U.S. Army Corps of Engineers
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Survival Estimates of Migrant Juvenile Salmonids in the Columbia River From The Dalles Dam Through Bonneville Dam Using Radio-Telemetry, 2001.

Annual Report of Research

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Executive Summary

During 2001, we estimated the survival of yearling and sub-yearling chinook salmon through the ice and trash sluiceway at The Dalles Dam. The average survival of yearling chinook salmon released through The Dalles Dam ice and trash sluiceway during the spring 2001 release period was 0.993 (± 0.048, 95% confidence interval). For releases of yearling chinook salmon made during the day, the average survival was estimated to be 1.010 (± 0.059, 95% confidence interval) and for the night releases was 0.977 (± 0.078, 95% confidence interval). No significant difference was detected between day and night survival for yearling chinook salmon (P = 0.74, one-tailed t-test). No significant relation was detected between the survival of yearling chinook salmon released through the ice and trash sluiceway and total and spill discharge and percent spill through The Dalles Dam (linear regression, $P > 0.10$).

The average sub-yearling chinook salmon survival for the summer release period was estimated to be 0.962 (± 0.056, 95% confidence interval). Average day survival was estimated to be 0.950 (± 0.078, 95% confidence interval) while night survival was estimated to be 0.974 (± 0.085, 95% confidence interval). The difference between day and night survival for sub-yearling chinook was found to be statistically insignificant (P = 0.35, one-tailed t-test). No significant relation was detected between the survival of sub-yearling chinook salmon released through the ice and trash sluiceway and total discharge through The Dalles Dam (linear regression, $P > 0.10$).

Introduction

As anadromous juvenile salmonids migrate from freshwater rearing habitats to the ocean, they are vulnerable to a host of factors that affect their survival. Direct effects associated with dam passage (e.g., instantaneous mortality, injury, loss of equilibrium, etc.) and indirect effects (e.g., predation, disease, and physiological stress) contribute to the total mortality of seaward migrating salmonids. Many studies have been conducted to determine the effects of hydroelectric dams on the survival of salmonid migrants (Raymond 1979, Stier and Kynard 1986, Iwamato et al. 1994, Muir et al. 1995, Smith et al. 1998). Based on this research and studies examining migrant salmonid behavior at dams in the Columbia River Basin, management actions are currently being implemented to improve the survival of salmonid migrants.

A primary objective of The National Marine Fisheries Service Federal Columbia River Power System (FCRPS) Biological Opinion is to increase survival of juvenile salmonid out migrants through the federal hydrosystem (NMFS 2000). To help meet this objective, specific water management scenarios have been specified for the hydropower system in general and also, specifically for each project. Based on past research, the NMFS has determined that measures that increase juvenile fish passage through spillways should be given the highest priority, while passing fish through turbines is the least preferred route of passage. Thus, various levels and configurations of spill are used to help meet the established survival and fish passage goals. While there is a consensus that survival is greater for fish diverted from turbines, questions regarding the effectiveness of different spill patterns and other passage scenarios remain (Dawley et al. 1998, NMFS 2000). To evaluate the efficacy of specified water management strategies, the FCRPS biological opinion stresses the importance of establishing a process to monitor, evaluate, and report on the efficacy of the specified measures to improve survival of juvenile migrants. Estimating the survival of migrant juvenile salmonids through projects and reservoirs in the lower Columbia River has been specified as a necessary step in this evaluation process.

New fish marking techniques and the development and acceptance of new statistical methodologies (see Leberton et al. 1992) have led scientists to reevaluate past techniques used to assess survival of migrant salmonids in the Columbia River Basin. For instance, the development of the passive integrated transponder (PIT) tag, which allowed for the unique identification of fish (Prentice et al. 1990), offered many advantages over previous marking techniques (fin-clipping, freeze branding) used in survival studies. Consequently, PIT-tag recoveries and release-recapture models (Burnham et al. 1987, Smith et al. 1996) have been used to assess the survival of migrant salmonid smolts through various reaches of the Columbia and Snake rivers (Iwamato et al. 1994, Muir et al. 1995, Skalski et al. 1998b, Smith et al. 1998, Dawley et al. 1998). However, the use of the PIT-tag technique relies on the availability of PIT tag detectors at hydroelectric dams and these detectors are not present at all locations in the Columbia River Basin. The absence of PIT tag detectors at certain projects (e.g., The Dalles Dam) and areas below Bonneville Dam has precluded survival estimation in some specific reaches of the Columbia River and fixed the spatial scale over which survival estimates can be made. Further, the relatively low detection probabilities associated with this technique requires that large numbers of fish be handled to obtain desired levels of precision in survival estimates (Skalski 1999b). Consequently, researchers have been motivated to examine the feasibility of using radio-telemetry to generate survival estimates (Normandeau Associates, Inc. et al. 1998, Skalski 1999a, Counihan et al. 2001).

Radio-telemetry has been used extensively to evaluate the survival of fish and wildlife populations (White 1983, Bell and Kynard 1985, Giorgi et al. 1985, Pollock et al. 1996, Normandeau Associates, Inc. et al. 1998) and to monitor the behavior of yearling and subyearling chinook salmon *Oncorhynchus tshawytscha* and juvenile steelhead *O. mykiss* through hydroelectric projects in the Columbia River Basin (Sheer et al. 1997, Hansel et al. 1998, Holmberg et al. 1998, Hensleigh et al. 1999, Vendetti et al. 2000). During 1999, the U. S. Army Corps of Engineers, Portland District requested that the USGS examine the feasibility of extracting juvenile salmonid survival information from radio-tagged fish. The results of this evaluation suggested that radio-telemetry could be used to evaluate survival of juvenile salmonids in the lower Columbia River, but that logistic adjustments were necessary to ensure that assumptions of the survival estimation procedure were necessary (Counihan et al. 2001).

During 2001, we evaluated the survival of radio-tagged yearling and sub-yearling chinook salmon at The Dalles Dams. As was true for the survival evaluations at John Day and Bonneville dams, the objectives during 2001 at The Dalles Dam represent a subset of the originally planned objectives that were scaled back due to the low water year during 2001. Our objectives during 2001 were to 1) evaluate the survival of yearling chinook salmon through the ice and trash sluiceway 2) evaluate the survival of sub-yearling chinook salmon through the ice and trash sluiceway 3) evaluate potential differences between day and night survival through the ice and trash sluiceway 4) evaluate the potential for relations between the survival of yearling and sub-yearling chinook and dam operations present during releases of radio-tagged fish at this project.

Methods

Radio-telemetry detection arrays

Radio-telemetry detection arrays were set up at Bonneville Dam and in Bonneville Reservoir near Lyle, WA at river kilometer 286 and near Hood River, OR between river kilometers 260 and 268. Release and detection schemes used during 2001 are depicted in Figure 1. The arrays at each of the dams spanned the breadth of the river channel and were set up so that passage through various routes of passage could be determined (Beeman et al. 2001a, Beeman et al. 2001b, Evans et al. 2001). The detection array near Lyle, WA consists of one location on the Washington shore and another on the Oregon shore. The array near Hood River, OR consists of one location each on the Oregon and Washington shores.

Release locations

Treatment groups were released into the top of the ice and trash sluiceway through a 10 cm flexible hose above the intake for main turbine unit 1-1. Control groups were released into The Dalles Dam tailrace mid-channel directly below The Dalles Bridge.

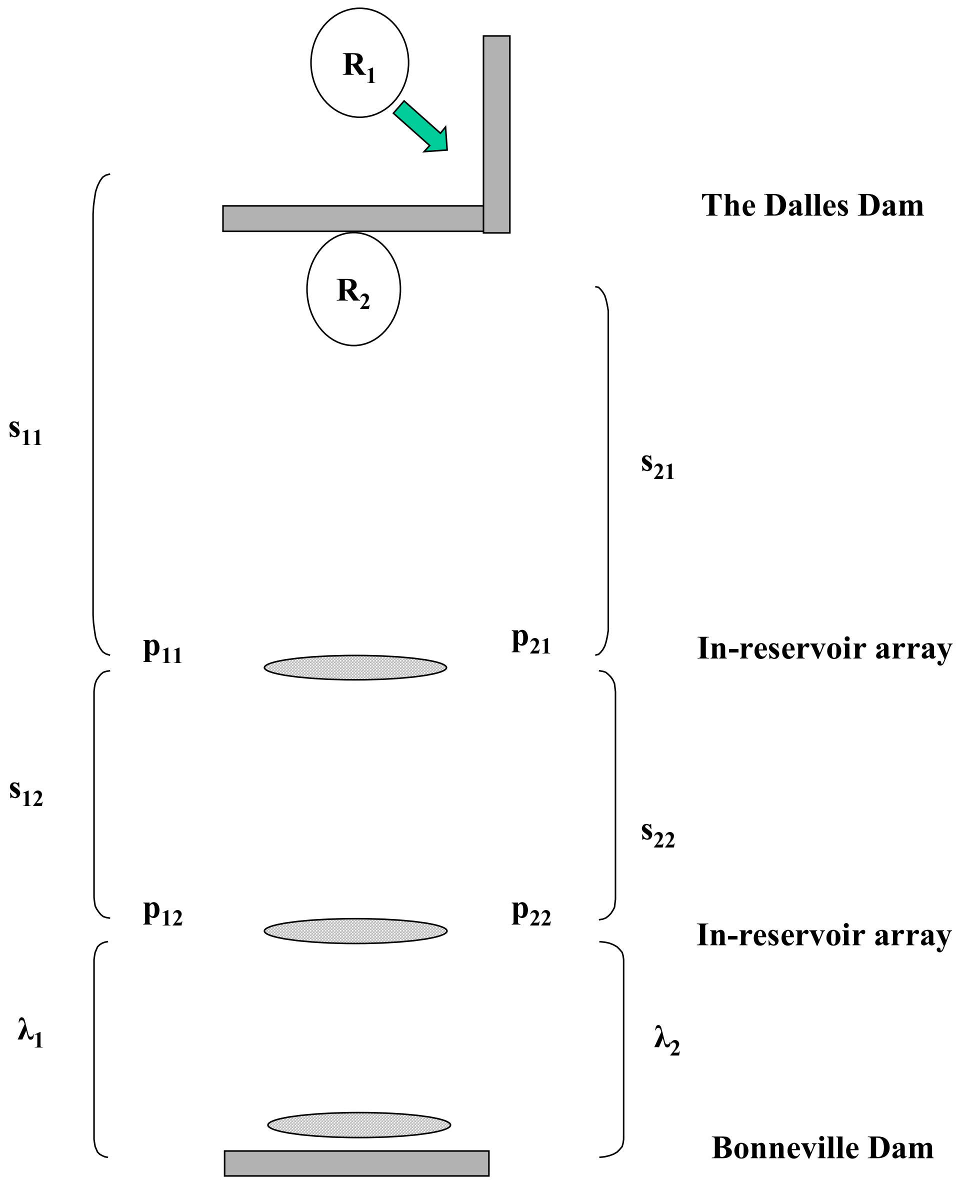

Figure 1. Schematic of estimable capture and survival probabilities (S = survival estimate, p = capture probability, and $\lambda = S \cdot p$) for releases made through the Ice and trash sluiceway at The Dalles Dam and in the tailrace. Dams are represented by rectangles and ovals represent detection arrays.

Collection, Transport and Tagging

Fish collection, transportation, tagging, holding, and release protocols are described in Allen et al (2001). The releases at The Dalles Dam consisted of 16 releases into the ice and trash sluiceway. Corresponding releases were made in The Dalles Dam tailrace to form the paired releases evaluated (Table 1). A total of 384 yearling chinook salmon were released into the Dalles Dam ice and trash sluiceway. The Dalles Dam tailrace releases consisted of 292 yearling chinook salmon (Table 2 and Table 3).

Releases of radio-tagged sub-yearling chinook salmon were also made into the ice and trash sluiceway at The Dalles Dam in 2001. Fourteen paired releases consisting of tailrace released fish combined with releases into the ice and trash sluiceway were made at The Dalles Dam (Table 4). A total of 395 sub-yearling chinook were released into the ice and trash sluiceway and 331 sub-yearling chinook were released into The Dalles Dam tailrace (Table 5 and Table 6).

Statistical methods

We used the single-release model at John Day Dam (Skalski et al. 1998) and the paired-release recapture models of Burnham et al. (1987) to estimate the survival of juvenile yearling chinook salmon and steelhead trout through the lower Columbia River. There are assumptions associated with using the single release and paired release-recapture (PR) model to estimate survival, some are biological and some pertain to the statistical models (Burnham et al. 1987, Skalski 1998, Skalski 1999a). The validity of some of the assumptions listed below can be evaluated using statistical tests and others can be met through careful consideration of fish collection, holding, tagging, and detection techniques. The assumptions are the following:

A1. Individuals marked for the study are a representative sample from the population of interest.

A2. Survival and capture probabilities are not affected by tagging or sampling (i.e., tagged animals have the same probabilities as untagged animals).

A3. All sampling events are “instantaneous” (i.e., sampling occurs over a short time relative to the length of the intervals between sampling events).

A4. The fate of each tagged individual is independent of the fate of all others.

A5. All individuals alive at a sampling location have the same probability of surviving until the end of that event.

A6. All tagged individuals alive at a sampling location have the same probability of being detected on that event.

A7. All tags are correctly identified and the status of fish (i.e., alive or dead) is correctly identified.

Table 1. Release dates and times for paired releases of yearling chinook salmon at The Dalles Dam, spring 2001.

Paired Release	Sluiceway		Tailrace	
	Begin Time	End Time	Begin Time	End Time
1	5/08/01 11:11	5/08/01 15:55	5/08/01 11:54	5/08/01 11:54
2	5/10/01 23:28	5/11/01 02:49	5/11/01 00:23	5/11/01 00:26
3	5/12/01 11:22	5/12/01 14:47	5/12/01 12:00	5/12/01 12:02
4	5/14/01 23:36	5/15/01 02:04	5/15/01 00:21	5/15/01 00:24
5	5/16/01 11:09	5/16/01 15:16	5/16/01 11:47	5/16/01 11:49
6	5/18/01 22:56	5/19/01 02:06	5/18/01 23:36	5/18/01 23:38
7	5/20/01 11:07	5/20/01 16:29	5/20/01 15:43	5/20/01 15:45
8	5/22/01 13:15	5/22/01 18:01	5/22/01 16:59	5/22/01 17:02
9	5/24/01 23:08	5/25/01 01:58	5/25/01 04:23	5/25/01 04:25
10	5/26/01 23:21	5/27/01 03:05	5/27/01 04:25	5/27/01 04:27
11	5/28/01 10:40	5/28/01 14:58	5/28/01 14:53	5/28/01 14:55
12	5/28/01 23:00	5/28/01 23:01	5/29/01 01:36	5/29/01 01:38
13	5/30/01 10:57	5/30/01 10:58	5/30/01 13:35	5/30/01 13:36
14	5/30/01 22:58	5/31/01 01:24	5/31/01 02:26	5/31/01 02:28
15	6/01/01 13:51	6/01/01 13:52	6/01/01 14:42	6/01/01 14:44
16	6/03/01 22:22	6/04/01 02:19	6/03/01 23:13	6/03/01 23:17

Table 2. The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of yearling chinook salmon released at The Dalles Dam, spring 2001.

Paired Release	Sluiceway				Tailrace			
	N	Mean	SD	Range	N	Mean	SD	Range
1	25	165.0	15.7	138-204	19	166.2	10.8	149-190
2	21	159.5	10.0	143-181	18	168.1	15.0	140-202
3	22	162.9	14.8	143-196	19	162.1	8.4	150-180
4	21	165.4	9.5	152-183	19	166.0	16.2	145-204
5	24	166.3	15.7	146-196	19	170.1	14.7	144-195
6	25	167.7	12.1	149-194	19	165.8	11.2	150-195
7	25	160.8	14.4	140-193	19	162.0	10.1	147-187
8	26	171.5	19.4	136-208	18	164.5	19.0	140-198
9	24	178.6	16.2	144-207	18	172.8	18.6	146-229
10	27	173.1	21.0	135-207	18	173.7	15.3	150-203
11	27	163.2	14.3	143-207	18	161.6	12.1	146-195
12	18	163.7	16.8	137-190	19	164.4	14.2	138-189
13	19	175.9	22.2	141-214	19	177.2	22.1	140-210
14	25	172.7	18.4	140-205	19	177.5	30.7	110-217
15	27	171.3	15.5	145-195	19	172.5	16.7	139-200
16	33	167.1	17.7	139-203	21	171.7	19.3	137-212
Overall	389	167.9	16.8	135-214	301	168.5	17.1	110-229

Table 3. The sample size (N), mean, standard deviation (SD), and range of weights (g) of yearling chinook salmon released at The Dalles Dam, spring 2001.

Paired release	Sluiceway				Tailrace			
	N	Mean	SD	Range	N	Mean	SD	Range
1	2	56.2	13.2	47-66	19	45.8	10.5	34 - 70
2	21	40.4	8.4	29-58	18	47.8	14.2	25 - 84
3	22	42.0	11.8	29-72	19	41.0	5.8	33 - 53
4	21	42.1	7.0	32-58	19	44.0	14.6	30 - 85
5	24	44.3	13.7	28-73	19	48.1	14.5	30 - 81
6	25	45.8	10.7	31-73	19	43.7	8.8	33 - 64
7	25	40.5	11.6	27-67	19	39.7	7.9	31 - 63
8	26	50.1	17.8	24-90	18	42.2	15.9	25 - 73
9	24	54.2	15.1	26-81	18	49.6	18.5	29-112
10	27	50.3	17.4	24-84	18	49.7	13.6	30 - 79
11	27	40.4	13.4	25-90	18	38.1	9.6	25 - 66
12	18	40.5	12.1	23-60	19	40.1	11.3	23 - 61
13	19	53.5	21.6	27-97	19	54.9	22.9	28 - 97
14	25	49.5	17.4	26-86	19	62.2	26.1	24 - 99
15	27	45.7	12.3	27-68	19	48.4	16.0	24 - 81
16	33	42.7	15.2	25-80	21	47.5	19.6	23-109
Overall	366	45.5	14.7	23-97	301	46.4	16.1	23-112

Table 4. Release dates and times for paired releases of sub-yearling chinook salmon at The Dalles Dam, summer 2001.

Paired Release	Sluiceway		Tailrace	
	Begin Time	End Time	Begin Time	End Time
1	6/19/01 10:35	6/19/01 10:37	6/19/01 11:15	6/19/01 11:18
2	6/22/01 00:52	6/22/01 00:55	6/22/01 01:51	6/22/01 01:54
3	6/23/01 10:47	6/23/01 10:49	6/23/01 11:34	6/23/01 11:37
4	6/25/01 22:56	6/25/01 22:58	6/25/01 23:53	6/25/01 23:56
5	6/27/01 10:37	6/27/01 10:39	6/27/01 11:23	6/27/01 11:26
6	6/29/01 22:37	6/29/01 22:40	6/29/01 23:52	6/29/01 23:54
7	7/01/01 11:06	7/01/01 11:08	7/01/01 11:56	7/01/01 11:58
8	7/03/01 23:13	7/03/01 23:17	7/04/01 00:35	7/04/01 00:38
9	7/05/01 11:53	7/05/01 11:54	7/05/01 12:59	7/05/01 13:13
10	7/07/01 23:56	7/07/01 23:59	7/08/01 00:52	7/08/01 00:56
11	7/09/01 11:44	7/09/01 11:46	7/09/01 12:24	7/09/01 12:27
12	7/09/01 23:14	7/09/01 23:17	7/10/01 00:15	7/10/01 00:18
13	7/11/01 11:11	7/11/01 11:13	7/11/01 11:56	7/11/01 11:58
14	7/11/01 23:32	7/11/01 23:34	7/12/01 00:38	7/12/01 00:41

Table 5. The sample size (N), mean, standard deviation (SD), and range of fork lengths (mm) of sub-yearling chinook salmon released at The Dalles Dam, summer 2001.

Paired Release	Sluiceway				Tailrace			
	N	Mean	SD	Range	N	Mean	SD	Range
1	30	116.8	4.0	110-125	22	120.8	9.1	110-140
2	28	123.0	5.4	115-133	24	121.8	7.7	113-146
3	29	120.8	7.8	111-147	24	123.2	8.9	112-144
4	25	127.4	12.7	115-159	24	128.9	10.9	115-162
5	26	123.4	6.7	113-142	23	122.3	6.3	114-133
6	29	124.9	8.9	110-149	22	122.0	7.7	113-139
7	29	120.9	7.2	111-138	24	121.1	7.5	111-141
8	30	121.5	8.1	113-140	22	117.7	5.3	113-133
9	23	120.9	8.3	110-145	23	120.0	8.1	110-145
10	28	124.3	8.8	113-146	23	123.0	6.7	115-140
11	30	121.0	5.7	113-137	23	121.3	8.0	113-144
12	27	122.5	9.9	112-153	27	122.1	7.2	112-140
13	29	119.4	5.7	112-130	25	119.2	5.6	110-135
14	32	119.7	5.7	112-137	25	119.0	6.3	111-138
Overall	395	121.8	8.0	110-159	331	121.6	7.9	110-162

Table 6. The sample size (N), mean, standard deviation (SD), and range of weights (g) of sub-yearling chinook salmon released at The Dalles Dam, summer 2001.

Paired Release	Sluiceway				Tailrace			
	N	Mean	SD	Range	N	Mean	SD	Range
1	30	17.1	1.9	14-22	22	19.5	5.1	15-35
2	28	19.2	2.7	15-26	24	18.9	4.5	15-34
3	29	19.4	4.6	14-36	24	20.7	4.7	15-33
4	25	23.8	8.5	16-47	24	24.2	7.5	16-48
5	26	19.7	3.5	16-32	23	19.1	3.1	15-26
6	29	22.3	5.8	15-39	22	20.2	4.3	15-31
7	29	19.4	3.8	15-29	24	19.6	4.1	14-32
8	30	18.8	4.7	14-31	22	16.6	2.9	14-25
9	23	18.8	4.7	14-32	23	18.9	4.6	14-33
10	28	21.1	5.4	15-35	23	20.3	3.5	15-29
11	30	18.9	3.2	15-29	23	19.2	4.6	14-32
12	27	19.9	6.0	14-40	27	19.8	4.3	14-31
13	29	18.0	3.0	14-25	25	18.7	2.9	14-28
14	32	18.4	3.4	14-29	25	18.3	3.4	14-28
Overall	395	19.6	4.8	14-47	331	19.6	4.6	14-48

We conducted statistical tests to evaluate assumptions A5 and A6 using tests developed by Burnham et al. (1987). Burnham et al. (1987) presents a series of tests of assumptions named Test 2 that examine whether upstream or downstream detections affect downstream survival and/or detection. To examine whether upstream capture histories affect downstream survival and/or capture, Burnham et al. (1987) present a series of tests called test 3.

Relative survival was estimated from paired releases by the expression:

$$\hat{S} = \frac{\hat{S}_{11}}{\hat{S}_{21}} \tag{1}$$

with a variance estimate based on the Delta method (Seber 1982) of:

$$\begin{aligned} V\hat{a}r\left(\hat{S}_W\right) &\doteq \left(\frac{\hat{S}_{11}}{\hat{S}_{21}}\right)^2 \left[\frac{Var\left(\hat{S}_{11}\right)}{\hat{S}_{11}^2} + \frac{Var\left(\hat{S}_{21}\right)}{\hat{S}_{21}^2}\right] \\ &\doteq \hat{S}_W^2 \left[\hat{C}V\left(\hat{S}_{11}\right)^2 + \hat{C}V\left(\hat{S}_{21}\right)^2\right] \end{aligned} \tag{2}$$

where $\hat{S}_{11} =$ survival estimates for fish released above the project of interest or in the case, and $\hat{S}_{22} =$ fish released below the project.

and where

$$\hat{C}V\left(\hat{\theta}\right) = \frac{\sqrt{Var\left(\hat{\theta}\right)}}{\theta}$$

In order to estimate S, the survival S_{11} is assumed to be of the form:

$$S_{11} = S \cong S_{21}$$

leading to the relationship

$$\frac{S_{11}}{S_{21}} = \frac{S \cdot S_{21}}{S_{21}} = S. \tag{3}$$

The equality (3) suggests two additional assumptions for valid survival estimation using the paired release-recapture protocol.

A8. Survival in the upriver segment (S) is conditionally independent of survival in the lower river segment.

A9. Releases (R_1) and (R_2) have the same survival probability in the lower river segment (S_{21}).

The assumption of downstream mixing was tested at each downstream array. An R x C contingency table test of homogenous recoveries over time was performed using a table of the form:

		Release	
		R_1	R_2
Day of detections	1		
	2		
	3		
	⋮		
	D		

For each paired-release (R_1 and R_2) and evaluation at each project, a chi-square test of homogeneity was performed at each downstream array. Tests were performed at ∀ = 0.10. Because there were multiple releases and tests across paired releases, the Type I error rates were adjusted for an overall experimental-wise error rate of $\forall_{EW}$ = 0.10 pertaining specifically to each evaluation conducted at John Day, The Dalles, and Bonneville Dams.

Inferences regarding mixing will be largely based on the sequential use of likelihood ratio tests. In any given survival estimation scenario, a number of potential models will be generated and subsequently evaluated (Burnham et al. 1987, Leberton et al. 1992). Forward-sequential and reverse-sequential procedures will be used to find the most parsimonious statistical model that adequately describes the downstream survival and capture processes of the paired-release. The most efficient estimate of survival will be based on the statistical model for the paired releases that properly share all common parameters between release groups.

A weighted average of the survival estimates from the replicated releases can be calculated according to the formula:

$$\hat{\bar{S}} = \frac{\sum_{i=1}^{k} W_i \hat{S}_i}{\sum_{i=1}^{k} W_i} \qquad (4)$$

where k = number of replicate releases:

and where $\hat{S}_i$ = survival estimates from the ith release (i = 1, ..., k);

The weight W_i is calculated using the formula:

$$W_i = \frac{1}{\left(\frac{V\hat{a}r\left(\hat{S}_i\right)}{\hat{S}_i^2}\right)} = \frac{1}{CV\left(\hat{S}_i\right)^2} \qquad (5)$$

with variance

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

If the average is estimating a mean over some static process then weighting would be inversely proportional to the variance. However, in the release-recapture models,

$$Var\left(\hat{S}\right) \propto S^2$$

Therefore, the variance is correlated with the point estimates of survival. The weight (5) eliminates this correlation yet weights in proportion to the sampling precision (i.e., *CV*). Unfortunately, while the weighted average has been applied by others examining the survival of PIT-tagged salmonids in the Columbia River Basin, the use of this methodology for estimating mean survival using radio-tagged fish has resulted in certain estimates (e.g., those that have survival and capture probabilities near 1) having highly disproportionate weights that invariably results in estimates of relative survival that are very near 1 despite the fact that very few of the relative survival estimates reflect this value. While weighted averages are designed to weight the average by certain observations with given qualities or other derived variables or quantities and thus cannot be expected to represent the value that would exist given an un-weighted estimator, the use of a weighted estimator that always skews the evaluation to indicate that the survival of fish passing a given project is 1, when as researchers we know this to not be the case, is unacceptable. The high capture probabilities possible with current radio-telemetry systems and the nature of the way the SURPH software calculates the variance of the survival estimates of the individual releases (e.g., analogous to the binomial variance formula) has resulted in this difficulty. Coordination between the USGS and the University of Washington, and subsequent efforts by University of Washington personnel have failed to resolve this computational difficulty. Consequently, we will evaluate the use of the weighted average, but will use the arithmetic mean to represent the survival of yearling and sub-yearling chinook salmon if it appears that the use of the weighted estimator results in estimates that are disproportionately influenced by the aforementioned computational difficulty.

We evaluated t-tests to compare the relative survival of yearling and sub-yearling chinook salmon released through The Dalles Dam ice and trash sluiceway during the day and night. The specific hypotheses tested were as follows:

<u>Yearling chinook</u>

$$H_0 : S_{IandTSluice\,DAY} \leq S_{IandTSluice\,NIGHT}$$

$$H_A : S_{IandTSluice\,DAY} > S_{IandTSluice\,NIGHT}$$

<u>Sub-yearling chinook</u>

$$H_0 : S_{IandTSluice\,DAY} \geq S_{IandTSluice\,NIGHT}$$

$$H_A : S_{IandTSluice\,DAY} < S_{IandTSluice\,NIGHT}$$

Bartlett's, Brown-Forsythe, and Levene's tests for equal variance were evaluated for each comparison and where suggested by the results of these tests, variance weighted t-tests were evaluated. To examine the relation of the relative survival of our individual paired release groups at John Day Dam to various environmental and dam operation conditions present at these projects during 2001, we evaluated linear regressions. All linear regressions were examined for outliers using regression diagnostics (e.g., studentized deleted residuals, Cook's distance, DFFITS, as per Neter et al. 1989). Outlying observations were eliminated where appropriate and the fit and significance of the resulting models were examined.

Results

Burnham Tests

The results of the Burnham Test 2 for the yearling chinook paired releases into the ice and trash sluiceway at The Dalles Dam (treatment group) and the tailrace (control group), no significant differences ($P \geq 0.10$) were detected in 24 of the 32 possible tests (Table 7). The remaining eight tests were inaccessible due to the presence of all zeroes in either rows or columns in the chi-square contingency tables (Table 7). Testing assumption A6 was inconclusive. For Test 3, 5 of the 32 tests were not significant ($P \geq 0.10$). The remaining 27 tests were inaccessible due to the presence of all zeroes in either rows or columns in the chi-square contingency tables (Table 7).

For the sub-yearling chinook salmon released into the ice and trash sluiceway at The Dalles Dam and their corresponding tailrace releases, the results obtained for the Burnham Tests 2 and 3 indicated that assumptions A5 and A6 were not violated. For Test 2, no significant differences were observed with 25 of the 28 possible tests (Table 8). However, two tests showed significant differences. The one remaining test was inaccessible due to the presence of all zeroes in either rows or columns in the chi-square contingency tables. For Test 3, no significant results were detected in 19 of the 28 tests, and the remaining eight tests were inaccessible due to the presence of all zeroes in either rows or columns in the chi-square contingency tables (Table 8).

Tests of the assumption of mixing of the treatment and control groups

The chi-square tests of homogeneity testing for the similarity in arrival times of paired releases of yearling chinook salmon at the radio-telemetry array at river kilometer 286 in Bonneville Reservoir indicated that treatment and control groups had similar arrival times. Of the 16 tests conducted, 12 paired release groups arrived at the array on the same day indicating that the treatment and control groups were mixed (Table 9). The remaining 4 tests indicated that there were no significant differences detected ($P < 0.10$) in arrival times. For paired releases known to have passed the array at river kilometer 264, 10 paired treatment and control groups arrived at this array on the same day, no significant differences in arrival times were found between 5 other paired release groups, but a marginal significant difference was detected for one paired release group (Table 9; $P = 0.10$). At the array at Bonneville Dam, 12 of the 16 paired release groups showed no significant differences in arrival times, three paired release groups arrived on the same day, and one significant difference ($P < 0.01$) was detected.

Results of the chi-square tests of homogeneity testing for the similarity in arrival times of paired treatment and control groups of sub-yearling chinook salmon suggested that there were no significant differences in the arrival times at the array at river kilometer 286 (Table 10). However, at river kilometer 264, 3 of the 14 tests indicated significant differences in arrival times, but the remaining 11 test evaluated indicated no significant differences. At the array at Bonneville Dam, no significant differences were detected in any of the 14 tests, indicating that the treatment and control groups of sub-yearling chinook were mixed as by the time they approached Bonneville Dam.

Sequential evaluation of log-likelihood tests

A sequential evaluation of log-likelihood tests testing for significant difference in the survival model parameters was also performed to further evaluate the assumption of mixing and evaluate assumption A9 (e.g., Releases R1 and R2 have the same survival probability in the lower river segment S 21 , see Table 11). For the evaluation of the survival of yearling chinook salmon released into the Ice and Trash Sluiceway at The Dalles Dam, three of the 16 models chosen were designated as CJS because of computational difficulties experienced in the SURPH software program. Of the remaining models the majority suggested no difference in the survival and capture probabilities for the treatment and control groups (Table 11). For sub-yearling chinook salmon, the results of the sequential evaluation of the log-likelihood tests were mixed. Differences in the capture and survival probabilities in various reaches or joint capture/survival probabilities in the last reach were different for the treatment and control groups (Table 12). No specific trends in the differences were indicated.

Releases of dead radio-tagged fish

Dead radio-tagged yearling and sub-yearling chinook salmon (30 of each species) were released at the tailrace release location below The Dalles Dam to explore the possibility of obtaining false-positive detections (e.g., detections of dead fish thatwould suggest they were alive) at arrays downstream of this project. No dead radio-tagged yearling or subyearling chinook salmon were detected at any of the radio-telemetry detection arrays below The Dalles Dam.

Survival Probability Assessment

Yearling chinook salmon

We estimated that the survival of yearling chinook salmon released through The Dalles Dam Ice and trash Sluiceway ranged from 0.89 to 1.25 (Table 13). The average survival of yearling chinook salmon released through The Dalles Dam ice and trash sluiceway during the spring 2001 release period was 0.993 (± 0.048, 95% confidence interval). For releases of yearling chinook salmon made during the day, the average survival was estimated to be 1.010 (± 0.059, 95% confidence interval) and for the night releases was 0.977 (± 0.078, 95% confidence interval). No significant difference was detected between day and night survival for yearling chinook salmon (P = 0.74, one-tailed t-test). No significant relation was detected between the survival of yearling chinook salmon released through the ice and trash sluiceway and total and spill discharge and percent spill through The Dalles Dam (linear regression, $P > 0.10$).

Table 7. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 16 paired releases of yearling chinook salmon, spring 2001. The treatment fish were released into the ice and trash sluiceway at The Dalles Dam and the control fish were released into The Dalles Dam tailrace.

Release	Population	Test 2 df	Test 2 χ^2	Test 2 P	Test 3 df	Test 3 χ^2	Test 3 P
1	treatment	1	0.197	0.657		[a]	[a]
	control	1	0.364	0.546		[a]	[a]
2	treatment	1	0.556	0.456	1	0.212	0.645
	control		[a]	[a]		[a]	[a]
3	treatment	1	1.318	0.251	1	1.276	0.259
	control	1	0.443	0.506	1	0.502	0.479
4	treatment	1	0.008	0.930		[a]	[a]
	control	1	0.997	0.318		[a]	[a]
5	treatment	1	0.230	0.631		[a]	[a]
	control	1	0.435	0.509		[a]	[a]
6	treatment	1	0.039	0.844		[a]	[a]
	control	1	0.230	0.631	1	0.263	0.608
7	treatment	1	0.016	0.900	1	1.469	0.225
	control		[a]	[a]		[a]	[a]
8	treatment	1	1.342	0.247		[a]	[a]
	control	1	1.371	0.242		[a]	[a]
9	treatment	1	0.193	0.660		[a]	[a]
	control	1	0.120	0.729		[a]	[a]
10	treatment		[a]	[a]		[a]	[a]
	control		[a]	[a]		[a]	[a]
11	treatment	1	0.381	0.537		[a]	[a]
	control	1	0.219	0.640		[a]	[a]
12	treatment	1	0.327	0.568		[a]	[a]
	control		[a]	[a]		[a]	[a]
13	treatment	1	0.000	1.000		[a]	[a]
	control	1	0.166	0.684		[a]	[a]
14	treatment		[a]	[a]		[a]	[a]
	control	1	0.685	0.408		[a]	[a]
15	treatment		[a]	[a]		[a]	[a]
	control	1	0.013	0.908		[a]	[a]
16	treatment	1	0.012	0.913		[a]	[a]
	control		[a]	[a]		[a]	[a]

[a] - Chi-square statistic was not accessible for these tests due to the presence of only zeroes in rows or columns in the contingency

Table 8. Summary statistics for goodness-of-fit tests (tests 2 and 3, Burnham et al. 1987) for each of 14 paired releases of sub-yearling chinook salmon, summer 2001. The treatment fish were released into the ice and trash sluiceway at The Dalles Dam and the control fish were released into The Dalles Dam tailrace.

		Test 2			Test 3		
Release	Population	df	χ^2	P	df	χ^2	P
1	treatment	1	7.091	0.008	1	0.603	0.438
	control	1	2.757	0.097		[a]	[a]
2	treatment	1	1.149	0.284	1	0.500	0.480
	control	1	1.516	0.218		[a]	[a]
3	treatment	1	0.084	0.772	1	0.044	0.834
	control	1	1.248	0.264	1	2.269	0.132
4	treatment	1	0.438	0.508	1	0.017	0.896
	control		[a]	[a]	1	0.041	0.839
5	treatment	1	2.624	0.105	1	0.522	0.470
	control	1	2.484	0.115		[a]	[a]
6	treatment	1	0.078	0.780	1	0.031	0.860
	control	1	0.250	0.617	1	0.011	0.915
7	treatment	1	0.014	0.907	1	0.168	0.682
	control	1	0.005	0.944	1	0.000	1.000
8	treatment	1	0.046	0.831	1	0.141	0.708
	control	1	1.016	0.313		[a]	[a]
9	treatment	1	0.025	0.876		[a]	[a]
	control	1	0.313	0.576	1	1.975	0.160
10	treatment	1	5.120	0.024		[a]	[a]
	control	1	1.312	0.252	1	0.018	0.894
11	treatment	1	2.601	0.107	1	0.175	0.676
	control	1	0.672	0.412	1	2.982	0.084
12	treatment	1	0.200	0.655	1	0.175	0.676
	control	1	2.553	0.110	1	0.304	0.581
13	treatment	1	0.553	0.457		[a]	[a]
	control	1	0.002	0.961		[a]	[a]
14	treatment	1	0.359	0.549	1	0.000	1.000
	control	1	0.360	0.549		[a]	[a]

[a] - Chi-square statistic was not accessible for these tests due to the presence of only zeroes in rows or columns in the contingency tables.

Table 9. The results of chi-square tests of homogeneity testing for the similarity in arrival times of paired treatment and control groups of yearling chinook salmon released from The Dalles Dam sluiceway and detected at the radio-telemetry array at river kilometers 286 and 264 in the Bonneville reservoir, and the Bonneville Dam array, spring 2001.

Paired Release	Array at Rkm 286 in Bonneville Reservoir			Array at Rkm 264 in Bonneville Reservoir			Bonneville Dam Array		
	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	1	1.51	0.219	1	0.78	0.377	2	2.63	0.269
2	1	1.08	0.299	2	2.01	0.367	2	1.14	0.565
3	0	0	[a]	1	2.70	0.100	2	2.36	0.307
4	0	0	[a]	1	0.48	0.488	1	0	0.957
5	0	0	[a]	0	0	0	0	0	[a]
6	0	0	[a]	0	0	0	1	0.83	0.362
7	0	0	[a]	0	0	0	1	0.70	0.403
8	1	0.62	0.433	0	0	0	1	0.68	0.408
9	0	0	[a]	0	0	0	1	1.80	0.179
10	0	0	[a]	1	0.60	0.439	1	2.92	0.088
11	0	0	[a]	0	0	0	1	1.23	0.267
12	0	0	[a]	0	0	0	1	1.16	0.282
13	0	0	[a]	0	0	0	0	0	[a]
14	0	0	[a]	0	0	0	0	0	[a]
15	1	0.77	0.381	0	0	0	1	1.81	0.179
16	0	0	[a]	1	0.04	0.834	1	2.24	0.134

[a] - All fish arrived on the same day at this detection array suggesting that the treatment and control groups were mixed.

Table 10. The results of chi-square tests of homogeneity testing for similarity in arrival times of paired releases of sub-yearling chinook salmon from The Dalles Dam sluiceway and detected at the radio-telemetry arrays at river kilometers 286 and 264, and the Bonneville Dam array, summer 2001.

	Array at Rkm 286 in Bonneville Reservoir			Array at Rkm 264 in Bonneville Reservoir			Bonneville Dam Array		
Paired Release	DF	Chi-square	P	DF	Chi-square	P	DF	Chi-square	P
1	0	0	[a]	0	0	[a]	1	0.04	0.841
2	0	0	[a]	1	0.31	0.580	2	0.02	0.992
3	1	0.87	0.350	1	5.28	0.022	1	1.28	0.258
4	0	0	[a]	1	1.03	0.311	2	2.24	0.326
5	0	0	[a]	1	0.04	0.843	1	1.66	0.198
6	0	0	[a]	1	3.11	0.078	1	0.14	0.713
7	0	0	[a]	0	0	[a]	2	1.12	0.571
8	0	0	[a]	1	0.97	0.324	2	1.58	0.454
9	0	0	[a]	1	0.00	0.971	2	3.90	0.142
10	1	0.10	0.748	2	1.05	0.592	3	2.09	0.555
11	0	0	[a]	1	2.75	0.097	2	3.03	0.220
12	0	0	[a]	1	0.80	0.370	2	1.67	0.435
13	1	1.37	0.242	2	1.49	0.476	3	3.26	0.350
14	0	0	[a]	2	2.27	0.321	3	4.96	0.175

[a] - All fish arrived on the same day at this detection array suggesting that the treatment and control groups were mixed.

Table 11. Frequency of models selected as a result of evaluating log-likelihood ratio tests that test for differences in survival and capture probabilities between control and treatment groups of paired releases of yearling chinook salmon. Model designations indicate the parameters that control and treatment groups have in common. For instance, model designation lambda p2 s2 p1 indicates that all the survival and capture probabilities were found not to be significantly different between the control and release groups. Model designation CJS refers to Cormack-Jolly-Seber model estimates that assume all estimated parameters were different for the treatment and control groups. In all cases, use of the CJS models resulted from computational constraints (e.g., variance estimates inaccessible) associated with the SURPH software program and do not indicate that all parameters were tested and found to be significantly different.

	Yearling Chinook Salmon
Model	Model Frequency
Lambda p2 s2 p1	8
Lambda p2 s2	1
Lambda p2 p1	1
Lambda s2 p1	2
p2 s2	1
CJS	3

Table 12. Frequency of models selected as a result of evaluating log-likelihood ratio tests that test for differences in survival and capture probabilities between control and treatment groups of paired releases of sub-yearling chinook salmon. Model designations indicate the parameters that control and treatment groups have in common. For instance, model designation lambda p2 s2 p1 indicates that all the survival and capture probabilities were found not to be significantly different between the control and release groups. Model designation CJS refers to Cormack-Jolly-Seber model estimates that assume all parameters were different. In all cases, use of the CJS models resulted from computational constraints (e.g., variance estimates inaccessible) associated with the SURPH software program and do not indicate that all parameters were tested and found to be significantly different.

	Sub-Yearling Chinook Salmon
Model	Model Frequency
Lambda p2 S2 p1	6
Lambda p2 S2	2
Lambda s2	1
Lambda s2 p1	2
Lambda p1 p2	1
p2 s2 p1	2

Table 13. Survival probabilities and associated standard errors for yearling chinook salmon passing via the Ice and Trash Sluiceway based on paired releases of yearling chinook released into the Ice and Trash Sluiceway and in the tailrace of The Dalles Dam.

Paired Release	The Dalles Dam Sluiceway Survival		
	Day/Night	Survival	Standard Error
1	Day	0.93	0.10
2	Night	0.96	0.09
3	Day	1.05	0.10
4	Night	0.93	0.14
5	Day	1.05	0.10
6	Night	0.93	0.08
7	Day	1.01	0.07
8	Day	1.05	0.09
9	Night	1.25	0.17
10	Night	0.96	0.09
11	Day	1.15	0.13
12	Night	0.95	0.10
13	Day	0.95	0.10
14	Night	0.92	0.10
15	Day	0.89	0.10
16	Night	0.91	0.09

Table 14. Survival probabilities and associated standard errors for sub-yearling chinook salmon passing via the Ice and Trash Sluiceway based on paired releases of yearling chinook released into the Ice and Trash Sluiceway and in the tailrace of The Dalles Dam.

Paired Release	The Dalles Dam Sluiceway Survival		
	Day/Night	Survival	Standard Error
1	Day	1.01	0.17
2	Night	1.00	0.12
3	Day	0.96	0.10
4	Night	1.01	0.11
5	Day	0.80	0.12
6	Night	0.78	0.12
7	Day	0.82	0.10
8	Night	0.90	0.14
9	Day	1.00	0.09
10	Night	0.98	0.09
11	Day	0.99	0.09
12	Night	1.16	0.12
13	Day	1.09	0.11
14	Night	0.99	0.12

Sub-yearling chinook salmon

For sub-yearling chinook salmon released through The Dalles Dam ice and trash sluiceway, the estimated survival ranged from 0.78 to 1.16 (Table 14). The average survival for the summer release period was estimated to be 0.962 (± 0.056, 95% confidence interval). Average day survival was estimated to be 0.950 (± 0.078, 95% confidence interval) while night survival was estimated to be 0.974 (± 0.085, 95% confidence interval). The difference between day and night survival for sub-yearling chinook was found to be statistically insignificant (P = 0.35, one-tailed t-test). No significant relation was detected between the survival of sub-yearling chinook salmon released through the ice and trash sluiceway and total discharge through The Dalles Dam (linear regression, $P > 0.10$).

Discussion

For the Burnham Test 2, the tests were mostly accessible for releases of yearling and subyearling chinook salmon at The Dalles Dam. However, for the Burnham Test 3, the tests were mostly inaccessible for releases of yearling chinook salmon at The Dalles Dam. That these tests were largely accessible for sub-yearling chinook salmon may be attributed to the lower capture probabilities for these fish. We will continue to evaluate Burnham tests 2 and 3, however, the utility of these tests to discern whether assumptions A5 and A6 have been met is limited by the high capture probabilities now possible with the radio-telemetry detection arrays. Since we have constructed detection arrays that span the entire river channel, the possibility that this assumption could be violated if downstream detections were influenced by upstream passage routes is minimized (Skalski 1999a). Also, the lack of handling following initial release of radio-tagged fish also minimizes the risk that upstream detections affect survival (Skalski 1999a).

Releases of yearling and sub-yearling chinook salmon into The Dalles Dam ice and trash sluiceway and into the tailrace were conducted during 2001 to provide estimates of survival through The Dalles Dam. Our objective was to time releases so that fish released into the ice and trash sluiceway migrate downstream at approximately the same time as the control groups in the tailrace area of The Dalles Dam. For the releases of yearling chinook, this objective was accomplished and consequently the assumption of mixing of the treatment and control groups was satisfied. For yearling chinook salmon, the results of the sequential evaluation of the log-liklihood tests further corroborated the results of the arrival time evaluations.

However, four significant differences (out of 36 tests evaluated) in arrival times of treatment and control groups were detected for sub-yearling chinook salmon released at The Dalles Dam and interrogated at Rkm 286, Rkm 264, and Bonneville Dam. The number of significant differences in arrival times were greater at the array that was furthest downriver than the two arrays upriver of this location. This result suggests that the differences in arrival times between the treatment and control groups of sub-yearling chinook became greater for those paired release groups as they traveled further downriver. For the paired releases of sub-yearling chinook The Dalles Dam that were interrogated in Bonneville Reservoir, most fish arrived at the first telemetry array on the same day, suggesting that fish traveling through the first river reach (the primary reach of interest for estimating survival through The Dalles Dam) were mixed The results of the model selection process for the sub-yearling chinook paired release also indicated differential survival and/or capture probabilities for some releases. The low discharge conditions present during the 2001 release season may have affected our ability to completely satisfy the assumption of mixing. However, as we continue to collect travel time information over wider ranges of discharge conditions, our ability to predict travel times in this river each will increase.

Evaluations of the survival of yearling and sub-yearling chinook salmon were made through the ice and trash sluiceway at The Dalles Dam during 2001. During 2000, nine paired releases of both yearling and sub-yearling chinook salmon were made to evaluate survival through the ice and trash sluiceway and to provide comparisons between survival estimates generated from radio-tagged yearling chinook salmon and releases of PIT-tagged yearling chinook salmon and coho (Counihan et al. 2002b). Despite the differences in discharge conditions during the 2000 and 2001 release period (see: http://www.cqs.washington.edu/dart/river.html), the estimates generated were similar. During 2000, the average yearling chinook survival through the ice and trash sluiceway was 0.991 (± 0.041, 95% confidence interval) and during 2001 was 0.993 (± 0.048, 95% confidence interval). For sub-yearling chinook the estimates generated were less similar (2000: 0.902, ± 0.169, 95% confidence interval; 2001: 0.962 ± 0.056, 95% confidence interval). However, the difference between the estimates were statistically insignificant (one-tailed t-test for unequal variances, P = 0.26). These results suggest that survival of yearling and sub-yearling chinook through the ice and trash sluiceway was relatively consistent among the years regardless of the different discharge conditions.

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