon Based on Paired-Release Survival Models for Spring 2006

All predicted estimates of 95% confidence intervals (CI) are based upon spring 2006 estimates of survival and detection probabilities, and sample-size estimates associated with a one-half 95% CIs of about 2%, 3%, 4%, and 5% on the primary-array survival of treatment fish (S1 in the third column) are highlighted when listed.

Table J.1. Predictions of One-half 95% Confidence Intervals (CI) on Survivals of Control and Treatment Fish Traveling to Array 1J (S1) and from Array 1J to Array 1T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probabilities (λ) as a Function of Possible Total Numbers that Could be Released. Release locations include a turbine (treatment) and the front roll (controls) to assess turbine survival.

Release Number	One half 95% CI on Control S1	One half 95% CI on Treatment S1	One half 95% CI on Control S2	One half 95% CI on Treatment S2	One half 95% CI on Control P1	One half 95% CI on Treatment P1	One half 95% CI on Control P2	One half 95% CI on Treatment P2	One half 95% CI on Control Lamda	One half 95% CI on Treatment Lamda
300	0.016033	0.044139	0.028832	0.031046	0.014641	0.015758	0.043473	0.046805	0.054312	0.058467
400	0.013877	0.038220	0.024970	0.026891	0.012681	0.013642	0.037652	0.040533	0.047020	0.050627
500	0.012426	0.034182	0.022324	0.024049	0.011329	0.012211	0.033673	0.036260	0.042062	0.045296
600	0.011329	0.031203	0.020384	0.021952	0.010349	0.011152	0.030733	0.033104	0.038396	0.041336
700	0.010506	0.028890	0.018875	0.020325	0.009584	0.010310	0.028459	0.030635	0.035554	0.038279
800	0.009820	0.027028	0.017660	0.019012	0.008957	0.009643	0.026617	0.028655	0.033261	0.035809
900	0.009251	0.025480	0.016640	0.017914	0.008448	0.009094	0.025108	0.027028	0.031360	0.033751
1000	0.008781	0.024167	0.015798	0.017013	0.008016	0.008624	0.023814	0.025637	0.029733	0.032026
1100	0.008369	0.023050	0.015053	0.016209	0.007644	0.008232	0.022697	0.024441	0.028361	0.030537
1200	0.008016	0.022070	0.014426	0.015523	0.007311	0.007879	0.021736	0.023402	0.027146	0.029243
1300	0.007703	0.021207	0.013857	0.014916	0.007036	0.007566	0.020894	0.022481	0.026088	0.028087
1400	0.007428	0.020423	0.013348	0.014367	0.006782	0.007291	0.020129	0.021678	0.025127	0.027068
1500	0.007174	0.019737	0.012897	0.013877	0.006546	0.007056	0.019443	0.020933	0.024284	0.026146
1600	0.006938	0.019110	0.012485	0.013446	0.006331	0.006821	0.018816	0.020266	0.023520	0.025323
1700	0.006742	0.018542	0.012113	0.013034	0.006154	0.006625	0.018267	0.019659	0.022814	0.024559
1800	0.006546	0.018012	0.011780	0.012681	0.005978	0.006429	0.017758	0.019110	0.022168	0.023873
1900	0.006370	0.017542	0.011466	0.012328	0.005821	0.006252	0.017268	0.018600	0.021580	0.023226
2000	0.006213	0.017091	0.011172	0.012015	0.005664	0.006096	0.016836	0.018130	0.021031	0.022638
2100	0.006056	0.016680	0.010898	0.011740	0.005527	0.005958	0.016425	0.017699	0.020521	0.022089
2200	0.005919	0.016288	0.010643	0.011466	0.005410	0.005821	0.016052	0.017287	0.020051	0.021599
2300	0.005782	0.015935	0.010408	0.011211	0.005292	0.005684	0.015700	0.016915	0.019620	0.021109
2400	0.005664	0.015602	0.010192	0.010976	0.005174	0.005566	0.015366	0.016542	0.019208	0.020678
2500	0.005547	0.015288	0.009996	0.010760	0.005076	0.005468	0.015053	0.016209	0.018816	0.020247
2600	0.005449	0.014994	0.009800	0.010545	0.004978	0.005351	0.014759	0.015896	0.018444	0.019855
2700	0.005351	0.014720	0.009604	0.010349	0.004880	0.005253	0.014484	0.015602	0.018110	0.019482
2800	0.005253	0.014445	0.009447	0.010153	0.004782	0.005155	0.014230	0.015327	0.017777	0.019130
2900	0.005155	0.014190	0.009271	0.009976	0.004704	0.005076	0.013975	0.015053	0.017464	0.018796
3000	0.005076	0.013955	0.009114	0.009820	0.004626	0.004978	0.013740	0.014798	0.017170	0.018483

Table J.2. Predictions of One-half 95% Confidence Intervals (CI) on Survivals of Control and Treatment Fish Traveling to Array 1T (S1) and from Array 1T to Array 2T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probabilities (λ) as a Function of Possible Total Numbers that Could be Released. Release locations include the JDA Tailrace (treatment) and TDA Tailrace (controls) to assess TDA survival.

Release Number	One half 95% CI on Control S1	One half 95% CI on Treatment S1	One half 95% CI on Control S2	One half 95% CI on Treatment S2	One half 95% CI on Control P1	One half 95% CI on Treatment P1	One half 95% CI on Control P2	One half 95% CI on Treatment P2	One half 95% CI on Control Lamda	One half 95% CI on Treatment Lamda
300	0.012446	0.042101	0.015249	0.016425	0.028655	0.030850	0.009114	0.009820	0.009800	0.010545
400	0.010780	0.036456	0.013210	0.014210	0.024814	0.026715	0.007899	0.008506	0.008487	0.009134
500	0.009643	0.032614	0.011819	0.012720	0.022187	0.023892	0.007056	0.007605	0.007585	0.008173
600	0.008800	0.029772	0.010780	0.011603	0.020266	0.021815	0.006448	0.006938	0.006938	0.007468
700	0.008154	0.027558	0.009976	0.010741	0.018757	0.020208	0.005958	0.006429	0.006409	0.006899
800	0.007624	0.025774	0.009330	0.010055	0.017542	0.018894	0.005586	0.006017	0.005998	0.006468
900	0.007193	0.024304	0.008800	0.009486	0.016542	0.017816	0.005253	0.005664	0.005664	0.006096
1000	0.006821	0.023050	0.008350	0.008996	0.015700	0.016895	0.004998	0.005370	0.005370	0.005782
1100	0.006507	0.021991	0.007958	0.008565	0.014974	0.016111	0.004763	0.005116	0.005116	0.005508
1200	0.006233	0.021050	0.007624	0.008212	0.014328	0.015425	0.004567	0.004900	0.004900	0.005272
1300	0.005978	0.020227	0.007330	0.007879	0.013759	0.014818	0.004371	0.004724	0.004704	0.005076
1400	0.005762	0.019482	0.007056	0.007605	0.013269	0.014288	0.004214	0.004547	0.004528	0.004880
1500	0.005566	0.018836	0.006821	0.007350	0.012818	0.013798	0.004077	0.004390	0.004390	0.004724
1600	0.005390	0.018228	0.006605	0.007115	0.012407	0.013367	0.003940	0.004253	0.004253	0.004567
1700	0.005233	0.017679	0.006409	0.006899	0.012034	0.012956	0.003822	0.004116	0.004116	0.004430
1800	0.005076	0.017189	0.006233	0.006703	0.011701	0.012603	0.003724	0.003998	0.003998	0.004312
1900	0.004939	0.016738	0.006056	0.006527	0.011388	0.012270	0.003626	0.003900	0.003900	0.004194
2000	0.004822	0.016307	0.005900	0.006350	0.011094	0.011956	0.003528	0.003802	0.003802	0.004096
2100	0.004704	0.015915	0.005762	0.006213	0.010839	0.011662	0.003450	0.003704	0.003704	0.003979
2200	0.004606	0.015543	0.005625	0.006056	0.010584	0.011388	0.003371	0.003626	0.003626	0.003900
2300	0.004488	0.015210	0.005508	0.005939	0.010349	0.011152	0.003293	0.003548	0.003548	0.003802
2400	0.004410	0.014876	0.005390	0.005802	0.010133	0.010917	0.003214	0.003469	0.003469	0.003724
2500	0.004312	0.014582	0.005272	0.005684	0.009918	0.010682	0.003156	0.003391	0.003391	0.003665
2600	0.004234	0.014308	0.005174	0.005586	0.009741	0.010486	0.003097	0.003332	0.003332	0.003587
2700	0.004155	0.014034	0.005076	0.005468	0.009545	0.010290	0.003038	0.003273	0.003273	0.003508
2800	0.004077	0.013779	0.004998	0.005370	0.009388	0.010094	0.002979	0.003214	0.003214	0.003450
2900	0.003998	0.013544	0.004900	0.005272	0.009212	0.009918	0.002940	0.003156	0.003156	0.003391
3000	0.003940	0.013308	0.004822	0.005194	0.009055	0.009761	0.002881	0.003097	0.003097	0.003332
3100	0.003881	0.013093	0.004743	0.005116	0.008918	0.009604	0.002842	0.003058	0.003058	0.003273
3200	0.003822	0.012897	0.004665	0.005018	0.008781	0.009447	0.002783	0.002999	0.002999	0.003234
3300	0.003763	0.012701	0.004606	0.004959	0.008644	0.009310	0.002744	0.002960	0.002960	0.003175
3400	0.003704	0.012505	0.004528	0.004880	0.008506	0.009173	0.002705	0.002920	0.002920	0.003136
3500	0.003646	0.012328	0.004469	0.004802	0.008389	0.009036	0.002666	0.002881	0.002862	0.003097
3600	0.003587	0.012152	0.004410	0.004743	0.008271	0.008898	0.002626	0.002842	0.002822	0.003038
3700	0.003548	0.011995	0.004351	0.004684	0.008154	0.008781	0.002587	0.002803	0.002783	0.002999
3800	0.003489	0.011838	0.004292	0.004606	0.008056	0.008663	0.002568	0.002764	0.002744	0.002960
3900	0.003450	0.011682	0.004234	0.004547	0.007938	0.008565	0.002528	0.002724	0.002724	0.002920
4000	0.003410	0.011525	0.004175	0.004488	0.007840	0.008448	0.002489	0.002685	0.002685	0.002881
4100	0.003371	0.011388	0.004116	0.004449	0.007742	0.008350	0.002470	0.002646	0.002646	0.002862
4200	0.003332	0.011250	0.004077	0.004390	0.007664	0.008252	0.002430	0.002626	0.002626	0.002822
4300	0.003293	0.011113	0.004018	0.004332	0.007566	0.008154	0.002411	0.002587	0.002587	0.002783
4400	0.003254	0.010996	0.003979	0.004292	0.007487	0.008056	0.002372	0.002568	0.002568	0.002764
4500	0.003214	0.010878	0.003940	0.004234	0.007389	0.007958	0.002352	0.002528	0.002528	0.002724
4600	0.003175	0.010760	0.003900	0.004194	0.007311	0.007879	0.002332	0.002509	0.002509	0.002685
4700	0.003136	0.010643	0.003861	0.004155	0.007232	0.007801	0.002293	0.002470	0.002470	0.002666
4800	0.003116	0.010525	0.003802	0.004096	0.007174	0.007722	0.002274	0.002450	0.002450	0.002646
5000	0.003058	0.010310	0.003744	0.004018	0.007017	0.007566	0.002234	0.002411	0.002391	0.002587

Table J.3. Predictions of One-half 95% Confidence Intervals (CI) on Survivals of Control and Treatment Fish Traveling to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probabilities (λ) as a Function of Possible Total Numbers that Could be Released. Release locations include the TDA Tailrace (treatment) and BON Tailrace (controls) to assess BON survival.

Release Number	One half 95% CI on Control S1	One half 95% CI on Treatment S1	One half 95% CI on Control S2	One half 95% CI on Treatment S2	One half 95% CI on Control P1	One half 95% CI on Treatment P1	One half 95% CI on Control P2	One half 95% CI on Treatment P2	One half 95% CI on Control Lamda	One half 95% CI on Treatment Lamda
300	0.058526	0.096197	0.107530	0.113330	0.067032	0.070658	0.087651	0.092394	0.077126	0.081301
400	0.050686	0.083300	0.093120	0.098160	0.058055	0.061191	0.075911	0.080027	0.066797	0.070403
500	0.045335	0.074519	0.083280	0.087790	0.051920	0.054743	0.067894	0.071579	0.059741	0.062975
600	0.041395	0.068012	0.076030	0.080140	0.047412	0.049960	0.061995	0.065346	0.054527	0.057487
700	0.038318	0.062975	0.070380	0.074190	0.043884	0.046256	0.057389	0.060486	0.050490	0.053214
800	0.035848	0.058918	0.065840	0.069400	0.041042	0.043277	0.053684	0.056585	0.047236	0.049784
900	0.033790	0.055546	0.062070	0.065420	0.038710	0.040807	0.050607	0.053351	0.044531	0.046942
1000	0.032066	0.052685	0.058900	0.062070	0.036711	0.038710	0.048020	0.050607	0.042238	0.044531
1100	0.030576	0.050235	0.056150	0.059190	0.035006	0.036907	0.045786	0.048255	0.040278	0.042454
1200	0.029263	0.048098	0.053760	0.056660	0.033516	0.035339	0.043826	0.046197	0.038553	0.040650
1300	0.028126	0.046217	0.051650	0.054450	0.032203	0.033947	0.042120	0.044394	0.037044	0.039063
1400	0.027087	0.044531	0.049760	0.052470	0.031027	0.032712	0.040572	0.042767	0.035692	0.037632
1500	0.026186	0.043022	0.048080	0.050690	0.029988	0.031595	0.039200	0.041317	0.034496	0.036358
1600	0.025343	0.041650	0.046550	0.049080	0.029028	0.030596	0.037965	0.040004	0.033398	0.035202
1700	0.024598	0.040415	0.045160	0.047610	0.028165	0.029694	0.036828	0.038808	0.032399	0.034143
1800	0.023892	0.039278	0.043900	0.046280	0.027362	0.028851	0.035790	0.037730	0.031478	0.033183
1900	0.023265	0.038220	0.042730	0.045040	0.026636	0.028087	0.034829	0.036711	0.030654	0.032301
2000	0.022677	0.037260	0.041650	0.043880	0.025970	0.027362	0.033947	0.035790	0.029870	0.031478
2100	0.022128	0.036358	0.040630	0.042850	0.025343	0.026715	0.033124	0.034927	0.029145	0.030733
2200	0.021619	0.035515	0.039710	0.041850	0.024755	0.026088	0.032379	0.034124	0.028479	0.030027
2300	0.021148	0.034751	0.038830	0.040920	0.024206	0.025519	0.031654	0.033379	0.027852	0.029361
2400	0.020698	0.034006	0.038000	0.040060	0.023696	0.024990	0.030988	0.032673	0.027264	0.028734
2500	0.020286	0.033320	0.037240	0.039260	0.023226	0.024480	0.030360	0.032007	0.026715	0.028165
2600	0.019874	0.032673	0.036510	0.038490	0.022775	0.024010	0.029772	0.031380	0.026205	0.027616
2700	0.019502	0.032066	0.035850	0.037770	0.022344	0.023559	0.029224	0.030792	0.025715	0.027107
2800	0.019169	0.031497	0.035200	0.037100	0.021952	0.023128	0.028694	0.030243	0.025245	0.026617
2900	0.018836	0.030948	0.034570	0.036460	0.021560	0.022736	0.028185	0.029714	0.024814	0.026146
3000	0.018502	0.030419	0.034010	0.035850	0.021207	0.022344	0.027714	0.029224	0.024382	0.025715
3100	0.018208	0.029929	0.033460	0.035260	0.020854	0.021991	0.027264	0.028753	0.023990	0.025284
3200	0.017914	0.029459	0.032930	0.034710	0.020521	0.021638	0.026832	0.028302	0.023618	0.024892
3300	0.017640	0.029008	0.032420	0.034160	0.020208	0.021305	0.026421	0.027852	0.023246	0.024520
3400	0.017385	0.028577	0.031930	0.033670	0.019914	0.020992	0.026048	0.027440	0.022912	0.024147
3500	0.017130	0.028165	0.031480	0.033180	0.019620	0.020698	0.025656	0.027048	0.022579	0.023794
3600	0.016895	0.027773	0.031050	0.032710	0.019345	0.020404	0.025304	0.026676	0.022266	0.023461
3700	0.016660	0.027401	0.030620	0.032280	0.019090	0.020129	0.024970	0.026303	0.021952	0.023148
3800	0.016444	0.027028	0.030200	0.031850	0.018836	0.019855	0.024637	0.025970	0.021678	0.022834
3900	0.016229	0.026676	0.029810	0.031440	0.018600	0.019600	0.024304	0.025637	0.021384	0.022540
4000	0.016033	0.026342	0.029440	0.031050	0.018365	0.019345	0.024010	0.025304	0.021129	0.022266
4100	0.015837	0.026029	0.029090	0.030650	0.018130	0.019110	0.023716	0.024990	0.020854	0.021991
4200	0.015641	0.025715	0.028730	0.030280	0.017914	0.018894	0.023422	0.024696	0.020619	0.021717
4300	0.015464	0.025402	0.028400	0.029930	0.017699	0.018659	0.023148	0.024402	0.020364	0.021482
4400	0.015288	0.025127	0.028070	0.029600	0.017503	0.018444	0.022893	0.024128	0.020129	0.021227
4500	0.015112	0.024833	0.027750	0.029260	0.017307	0.018248	0.022638	0.023853	0.019914	0.020992
4600	0.014955	0.024559	0.027460	0.028950	0.017111	0.018052	0.022383	0.023598	0.019698	0.020756
4700	0.014778	0.024304	0.027170	0.028640	0.016934	0.017856	0.022148	0.023344	0.019482	0.020541
4800	0.014641	0.024049	0.026870	0.028340	0.016758	0.017660	0.021913	0.023108	0.019286	0.020325
5000	0.014347	0.023559	0.026340	0.027750	0.016425	0.017307	0.021482	0.022638	0.018894	0.019914

Appendix K

Model Estimates of One-Half 95% Confidence Intervals on Detection and Survival Statistics for Subyearling Chinook Salmon Based on Single-Release Survival Models for Summer 2006

Appendix K

Model Estimates of One-half 95% Confidence Intervals on Detection and Survival Statistics for Subyearling Chinook Salmon Based on Single-Release Survival Models for Summer 2006

All predicted estimates of 95% confidence intervals (CI) are based upon summer 2006 estimates of survival and detection probabilities, and sample-size estimates associated with a one-half 95% CIs of 2%, 3%, 4%, and 5% on primary array survival (S1) are highlighted when listed.

Table K.1. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Little Goose Tailrace to Array 1J (S1) and from Array 1J to Array 1T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.044923	0.012250	0.058330	0.051960	0.054860
400	0.038906	0.010604	0.050509	0.045002	0.047510
500	0.034790	0.009486	0.045178	0.040258	0.042493
600	0.031772	0.008663	0.041238	0.036750	0.038788
700	0.029420	0.008016	0.038181	0.034026	0.035907
800	0.027518	0.007507	0.035711	0.031811	0.033594
900	0.025931	0.007076	0.033673	0.030008	0.031674
1000	0.024598	0.006703	0.031948	0.028459	0.030047
1100	0.023461	0.006390	0.030458	0.027146	0.028655
1200	0.022462	0.006135	0.029165	0.025990	0.027420
1300	0.021580	0.005880	0.028028	0.024970	0.026342
1400	0.020796	0.005664	0.027009	0.024049	0.025402
1500	0.020090	0.005488	0.026088	0.023246	0.024539
1600	0.019443	0.005312	0.025264	0.022501	0.023755
1700	0.018875	0.005155	0.024500	0.021834	0.023050
1800	0.018346	0.004998	0.023814	0.021207	0.022403
1900	0.017856	0.004861	0.023187	0.020639	0.021795
2000	0.017405	0.004743	0.022599	0.020129	0.021246
2100	0.016974	0.004626	0.022050	0.019639	0.020737
2200	0.016582	0.004528	0.021540	0.019188	0.020247
2300	0.016229	0.004430	0.021070	0.018757	0.019816
2400	0.015876	0.004332	0.020619	0.018365	0.019384
2500	0.015562	0.004253	0.020208	0.017993	0.018992
2600	0.015268	0.004155	0.019816	0.017660	0.018640
2700	0.014974	0.004077	0.019443	0.017326	0.018287
2800	0.014700	0.004018	0.019090	0.017013	0.017954
3000	0.014210	0.003881	0.018444	0.016425	0.017346

Table K.2. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Little Goose Tailrace to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.041062	0.056134	0.024030	0.002920	0.002920
400	0.035574	0.048608	0.020815	0.002528	0.002528
500	0.031811	0.043473	0.018620	0.002254	0.002254
600	0.029047	0.039690	0.016993	0.002058	0.002058
700	0.026891	0.036750	0.015739	0.001901	0.001901
800	0.025147	0.034378	0.014720	0.001784	0.001784
900	0.023716	0.032399	0.013877	0.001686	0.001686
1000	0.022501	0.030752	0.013152	0.001588	0.001588
1100	0.021442	0.029322	0.012544	0.001529	0.001529
1200	0.020541	0.028067	0.012015	0.001450	0.001450
1300	0.019737	0.026970	0.011544	0.001392	0.001392
1400	0.019012	0.025990	0.011113	0.001352	0.001352
1500	0.018365	0.025108	0.010741	0.001313	0.001313
1600	0.017777	0.024304	0.010408	0.001254	0.001254
1700	0.017248	0.023579	0.010094	0.001235	0.001235
1800	0.016758	0.022912	0.009800	0.001196	0.001196
1900	0.016327	0.022305	0.009545	0.001156	0.001156
2000	0.015915	0.021736	0.009310	0.001137	0.001137
2100	0.015523	0.021207	0.009075	0.001098	0.001098
2200	0.015170	0.020737	0.008879	0.001078	0.001078
2300	0.014837	0.020266	0.008683	0.001058	0.001058
2400	0.014524	0.019855	0.008487	0.001039	0.001039
2500	0.014230	0.019443	0.008330	0.001019	0.001019
2600	0.013955	0.019071	0.008154	0.001000	0.001000
2700	0.013681	0.018718	0.008016	0.000980	0.000980
2800	0.013446	0.018365	0.007860	0.000960	0.000960
3000	0.012995	0.017758	0.007605	0.000921	0.000921

Table K.3. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Little Goose Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.044355	0.201740	0.200140
400	0.038416	0.174710	0.173320
500	0.034359	0.156270	0.155020
600	0.031360	0.142650	0.141510
700	0.029047	0.132060	0.131010
800	0.027166	0.123540	0.122560
900	0.025617	0.116480	0.115540
1000	0.024304	0.110500	0.109620
1100	0.023167	0.105350	0.104510
1200	0.022187	0.100880	0.100060
1300	0.021305	0.096920	0.096140
1400	0.020541	0.093390	0.092650
1500	0.019835	0.090220	0.089490
1600	0.019208	0.087360	0.086650
1700	0.018640	0.084750	0.084060
1800	0.018110	0.082360	0.081690
1900	0.017620	0.080160	0.079520
2000	0.017170	0.078130	0.077520
2100	0.016758	0.076240	0.075640
2200	0.016386	0.074500	0.073910
2300	0.016013	0.072850	0.072280
2400	0.015680	0.071320	0.070760
2500	0.015366	0.069890	0.069330
2600	0.015072	0.068520	0.067970
2700	0.014778	0.067250	0.066720
2800	0.014524	0.066030	0.065500
3000	0.014034	0.063800	0.063290

Table K.4. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Tailrace to Array 1J (S1) and from Array 1J to Array 1T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.009232	0.006821	0.006625	0.020717	0.027264
400	0.007997	0.005900	0.005743	0.017934	0.023598
500	0.007154	0.005272	0.005135	0.016052	0.021109
600	0.006527	0.004822	0.004684	0.014641	0.019267
700	0.006056	0.004469	0.004332	0.013563	0.017836
800	0.005664	0.004175	0.004057	0.012681	0.016699
900	0.005331	0.003940	0.003822	0.011956	0.015739
1000	0.005057	0.003744	0.003626	0.011348	0.014935
1100	0.004822	0.003567	0.003450	0.010819	0.014230
1200	0.004626	0.003410	0.003312	0.010349	0.013622
1300	0.004430	0.003273	0.003175	0.009957	0.013093
1400	0.004273	0.003156	0.003058	0.009584	0.012622
1500	0.004136	0.003058	0.002960	0.009271	0.012191
1600	0.003998	0.002960	0.002862	0.008977	0.011799
1700	0.003881	0.002862	0.002783	0.008702	0.011446
1800	0.003763	0.002783	0.002705	0.008448	0.011133
1900	0.003665	0.002705	0.002626	0.008232	0.010839
2000	0.003587	0.002646	0.002568	0.008016	0.010564
2100	0.003489	0.002568	0.002509	0.007820	0.010310
2200	0.003410	0.002509	0.002450	0.007644	0.010074
2300	0.003332	0.002470	0.002391	0.007487	0.009839
2400	0.003273	0.002411	0.002332	0.007330	0.009643
2500	0.003195	0.002372	0.002293	0.007174	0.009447
2600	0.003136	0.002313	0.002254	0.007036	0.009251
2700	0.003077	0.002274	0.002215	0.006899	0.009094
2800	0.003018	0.002234	0.002176	0.006782	0.008918
3000	0.002920	0.002156	0.002097	0.006546	0.008624

Table K.5. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the JDA Tailrace to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.043218	0.011329	0.013798	0.001254	0.000118
400	0.037436	0.009800	0.011956	0.001078	0.000098
500	0.033477	0.008761	0.010702	0.000960	0.000098
600	0.030556	0.007997	0.009761	0.000882	0.000078
700	0.028302	0.007409	0.009036	0.000823	0.000078
800	0.026460	0.006938	0.008448	0.000764	0.000078
900	0.024951	0.006527	0.007977	0.000725	0.000078
1000	0.023677	0.006194	0.007566	0.000686	0.000059
1100	0.022579	0.005919	0.007213	0.000647	0.000059
1200	0.021619	0.005664	0.006899	0.000627	0.000059
1300	0.020756	0.005429	0.006625	0.000608	0.000059
1400	0.020012	0.005233	0.006390	0.000588	0.000059
1500	0.019326	0.005057	0.006174	0.000568	0.000059
1600	0.018718	0.004900	0.005978	0.000549	0.000059
1700	0.018150	0.004763	0.005802	0.000529	0.000059
1800	0.017640	0.004626	0.005645	0.000510	0.000059
1900	0.017170	0.004488	0.005488	0.000490	0.000039
2000	0.016738	0.004390	0.005351	0.000490	0.000039
2100	0.016327	0.004273	0.005214	0.000470	0.000039
2200	0.015954	0.004175	0.005096	0.000470	0.000039
2300	0.015602	0.004096	0.004978	0.000451	0.000039
2400	0.015288	0.003998	0.004880	0.000451	0.000039
2500	0.014974	0.003920	0.004782	0.000431	0.000039
2600	0.014680	0.003842	0.004684	0.000431	0.000039
2700	0.014406	0.003783	0.004606	0.000412	0.000039
2800	0.014151	0.003704	0.004528	0.000412	0.000039
3000	0.013661	0.003587	0.004371	0.000392	0.000039

Table K.6. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the John Day Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.064386	0.072128	0.072461
400	0.055762	0.062465	0.062759
500	0.049862	0.055860	0.056134
600	0.045531	0.050999	0.051234
700	0.042140	0.047216	0.047432
800	0.039416	0.044159	0.044374
900	0.037162	0.041650	0.041826
1000	0.035260	0.039514	0.039690
1100	0.033614	0.037671	0.037848
1200	0.032183	0.036064	0.036221
1300	0.030929	0.034653	0.034810
1400	0.029812	0.033379	0.033536
1500	0.028792	0.032262	0.032399
1600	0.027871	0.031223	0.031380
1700	0.027048	0.030302	0.030439
1800	0.026284	0.029439	0.029576
1900	0.025578	0.028655	0.028792
2000	0.024931	0.027930	0.028067
2100	0.024324	0.027264	0.027381
2200	0.023775	0.026636	0.026754
2300	0.023246	0.026048	0.026166
2400	0.022756	0.025500	0.025617
2500	0.022305	0.024990	0.025108
2600	0.021874	0.024500	0.024618
2700	0.021462	0.024049	0.024147
2800	0.021070	0.023618	0.023716
3000	0.020364	0.022814	0.022912

Table K.7. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the TDA Tailrace to Array 1T (S1) and from Array 1T to Array 1B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on S2	One-half 95% CI on P1	One-half 95% CI on P2	One-half 95% CI on Lamda
300	0.019678	0.023167	0.011035	0.001176	0.002626
400	0.017032	0.020051	0.009545	0.001019	0.002274
500	0.015249	0.017934	0.008546	0.000902	0.002038
600	0.013916	0.016386	0.007801	0.000823	0.001862
700	0.012877	0.015170	0.007213	0.000764	0.001725
800	0.012054	0.014190	0.006762	0.000725	0.001607
900	0.011368	0.013367	0.006370	0.000686	0.001509
1000	0.010780	0.012681	0.006037	0.000647	0.001431
1100	0.010270	0.012093	0.005762	0.000608	0.001372
1200	0.009839	0.011584	0.005508	0.000588	0.001313
1300	0.009447	0.011133	0.005292	0.000568	0.001254
1400	0.009114	0.010721	0.005096	0.000549	0.001215
1500	0.008800	0.010349	0.004939	0.000529	0.001176
1600	0.008526	0.010035	0.004782	0.000510	0.001137
1700	0.008271	0.009722	0.004626	0.000490	0.001098
1800	0.008036	0.009447	0.004508	0.000470	0.001078
1900	0.007820	0.009212	0.004390	0.000470	0.001039
2000	0.007624	0.008977	0.004273	0.000451	0.001019
2100	0.007428	0.008761	0.004175	0.000451	0.001000
2200	0.007272	0.008546	0.004077	0.000431	0.000960
2300	0.007115	0.008369	0.003979	0.000431	0.000941
2400	0.006958	0.008193	0.003900	0.000412	0.000921
2500	0.006821	0.008016	0.003822	0.000412	0.000902
2600	0.006684	0.007860	0.003744	0.000392	0.000882
2700	0.006566	0.007722	0.003685	0.000392	0.000882
2800	0.006448	0.007585	0.003606	0.000392	0.000862
3000	0.006213	0.007330	0.003489	0.000372	0.000823

Table K.8. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from The Dalles Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.054527	0.058349	0.063465
400	0.047236	0.050529	0.054958
500	0.042238	0.045198	0.049157
600	0.038553	0.041258	0.044884
700	0.035711	0.038200	0.041552
800	0.033398	0.035731	0.038867
900	0.031478	0.033692	0.036652
1000	0.029870	0.031968	0.034770
1100	0.028479	0.030478	0.033144
1200	0.027264	0.029165	0.031732
1300	0.026205	0.028028	0.030498
1400	0.025245	0.027009	0.029380
1500	0.024382	0.026088	0.028381
1600	0.023618	0.025264	0.027479
1700	0.022912	0.024520	0.026656
1800	0.022266	0.023814	0.025911
1900	0.021678	0.023187	0.025225
2000	0.021129	0.022599	0.024578
2100	0.020619	0.022050	0.023990
2200	0.020129	0.021540	0.023442
2300	0.019698	0.021070	0.022912
2400	0.019286	0.020619	0.022442
2500	0.018894	0.020208	0.021991
2600	0.018522	0.019816	0.021560
2700	0.018169	0.019443	0.021148
2800	0.017856	0.019090	0.020776
3000	0.017248	0.018444	0.020070

Table K.9. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Bonneville Tailrace to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.035476	0.049255	0.050235
400	0.030713	0.042669	0.043512
500	0.027479	0.038161	0.038906
600	0.025088	0.034829	0.035515
700	0.023226	0.032242	0.032889
800	0.021717	0.030164	0.030772
900	0.020482	0.028440	0.029008
1000	0.019424	0.026989	0.027518
1100	0.018522	0.025735	0.026244
1200	0.017738	0.024637	0.025127
1300	0.017032	0.023657	0.024128
1400	0.016425	0.022795	0.023265
1500	0.015856	0.022030	0.022462
1600	0.015366	0.021325	0.021756
1700	0.014896	0.020698	0.021109
1800	0.014484	0.020110	0.020502
1900	0.014092	0.019580	0.019953
2000	0.013740	0.019071	0.019463
2100	0.013406	0.018620	0.018992
2200	0.013093	0.018189	0.018561
2300	0.012818	0.017797	0.018150
2400	0.012544	0.017424	0.017758
2500	0.012289	0.017072	0.017405
2600	0.012054	0.016738	0.017072
2700	0.011819	0.016425	0.016738
2800	0.011603	0.016131	0.016444
3000	0.011211	0.015582	0.015896

Table K.10. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the B2CC to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.033928	0.043982	0.053626
400	0.029380	0.038102	0.046432
500	0.026284	0.034084	0.041532
600	0.023990	0.031105	0.037906
700	0.022207	0.028792	0.035104
800	0.020776	0.026930	0.032830
900	0.019580	0.025402	0.030948
1000	0.018581	0.024088	0.029361
1100	0.017718	0.022971	0.028008
1200	0.016974	0.021991	0.026813
1300	0.016307	0.021129	0.025754
1400	0.015700	0.020364	0.024814
1500	0.015170	0.019678	0.023971
1600	0.014700	0.019051	0.023226
1700	0.014249	0.018483	0.022520
1800	0.013857	0.017954	0.021893
1900	0.013485	0.017483	0.021305
2000	0.013132	0.017032	0.020756
2100	0.012818	0.016621	0.020266
2200	0.012524	0.016248	0.019796
2300	0.012250	0.015896	0.019365
2400	0.011995	0.015562	0.018953
2500	0.011760	0.015229	0.018581
2600	0.011525	0.014935	0.018208
2700	0.011309	0.014661	0.017875
2800	0.011113	0.014406	0.017542
3000	0.010721	0.013916	0.016954

Table K.11. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the B2 JBS to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.048726	0.055860	0.062073
400	0.042199	0.048373	0.053763
500	0.037730	0.043257	0.048079
600	0.034457	0.039494	0.043904
700	0.031889	0.036574	0.040631
800	0.029831	0.034202	0.038024
900	0.028126	0.032242	0.035848
1000	0.026695	0.030596	0.034006
1100	0.025441	0.029165	0.032418
1200	0.024363	0.027930	0.031046
1300	0.023402	0.026832	0.029831
1400	0.022560	0.025852	0.028734
1500	0.021795	0.024970	0.027754
1600	0.021090	0.024186	0.026872
1700	0.020462	0.023461	0.026088
1800	0.019894	0.022795	0.025343
1900	0.019365	0.022187	0.024676
2000	0.018875	0.021638	0.024049
2100	0.018424	0.021109	0.023461
2200	0.017993	0.020619	0.022932
2300	0.017601	0.020168	0.022422
2400	0.017228	0.019757	0.021952
2500	0.016876	0.019345	0.021501
2600	0.016542	0.018973	0.021090
2700	0.016248	0.018620	0.020698
2800	0.015954	0.018287	0.020325
3000	0.015406	0.017660	0.019639

Table K.12. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Bonneville Spillway to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Could be Released.

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.048980	0.053234	0.059956
400	0.042414	0.046099	0.051920
500	0.037946	0.041219	0.046432
600	0.034633	0.037632	0.042395
700	0.032066	0.034849	0.039259
800	0.029988	0.032595	0.036711
900	0.028283	0.030733	0.034614
1000	0.026832	0.029145	0.032830
1100	0.025578	0.027793	0.031321
1200	0.024500	0.026617	0.029968
1300	0.023540	0.025558	0.028792
1400	0.022677	0.024637	0.027754
1500	0.021913	0.023794	0.026813
1600	0.021207	0.023050	0.025970
1700	0.020580	0.022364	0.025186
1800	0.019992	0.021736	0.024480
1900	0.019463	0.021148	0.023834
2000	0.018973	0.020619	0.023226
2100	0.018522	0.020110	0.022658
2200	0.018091	0.019659	0.022148
2300	0.017699	0.019228	0.021658
2400	0.017326	0.018816	0.021207
2500	0.016974	0.018444	0.020776
2600	0.016640	0.018071	0.020364
2700	0.016327	0.017738	0.019992
2800	0.016033	0.017424	0.019620
3000	0.015484	0.016836	0.018953

Table K.13. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Bonneville Spillway to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that Might Pass Under a High 24-h Spill Treatment

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.0591	0.0664	0.0664
400	0.0512	0.0575	0.0575
500	0.0458	0.0515	0.0515
600	0.0418	0.0470	0.0470
700	0.0387	0.0435	0.0435
800	0.0362	0.0407	0.0407
900	0.0341	0.0383	0.0383
1000	0.0324	0.0364	0.0364
1100	0.0309	0.0347	0.0347
1200	0.0295	0.0332	0.0332
1300	0.0284	0.0319	0.0319
1400	0.0273	0.0307	0.0307
1500	0.0264	0.0297	0.0297
1600	0.0256	0.0288	0.0288
1700	0.0248	0.0279	0.0279
1800	0.0241	0.0271	0.0271
1900	0.0235	0.0264	0.0264
2000	0.0229	0.0257	0.0257
2100	0.0223	0.0251	0.0251
2200	0.0218	0.0245	0.0245
2300	0.0213	0.0240	0.0240
2400	0.0209	0.0235	0.0235
2500	0.0205	0.0230	0.0230
2600	0.0201	0.0226	0.0226
2700	0.0197	0.0221	0.0221
2800	0.0193	0.0217	0.0217
3000	0.0187	0.0210	0.0210

Table K.14. Predictions of One-half 95% Confidence Intervals (CI) on Survival of Fish Traveling from the Bonneville Spillway to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probability (λ) as a Function of Possible Total Numbers that that Might Pass Under Biological-Opinion Spill Treatment (75,000 cfs Day and Gas-cap Night Spill)

Release Number	One half 95% CI on S1	One-half 95% CI on P1	One-half 95% CI on Lamda
300	0.0514	0.0455	0.0613
400	0.0445	0.0394	0.0531
500	0.0398	0.0353	0.0475
600	0.0363	0.0322	0.0434
700	0.0336	0.0298	0.0402
800	0.0315	0.0279	0.0376
900	0.0297	0.0263	0.0354
1000	0.0281	0.0249	0.0336
1100	0.0268	0.0238	0.0320
1200	0.0257	0.0228	0.0307
1300	0.0247	0.0219	0.0295
1400	0.0238	0.0211	0.0284
1500	0.0230	0.0204	0.0274
1600	0.0222	0.0197	0.0266
1700	0.0216	0.0191	0.0258
1800	0.0210	0.0186	0.0250
1900	0.0204	0.0181	0.0244
2000	0.0199	0.0176	0.0238
2100	0.0194	0.0172	0.0232
2200	0.0190	0.0168	0.0227
2300	0.0186	0.0164	0.0221
2400	0.0182	0.0161	0.0217
2500	0.0178	0.0158	0.0212
2600	0.0174	0.0155	0.0208
2700	0.0171	0.0152	0.0204
2800	0.0168	0.0149	0.0201
3000	0.0162	0.0144	0.0194

Appendix L

Model Estimates of One-Half 95% Confidence Intervals on Detection and Survival Statistics for Subyearling Chinook Salmon Based on Paired-Release Survival Models for Summer 2006

Appendix L

Model Estimates of One-Half 95% Confidence Intervals on Detection and Survival Statistics for Subyearling Chinook Salmon Based on Paired-Release Survival Models for Summer 2006

All predicted estimates of 95% confidence intervals (CI) are based upon summer 2006 estimates of survival and detection probabilities, and sample-size estimates associated with a one-half 95% CIs of about 2%, 3%, 4%, and 5% on the primary-array survival of treatment fish (S1 in the third column) are highlighted when listed.

Table L.1. Predictions of One-half 95% Confidence Intervals (CI) on Survivals of Control and Treatment Fish Traveling to Array 1T (S1) and from Array 1T to Array 2T (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probabilities (λ) as a Function of Possible Total Numbers that Could be Released. Release locations include the JDA tailrace (treatment) and The Dalles Tailrace (controls) to assess TDA survival.

Release Number	One half 95% CI on Control S1	One half 95% CI on Treatment S1	One half 95% CI on Control S2	One half 95% CI on Treatment S2	One half 95% CI on Control P1	One half 95% CI on Treatment P1	One half 95% CI on Control P2	One half 95% CI on Treatment P2	One half 95% CI on Control Lamda	One half 95% CI on Treatment Lamda
300	0.019718	0.049882	0.023206	0.025578	0.012936	0.014269	0.001176	0.001294	0.002626	0.002901
400	0.019718	0.044002	0.023206	0.022148	0.012936	0.012368	0.001176	0.001117	0.002626	0.002509
500	0.019718	0.040062	0.023206	0.019816	0.012936	0.011054	0.001176	0.001000	0.002626	0.002234
600	0.019718	0.037201	0.023206	0.018091	0.012936	0.010094	0.001176	0.000921	0.002626	0.002038
700	0.019718	0.035025	0.023206	0.016738	0.012936	0.009349	0.001176	0.000843	0.002626	0.001901
800	0.019718	0.033300	0.023206	0.015660	0.012936	0.008742	0.001176	0.000784	0.002626	0.001764
900	0.019718	0.031889	0.023206	0.014759	0.012936	0.008232	0.001176	0.000745	0.002626	0.001666
1000	0.019718	0.030713	0.023206	0.014014	0.012936	0.007820	0.001176	0.000706	0.002626	0.001588
1100	0.019718	0.029714	0.023206	0.013348	0.012936	0.007448	0.001176	0.000666	0.002626	0.001509
1200	0.019718	0.028851	0.023206	0.012779	0.012936	0.007134	0.001176	0.000647	0.002626	0.001450
1300	0.019718	0.028106	0.023206	0.012289	0.012936	0.006860	0.001176	0.000627	0.002626	0.001392
1400	0.019718	0.027440	0.023206	0.011838	0.012936	0.006605	0.001176	0.000608	0.002626	0.001333
1500	0.019718	0.026872	0.023206	0.011446	0.012936	0.006390	0.001176	0.000568	0.002626	0.001294
1600	0.019718	0.026342	0.023206	0.011074	0.012936	0.006174	0.001176	0.000568	0.002626	0.001254
1700	0.019718	0.025892	0.023206	0.010741	0.012936	0.005998	0.001176	0.000549	0.002626	0.001215
1800	0.019718	0.025460	0.023206	0.010447	0.012936	0.005821	0.001176	0.000529	0.002626	0.001176
1900	0.019718	0.025088	0.023206	0.010172	0.012936	0.005664	0.001176	0.000510	0.002626	0.001156
2000	0.019718	0.024735	0.023206	0.009898	0.012936	0.005527	0.001176	0.000510	0.002626	0.001117
2100	0.019718	0.024402	0.023206	0.009663	0.012936	0.005390	0.001176	0.000490	0.002626	0.001098
2200	0.019718	0.024108	0.023206	0.009447	0.012936	0.005272	0.001176	0.000470	0.002626	0.001078
2300	0.019718	0.023834	0.023206	0.009232	0.012936	0.005155	0.001176	0.000470	0.002626	0.001039
2400	0.019718	0.023579	0.023206	0.009036	0.012936	0.005037	0.001176	0.000451	0.002626	0.001019
2500	0.019718	0.023344	0.023206	0.008859	0.012936	0.004939	0.001176	0.000451	0.002626	0.001000
2600	0.019718	0.023128	0.023206	0.008683	0.012936	0.004841	0.001176	0.000431	0.002626	0.000980
2700	0.019718	0.022932	0.023206	0.008526	0.012936	0.004763	0.001176	0.000431	0.002626	0.000960
2800	0.019718	0.022736	0.023206	0.008369	0.012936	0.004665	0.001176	0.000431	0.002626	0.000941
2900	0.019718	0.022560	0.023206	0.008232	0.012936	0.004586	0.001176	0.000412	0.002626	0.000921
3000	0.019718	0.022383	0.023206	0.008095	0.012936	0.004508	0.001176	0.000412	0.002626	0.000921
3100	0.019718	0.022226	0.023206	0.007958	0.012936	0.004430	0.001176	0.000412	0.002626	0.000902
3200	0.019718	0.022070	0.023206	0.007840	0.012936	0.004371	0.001176	0.000392	0.002626	0.000882
3300	0.019718	0.021932	0.023206	0.007703	0.012936	0.004312	0.001176	0.000392	0.002626	0.000882
3400	0.019718	0.021795	0.023206	0.007605	0.012936	0.004234	0.001176	0.000392	0.002626	0.000862
3500	0.019718	0.021678	0.023206	0.007487	0.012936	0.004175	0.001176	0.000372	0.002626	0.000843
3600	0.019718	0.021540	0.023206	0.007389	0.012936	0.004116	0.001176	0.000372	0.002626	0.000843
3700	0.019718	0.021442	0.023206	0.007291	0.012936	0.004057	0.001176	0.000372	0.002626	0.000823
3800	0.019718	0.021325	0.023206	0.007193	0.012936	0.004018	0.001176	0.000372	0.002626	0.000804
3900	0.019718	0.021227	0.023206	0.007095	0.012936	0.003959	0.001176	0.000353	0.002626	0.000804
4000	0.019718	0.021109	0.023206	0.006997	0.012936	0.003900	0.001176	0.000353	0.002626	0.000784

Table L.2. Predictions of One-half 95% Confidence Intervals (CI) on Survivals of Control and Treatment Fish Traveling to Array 1B (S1) and from Array 1B to Array 2B (S2), on Associated Detection Probabilities P1 and P2, and on the Joint Probabilities (λ) as a Function of Possible Total Numbers that Could be Released. Release locations include the TDA Tailrace (treatment) and BON Tailrace (controls) to assess BON survival.

Release Number	95% CI on Control S1	95% CI on Treatment S1	95% CI on Control P1	95% CI on Treatment P1	95% CI on Control Lamda	95% CI on Treatment Lamda
500	0.027479	0.049274	0.038161	0.042493	0.038906	0.043336
600	0.027479	0.045982	0.038161	0.038788	0.038906	0.039572
700	0.027479	0.043492	0.038161	0.035927	0.038906	0.036632
800	0.027479	0.041513	0.038161	0.033594	0.038906	0.034261
900	0.027479	0.039906	0.038161	0.031674	0.038906	0.032301
1000	0.027479	0.038573	0.038161	0.030047	0.038906	0.030654
1100	0.027479	0.037456	0.038161	0.028655	0.038906	0.029224
1200	0.027479	0.036476	0.038161	0.02744	0.038906	0.027969
1300	0.027479	0.035652	0.038161	0.026362	0.038906	0.026872
1400	0.027479	0.034927	0.038161	0.025402	0.038906	0.025911
1500	0.027479	0.034280	0.038161	0.024539	0.038906	0.025029
1600	0.027479	0.033692	0.038161	0.023755	0.038906	0.024226
1700	0.027479	0.033183	0.038161	0.02305	0.038906	0.0235
1800	0.027479	0.032712	0.038161	0.022403	0.038906	0.022834
1900	0.027479	0.032281	0.038161	0.021795	0.038906	0.022226
2000	0.027479	0.031909	0.038161	0.021246	0.038906	0.021678
2100	0.027479	0.031556	0.038161	0.020737	0.038906	0.021148
2200	0.027479	0.031223	0.038161	0.020266	0.038906	0.020658
2300	0.027479	0.030929	0.038161	0.019816	0.038906	0.020208
2400	0.027479	0.030654	0.038161	0.019404	0.038906	0.019776
2500	0.027479	0.030400	0.038161	0.019012	0.038906	0.019384
2600	0.027479	0.030164	0.038161	0.01864	0.038906	0.019012
2700	0.027479	0.029929	0.038161	0.018287	0.038906	0.018659
2800	0.027479	0.029714	0.038161	0.017954	0.038906	0.018306
2900	0.027479	0.029537	0.038161	0.01764	0.038906	0.017993
3000	0.027479	0.029341	0.038161	0.017346	0.038906	0.017699
3100	0.027479	0.029165	0.038161	0.017072	0.038906	0.017405
3200	0.027479	0.029008	0.038161	0.016797	0.038906	0.01713
3300	0.027479	0.028851	0.038161	0.016542	0.038906	0.016876
3400	0.027479	0.028714	0.038161	0.016307	0.038906	0.016621
3500	0.027479	0.028577	0.038161	0.016072	0.038906	0.016386
3600	0.027479	0.028440	0.038161	0.015837	0.038906	0.01615
3700	0.027479	0.028322	0.038161	0.015621	0.038906	0.015935
3800	0.027479	0.028204	0.038161	0.015425	0.038906	0.015719
3900	0.027479	0.028087	0.038161	0.01521	0.038906	0.015523
4000	0.027479	0.027969	0.038161	0.015033	0.038906	0.015327
4100	0.027479	0.027871	0.038161	0.014837	0.038906	0.015131
4200	0.027479	0.027773	0.038161	0.014661	0.038906	0.014955
4300	0.027479	0.027675	0.038161	0.014484	0.038906	0.014778
4400	0.027479	0.027597	0.038161	0.014328	0.038906	0.014602
4500	0.027479	0.027499	0.038161	0.014171	0.038906	0.014445
4600	0.027479	0.027420	0.038161	0.014014	0.038906	0.014288
4700	0.027479	0.027342	0.038161	0.013857	0.038906	0.014132
4800	0.027479	0.027264	0.038161	0.01372	0.038906	0.013994
5000	0.027479	0.027126	0.038161	0.013446	0.038906	0.013700

Appendix M

Detection History Data for 2006

(on accompanying CD)

Appendix M

Detection History Data for 2006

Table M.1. List of Appendix CSV Files on the Accompanying CD*

File	Description
Appendix M - Detection History Data for 2006.CSV	All captured history data 2006

*A CD with Table M1 accompanies the final report.

Table M.2. Definitions of Variables in Headings of Appendix M Table on the Accompanying CD.

Variable	Definition
Season	Release season Spring/Summer
AcousticTagCode	Acoustic Tag Code
TagCode	PIT tag code
ActivationDate	Acoustic Tag Activation date
Rel_Date2	Fish release date and time
ReleaseLoc	Fish Release Location
JDA0	Tag detected at John Day Dam egress array, 0 for not detected and 1 for detected
JDA1	Tag detected at John Day Dam primary array, 0 for not detected and 1 for detected
JDA2	Tag detected at John Day Dam secondary array, 0 for not detected and 1 for detected
JDA3	Tag detected at John Day Dam tertiary array, 0 for not detected and 1 for detected
TDA1	Tag detected at The Dalles Dam primary array, 0 for not detected and 1 for detected
TDA2	Tag detected at The Dalles Dam secondary array, 0 for not detected and 1 for detected
TDA3	Tag detected at The Dalles Dam tertiary array, 0 for not detected and 1 for detected
TDA4	Tag detected at Bonneville Dam spillway forebay array, 0 for not detected and 1 for detected
BON1	Tag detected at Bonneville Dam primary array, 0 for not detected and 1 for detected
BON2	Tag detected at Bonneville Dam secondary array, 0 for not detected and 1 for detected
BON3	Tag detected at Bonneville Dam tertiary array, 0 for not detected and 1 for detected
JDA0_TIME	First detected date and time at John Day Dam Egrass array (downstream of the dam)
JDA1_TIME	First detected date and time at John Day Dam primary array (downstream of the dam)
JDA2_TIME	First detected date and time at John Day Dam secondary array (downstream of the dam)
JDA3_TIME	First detected date and time at John Day Dam tertiary array (downstream of the dam)
TDA1_TIME	First detected date and time at The Dalles Dam primary array (downstream of the dam)
TDA2_TIME	First detected date and time at The Dalles Dam secondary array (downstream of the dam)
TDA3_TIME	First detected date and time at The Dalles Dam tertiary array (downstream of the dam)
TDA4_TIME	Last detected date and time at Bonneville Dam spillway forebay array
BON1_TIME	First detected date and time at Bonneville Dam primary array (downstream of the dam)
BON2_TIME	First detected date and time at Bonneville Dam secondary array (downstream of the dam)
BON3_TIME	First detected date and time at Bonneville Dam tertiary array (downstream of the dam)