Latent Mortality Associated with Passage through Snake River Dams: Tagging Activities for 2010 and Final Report for the 2007 Juvenile Migration Year

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Report of research by

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for

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97208 3621
Contract No. 32992, Project 2003-041-00
Performance period April 2010 through March 2011

November 2011

EXECUTIVE SUMMARY

During spring 2010, the National Marine Fisheries Service tagged yearling hatchery Chinook salmon *Oncorhynchus tshawytscha* for the 6th year of a 7-year study to evaluate latent mortality associated with passage through Snake River dams. We also monitored adult returns from study fish tagged and released as juveniles in 2007, 2008, and 2009. Returns of age-3-ocean adults in 2010 completed adult returns of fish tagged and released in 2007.

For the 2010 tagging season, we continued with a modified study design first used in 2007. In this modification, numbers of fish arriving at McNary Dam tailrace were estimated rather than actually detected. This method reduced the sample size required from 301,000 to 111,222 tagged fish

The Juvenile Fish Transportation Program at Snake River dams was delayed in spring 2010, similar to delays during 2007-2009; however, collection and transport began somewhat earlier in 2010, on 21 April instead of 1 May. We began tagging on 23 April and finished on 15 May, and we released a total of 122,375 hatchery spring/summer Chinook salmon. Of these fish, 29,007 were transported by truck and released below Ice Harbor Dam (reference group); these fish passed no Snake River dam below Lower Granite. Another 45,524 fish were transported by truck and returned to Lower Granite Dam for release into the tailrace (dam-passage group). These fish passed Little Goose, Lower Monumental, and Ice Harbor Dams. An additional 47,844 fish were released directly into the Lower Granite Dam tailrace with no transport to evaluate potential effects of the trucking (truck-effects group). For each release period, all study groups were released simultaneously.

In 2010, overall estimated juvenile survival to McNary Dam was 94.0% for the reference group, 80.0% for the dam-passage group, and 78.0% for the truck-effects group. Based on these estimated survival rates, we estimated numbers of fish arriving at McNary Dam tailrace at 27,267 from the reference group, 36,353 from the dam-passage group, and 37,240 from the truck-effects group. Estimated detection rates at McNary Dam were 26.1, 27.0, and 27.2% for reference, dam-passage, and truck-effects groups.

Bonneville Dam is the principle adult recovery site for this study. At Bonneville Dam during 2010, we detected 9 age-3-ocean adults released in 2007, 1,008 age-2-ocean adults released in 2008, and 77 jacks released in 2009. Tagged juveniles released in 2010 will return as adults from 2011 (jacks) through 2013 (3-ocean fish).

Returns of age-3-ocean adults in 2010 completed returns from fish marked as

juveniles in 2007. Because the Snake River Juvenile Fish Transportation Program, and subsequently our tagging operation, was delayed until 1 May 2007, only 6 of 10 releases were made in 2007 (48,000 less fish than planned).

Based on the number of juvenile study fish estimated to have survived to McNary Dam tailrace in 2007, SARs were 0.70 (95% CI 0.56-0.83) for the reference group, 0.28 (0.20-0.36) for the dam-passage group, and 0.34 (0.27-0.42) for the truck-effects group. This produced a weighted geomean SAR ratio of 0.42 (0.24-0.73) for dam-passage to reference groups. We examined the SARs ratio between dam-passage and truck-effects groups to determine whether a trucking effect existed. This comparison resulted in a weighted geomean SAR ratio of 0.91 (0.57-1.44), indicating no significant trucking effect.

The primary goal of this report is to provide preliminary information on fish tagged in 2007 and those returning in 2010. When the complete adult data from releases in 2011 are available in 2014, we will produce a synthesis report with analyses from all years of adult return data.

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INTRODUCTION

Populations of Snake River spring/summer Chinook salmon *Oncorhynchus tshawytscha* have declined extensively since completion of the Federal Columbia River Power System (Raymond 1979; Schaller et al. 1999). Declines began in the early 1970s as Lower Granite, Little Goose, Lower Monumental, and John Day Dams were added to the existing hydropower system. Initial decreases in abundance were mainly due to direct mortality suffered by smolts during downstream migration through the completed system (Raymond 1988). Since the early 1980s, direct mortality of smolts passing dams has been reduced considerably (Williams et al. 2001), coincident with structural and operational changes designed to enhance downstream passage survival (Williams and Matthews 1995). Despite these efforts, and substantial improvements in smolt passage survival, salmon populations in the Columbia River basin have not recovered.

Thus, an important question facing regional managers is whether or not migration through the hydropower system, as currently configured, causes latent mortality to anadromous salmonids, that is, mortality not expressed until after these fish have passed through the system (Budy et al. 2002). The concept of latent mortality related to the hydropower system was developed during the multi-agency process known as the Plan for Analyzing and Testing Hypotheses, or PATH (Marmorek et al. 1998). Latent mortality was hypothesized as a possible explanation for the greater loss in productivity postulated for upper Snake River populations of spring/summer yearling Chinook salmon relative to populations downstream from McNary Dam (Schaller et al. 1996, 2007).

Based on estimated spawner and recruit data, Schaller et al. (1999, 2007) and Deriso et al. (2001) concluded that productivity had declined more for upriver stocks, and that these declines were mostly caused by hydropower development. These researchers also believed that the declines had occurred primarily after completion of the three dams most recently constructed on the Snake River. Furthermore, they postulated that the decline differential for upriver populations was greater than could be explained by differences in direct mortality resulting from the three additional Snake River dams. Schaller et al. (1999) argued that there was little evidence that factors unrelated to the hydropower system could account for the differences in productivity and survival between upriver and lower river stocks.

This conclusion has been questioned by other researchers, who suggested that several other factors could be at least partially responsible for differences in productivity between salmon populations from the two areas (Zabel and Williams 2000; Hinrichsen 2001; ISAB 2007). However, the scientific debate surrounding this issue will continue unresolved in the absence of experimental data.

The goal of this study is to determine whether migration as smolts through Snake River dams and reservoirs causes latent mortality for upper Snake River yearling Chinook salmon. Specifically, the study will compare smolt-to-adult return (SAR) ratios among three treatment groups of yearling Chinook salmon passing McNary Dam. First, a reference group consisting of fish transported and released to the tailrace of Ice Harbor Dam; this group will avoid passage of three Snake River Dams. Second, a dam-passage group of fish transported and released to the tailrace of Lower Granite Dam to migrate in the river past Little Goose, Lower Monumental, and Ice Harbor Dam. Third, a truck-effects group of fish released to the tailrace of Lower Granite Dam with no transport. The dam-passage group will be compared with the reference group to evaluate the effects on SARs of passage through the three Snake River dams and reservoirs. The third group (truck effects) will be compared with the dam-passage group to evaluate the effects of trucking.

Here we present information on tagging of juveniles in 2010 and final results from study fish released in 2007. A synthesis of all adult return data will be reported after 2014, when adult return data are complete.

METHODS

Juvenile Collection and Tagging, 2010

In 2010, we collected and tagged Snake River hatchery spring/summer Chinook salmon at Lower Granite Dam from 23 April to 15 May. This tagging period coincided with passage timing at the dam for the largest proportions of hatchery spring Chinook. Timing of the tagging period was based on observations from previous studies, which have shown these fish generally begin passing Lower Granite Dam around 20-25 April and end by mid-May.

Collection and handling techniques, including use of a recirculating anesthetic water system, followed the methods of Marsh et al. (1996, 2001). The one exception in 2010 was our use of a new system of injection for the passive integrated transponder (PIT) tag. Prior to the tagging season, all PIT tags were pre-loaded into disposable single-use hypodermic needles (Biomark HPT12).[1] Each needle had an internal push-rod and a plastic safety cap with a hub keyed to the bevel of the needle. For each fish, a needle was loaded into a gun-style injector (Biomark MK-25 Rapid Implant) and inserted into the fish. The trigger of the injector was then pulled, implanting the tag into the fish. Because each needle had an internal push-rod, a single injector could be used for thousands of fish without needing to be disinfected.

Tagging for each of 10 triple releases was conducted in 2-d blocks over 20 total tagging days. On the first day of each 2-d block, fish for the truck-effects group (released directly to Lower Granite tailrace) were tagged and sent to a holding tank for 24 h. On the second day of each block, we tagged the dam-passage and reference groups. All tagging was concluded by 1600 PDT each day to comply with the limited number of driving hours allowed per day for truck drivers (for safety reasons). This allowed the driver releasing dam-passage fish at Lower Granite Dam to return to his base of operations within the allotted time.

All fish were released at approximately the same time of day. Upon arrival at Ice Harbor Dam (approximately 1900 PST), reference fish were released into the juvenile fish facility bypass pipe. A circuitous route was devised so that the truck carrying dam-passage fish would return to Lower Granite Dam at the same time the truck carrying reference fish was arriving at Ice Harbor Dam. Upon return to Lower Granite Dam,

[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

dam-passage fish were released through a pipe that runs along the top of the juvenile fish facility bypass pipe. Immediately following release of the dam-passage group, the truck-effects group was released through the same pipe.

Evaluation will be based on annual ratios of SARs, that is, $SAR_{dam\ passage}/SAR_{reference}$ or (dam-passage/reference SAR ratio). Note that as a ratio of SARs from groups "released" at McNary Dam, dam passage/reference is a measure of differential survival below McNary Dam. As such, it is analogous to the differential mortality parameter, *D*, which has been used in comparisons of transported to inriver migrant fish below Bonneville Dam.

Sample sizes for each year of this study were designed to provide an 80% probability of detection if the true dam-passage/reference ratio was less than or equal to 0.80 (i.e., $\beta = 0.20$ or survival was at least 20% lower for dam-passage fish). Differences were evaluated using a one-sided hypothesis test with $\alpha = 0.05$ (i.e., we tested the null hypothesis, that there was no difference between treatments, or the true SARs ratio was 1.00). We also assumed a SAR for reference fish of at least 1.5% (see below).

Required sample sizes were derived by determining the required precision around the estimated ratio of dam-passage to reference SARs such that the one-sided confidence interval on the true ratio did not contain the value 1.0, or the confidence interval of the true natural-log-transformed ratio, ln(dam passage/reference), did not contain zero. If the confidence interval did not contain 1.0, then we could reject the null hypothesis, that there is no difference in rates of survival to adulthood between dam-passage and reference fish, and that the true value of the SARs ratio of dam-passage to reference fish is thus less than 1.0. Therefore, for a desired $\alpha = 0.05$ and $\beta = 0.20$, the number of fish needed was

$$\ln\left(\frac{\text{dam passage}}{\text{reference}}\right) - \left(t_\alpha + t_\beta\right) \times SE\left[\ln\frac{\text{dam passage}}{\text{reference}}\right] \approx 0$$

and

$$SE\left[\ln\left(\frac{\text{dam passage}}{\text{reference}}\right)\right] \approx \sqrt{\left(\frac{1}{n_{reference}} + \frac{1}{n_{dam\ passage}}\right)} = \sqrt{\frac{2}{n}}$$

where n is the number of adult returns per treatment, and $n_{reference} = n_{dam\ passage}$ (we set the n-value for reference and dam-passage groups to be equal for simplicity). The previous two statements imply that the required number of adults is:

$$n \approx \frac{2\left(t_{\alpha}+t_{\beta}\right)^{2}}{\left(\ln\left(\frac{\text{dam passage}}{\text{reference}}\right)\right)^{2}}$$

As stated above, we assumed a SAR for reference fish of at least 1.5%, and we wanted sufficient statistical power to observe a real difference between treatments of at least 20% (i.e., dam passage/reference ≤ 0.80). Therefore, where N denotes the number of juveniles needed per treatment, the sample sizes needed were n = 333 and $N_{reference}$ = 22,200. Thus, if $N_{dam\ passage}$ = $N_{reference}$/(dam passage/reference) = 27,750, then N_{total} = 49,950.

These calculations provided the sample sizes needed for each "release group," or number of study fish estimated to be passing McNary Dam. However, these "release groups" were formed of fish from each treatment group that survived to the tailrace of McNary Dam. To determine the total number of fish needed for tagging, we used an assumed probability of survival to McNary Dam for the reference and dam-passage release groups. These assumed probabilities of survival were based on survival estimates from our 2006 study year, and accounted for fish removed for transport at Snake River dams below Lower Granite. For 2010, we estimated the proportions of fish surviving to McNary Dam tailrace were 0.830 for fish released to Ice Harbor Dam tailrace and 0.657 for fish released to Lower Granite Dam tailrace.

Thus, to obtain the necessary number of study-fish detections at McNary Dam required releases of approximately 26,747 reference fish (22,200/0.83) to the tailrace at Ice Harbor Dam and 42,237 dam-passage fish (27,750/0.657) to the tailrace of Lower Granite Dam. An additional 42,237 non-transported fish were released directly into the tailrace at Lower Granite Dam to evaluate potential truck effects. Therefore, the total tagging requirement was 111,222 fish. Because of the low SARs experienced over the past several years, we increased the release number to 120,000 fish. This number was then divided among 10 releases (with 3 treatment groups each) made over time in order to account for differences in smolt levels, varying river operations (at dams), and environmental fluctuations.

Juvenile Collection and Tagging, 2007

Juvenile collection and tagging methods used in 2007 were the same as those described above for tagging and release in 2010. However, we were not permitted to begin tagging for this study until general transport began at Lower Granite Dam. Collection for transport began on 1 May 2007; thus, we were able to begin tagging on 2 May (Marsh et al. 2007). As mentioned above, hatchery spring/summer Chinook

salmon pass Lower Granite Dam in a compressed 3-4 week period, which typically ends in mid-May. In 2007, the migration of juvenile hatchery spring/summer Chinook was typical, with collection numbers falling from 49,200 on 13 May to 8,200 on 17 May. In addition, steelhead numbers, while also falling, ranged from 74,000 to 36,000 during this time period. The dwindling numbers of hatchery Chinook salmon therefore had to be sorted from among large numbers of steelhead, which required excessive handling. To avoid undue handling of steelhead, we ended the 2007 tagging period on 15 May, after only 6 of the 10 planned releases had been completed

Adult Recovery and Analyses of Smolt-to-Adult Return Ratios

Bonneville Dam serves as the principal adult recovery site for this study. Using this site for adult recovery provides maximum SARs for the study, since no adults are lost to upstream dam-passage mortality or to the mainstem fisheries above Bonneville Dam. For the 2010 marking year, we will analyze results in 2013, when adult returns for the 2010 study releases are complete. We will then evaluate SARs ratios for dam-passage vs. reference release groups based on estimates of juvenile fish passing McNary Dam in 2010. Confidence intervals for dam-passage/reference ratios will be calculated using the ratios of these estimates and their associated variances (Burnham et al. 1987).

For returns to date, we have assumed the true distribution of dam-passage to reference ratios was approximately log normal. We therefore calculated confidence intervals on the natural-log scale and then back-transformed the endpoints to the original scale. For the mean using ratios of paired study groups released over time, this process was the same as calculating a geometric mean. Additionally, we used a weighted geometric mean, where the weights were the estimated inverse of the relative variances (coefficient of variation squared) of ratios between paired groups released over time (Smith et al. 2006). Estimates of variance in SARs ratios for these temporal release groups had to be adjusted to account for variation in the estimation process (since the SARs ratios were themselves estimates). This *a posteriori* adjustment method was used to estimate the number of juveniles that survived and were detected in the tailrace of McNary Dam and is detailed in Appendix B.

RESULTS

Juvenile Collection and Tagging, 2010

The sixth year of juvenile tagging for this study was completed in 2010, with tagging goals met for all three treatment groups of fish. With the expectation that large numbers of hatchery spring/summer Chinook salmon would reach Lower Granite Dam between 20 and 25 April, we began tagging on 23 April and ended on 15 May. In 2008 and 2009, hatchery Chinook salmon did not begin arriving at the dam in large numbers until 29 April. In contrast, fish in 2010 began to arrive just as we began tagging, with numbers surging from 4,350 on 21 April to 73,100 on 23 April.

In anticipation of the historical drop in these numbers by mid-May, we took advantage of the large numbers of early arriving fish and tagged above our daily goals for the first two releases. However in 2010, the migration of hatchery juvenile spring/summer Chinook salmon was more protracted than usual, and the drop did not occur. Large numbers of hatchery Chinook salmon continued being collected until late May. We had to reduce tagging effort during the last few releases to stay near our overall tagging goal of 120,000, which we exceeded by 2,764 fish.

From 23 April to 15 May, we tagged 122,764 hatchery yearling spring/summer Chinook salmon, releasing a total of 122,375 (Table 1). Fish were divided into three groups, with 29,007 released below Ice Harbor Dam (reference), 45,524 released into Lower Granite Dam tailrace after being transported by truck for an equal amount of time (dam passage), and 47,844 released as reference fish into Lower Granite Dam tailrace with no transport (truck effects).

Post-tagging mortality was determined using the truck-effects group, which was held for 24-h prior to release. Average post-tagging mortality for the entire period was 0.27%, with daily values ranging from 0.05 to 0.78%. This rate was much lower than observed in past efforts to tag hatchery spring/summer Chinook salmon at Lower Granite Dam. We believe the new tagging system, which allowed the use of a new, sharp needle for every fish, was the reason for our lower tagging mortality.

Mortalities were examined for any obvious injury that would indicate problems with tagging technique (e.g., punctured kidney or other organ damage). During tagging, 2.65% of fish were recorded as descaled at the time of tagging, while 6.45% had a reported body injury. However, unlike past years, we found no link between descaling or body injury and post-tagging mortality. Levels of descaling and injury in 2010 can be compared only to levels in 2009 because that year we re-emphasized the recording of fish condition during tagging, a practice that had fallen off in recent years.

Table 1. Dates of collection, PIT-tagging, and release of hatchery yearling spring/summer Chinook salmon for the latent mortality study at Lower Granite Dam in 2010. Numbers of fish released are also shown.

Spring/summer Chinook salmon, 2010			Number of fish released	Release number per 2-d block
Collected	Tagged	Released		
22 April	23 April	24 April	6,164	
23 April	24 April	24 April	7,308	13,472
25 April	26 April	27 April	2,586	
26 April	27 April	27 April	8,351	10,937
27 April	28 April	29 April	7,725	
28 April	29 April	29 April	7,796	15,521
29 April	30 April	1 May	6,349	
30 April	1 May	1 May	10,124	16,473
2 May	3 May	4 May	5,087	
3 May	4 May	4 May	7,995	13,082
4 May	5 May	6 May	4,951	
5 May	6 May	6 May	8,313	13,263
6 May	7 May	8 May	4,124	
7 May	8 May	8 May	7,235	11,359
9 May	10 May	11 May	3,649	
10 May	11 May	11 May	6,061	9,710
11 May	12 May	13 May	3,641	
12 May	13 May	13 May	5,769	9,410
13 May	14 May	15 May	3,568	
14 May	15 May	15 May	5,580	9,148

Estimated juvenile survival to McNary Dam in 2010 was 94.0% for the reference group, 80.0% for the dam-passage group, and 78.0% for the truck-effects group (Table 2). Based on these survival estimates, we estimated the numbers of tagged fish reaching McNary Dam tailrace at 27,267 reference treatment fish, 36,353 dam-passage fish, and 37,240 truck-effects fish. When adult returns are complete in 2013, these juvenile numbers will be used to determine SARs ratios for comparison among the three groups.

Table 2. Number of PIT-tagged hatchery yearling spring/summer Chinook salmon released by treatment group for evaluation of latent mortality, 2010. Estimated survival from release to McNary Dam and estimated numbers of fish arriving in the tailrace of McNary Dam by treatment are also shown.

Release group	Number released	Survival to McNary Dam (%)	Estimated number at McNary Dam tailrace
Dam passage (Lower Granite trucked)	45,518	94.0	27,267
Truck effects (no transport)	47,837	80.0	36,353
Reference (Ice Harbor trucked)	29,005	78.0	37,240

Juvenile survival rates for the reference and dam-passage groups in 2010 were the highest of the six tagging years, while the survival rate for the 2010 truck-effects group was second highest (behind 2009). As in past years, the similarity in survival rates between the dam-passage and truck-effects groups indicated that transporting fish by truck had little or no effect on juvenile survival through the hydropower system. We await adult returns to determine whether any delayed effects from trucking are evident in SARs.

Juvenile Collection and Tagging, 2007

Details of juvenile collection and tagging in 2007 were reported by Marsh et al. (2007), and numbers of fish released in 2007 from the three treatments combined are shown in Table 3. Total tagging and release numbers by treatment are shown in Appendix Table A1. As mentioned above, we were able to release only 6 of the 10 sets of releases planned in 2007.

Juvenile fish were monitored as they migrated downstream after release (Table 4 and Appendix Table A2), allowing us to estimate the number of fish arriving in the McNary Dam tailrace from each treatment group. The purpose of the non-transported group released at Lower Granite Dam was to provide a reference for potential effects of transport (truck effects). Based on juvenile detections of the 2007 releases, trucking did not appear to affect the juvenile stage, as the truck-effects and dam-passage groups released at Lower Granite in 2007 were estimated to have arrived at McNary Dam in nearly the same proportions (Table 4).

Table 3. Dates of collection, PIT-tagging, and release of hatchery yearling spring/summer Chinook salmon for the latent mortality study at Lower Granite Dam in 2007. Numbers of fish released are also shown.

Spring/summer Chinook salmon, 2007			Number of fish released	Release number per 2-d block
Collected	Tagged	Released		
1 May	2 May	3 May	8,050	
2 May	3 May	3 May	7,578	15,628
3 May	4 May	5 May	5,617	
4 May	5 May	5 May	6,504	12,121
6 May	7 May	8 May	3,600	
7 May	8 May	8 May	4,562	8,162
8 May	9 May	10 May	4,792	
9 May	10 May	10 May	6,942	11,734
10 May	11 May	12 May	4,842	
11 May	12 May	12 May	9,302	14,144
13 May	14 May	15 May	4,583	
14 May	15 May	15 May	5,719	10,302

Table 4. The number of PIT-tagged hatchery yearling spring/summer Chinook salmon released at Lower Granite Dam after trucking (dam passage), released at Lower Granite Dam without trucking (truck effects), and released at Ice Harbor Dam (reference) for evaluation of latent mortality in 2007. Survival estimates to McNary Dam are shown for each treatment group, along with numbers transported from a downstream collector dam total estimated numbers arriving in the tailrace of McNary Dam.

2007 treatment groups	Number released	Estimated survival to McNary Dam (%)	Diverted for transport below Lower Granite	Estimated survival to McNary Dam (n)
Dam passage	23,857	76.4	253	17,981
Truck effects	31,484	76.7	335	23,769
Reference	16,750	89.7	1	15,030

Adult Recovery and Analyses of Smolt-to-Adult Return Ratios

We began recovering jacks in 2008 from study fish released in 2007. In August 2010, we completed recoveries from the 2007 release year with the collection of age-3-ocean adults. Using the modified study design, the estimated number of juveniles that reached the McNary Dam tailrace in 2007 ranged from approximately 15,000 to 23,000 fish (Table 4 and Appendix Table A3). A total of 237 adults returned from all 2007 treatment group releases combined.

Release groups in 2007 were formed from estimated numbers of study fish from each treatment arriving in the tailrace of McNary Dam. Based on these juvenile "release groups," SARs from the 2007 releases were 0.70 for reference fish, 0.28 for dam-passage fish, and 0.34 for truck-effects fish (Table 5). These SARs were based on the 105, 50, and 82 adults (including jacks) returning from each respective treatment. Based on these SARs, the weighted geomean of SARs ratios between dam-passage and reference groups was 0.42 (95% CI, 0.24 0.73), indicating significant mortality caused by migration through the three lower Snake River dams. When we compared SARs ratios between the dam-passage and truck-effects groups, the weighted geomean was 0.91 (95% CI, 0.57 1.44), indicating no significant effect of trucking. Unlike the 2006 study year, which showed a trend of increasing SARs ratios between dam-passage and reference groups, the temporal pattern in 2007 showed a decrease in these SARs ratios over time (Figure 1).

Table 5. Number of juveniles released, number of returning adults, and SARs and weighted geomean SAR ratios for PIT-tagged hatchery yearling spring/summer Chinook salmon estimated to have arrived in McNary Dam tailrace. Treatment groups were released in 2007 at Lower Granite Dam after trucking (dam passage), released at Lower Granite Dam without trucking (truck effects), or released at Ice Harbor Dam (reference) for a study to evaluate latent mortality.

Juvenile numbers	Returns by age-class			SAR (95% CI)	Weighted geomean SAR ratio (95% CI):
	Jack	2-ocean	3-ocean		
Reference (trucked to Ice Harbor)					
15,030	14	85	6	0.70 (0.56-0.83)	
Dam passage (Lower Granite trucked)					
17,981	10	38	2	0.28 (0.20-0.36)	dam passage/reference 0.42 (0.24-0.73)
Truck effects (no transport)					
23,769	20	61	1	0.34 (0.27-0.42)	dam passage/truck effects 0.91 (0.57-1.44)

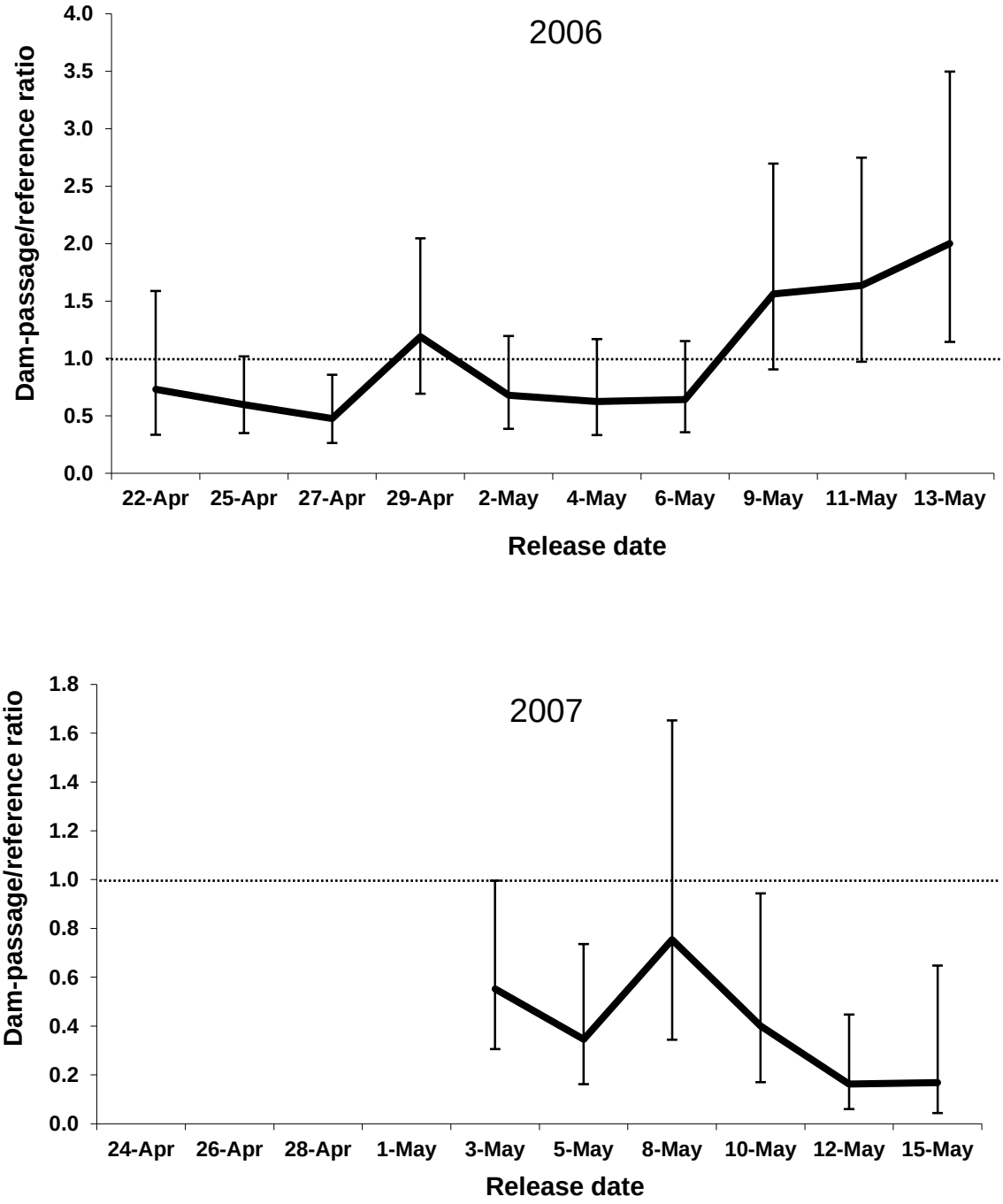

Figure 1. Temporal patterns in the ratio of dam-passage to reference SARs shown against study groups released over the juvenile migration seasons in 2006 and 2007. Upper panel shows increasing trend for 2006 releases; lower panel shows ratio decreasing over time for 2007 releases. Dotted line indicates 1 (dam-passage SAR = reference SAR). Values less than one indicate higher SARs for reference fish; values greater than one indicate higher SARs for dam-passage fish. Note that four releases planned for 2007 were not made due to a delayed start in transport operations.

DISCUSSION

In 2007 we began tagging juvenile fish at Lower Granite Dam on 2 May and finished on 15 May. Tagging operations were delayed because collection for general transport at Lower Granite Dam was delayed until 1 May, the date when we were able to begin collecting fish. This delay and the subsequent arrival of large numbers of steelhead caused us to suspend tagging operations after completing only 6 of 10 planned releases.

Completion of the remaining releases would have required an excessive amount of handling to sort smaller numbers of yearling Chinook from the larger numbers of steelhead. However, we were able to release 72,091 fish within the six releases completed (the goal was 12,000 fish per release). Due to the compressed period of juvenile migration for hatchery spring/summer Chinook salmon, a significant portion of hatchery Chinook salmon had passed by the time we were able to begin tagging operations; thus we were unable to compensate for the missed releases.

For juvenile salmon migrating in 2007, estimated survival from release at Lower Granite Dam to the McNary Dam tailrace was similar to survival estimated for this reach annually in recent years (Faulkner et al. 2009). River flow and spill in May 2007 were below the 10-year average (1997-2006), and were the lowest of the study years through 2009. Ocean conditions were moderately favorable for juvenile salmonids entering the ocean in spring 2007 (Peterson et al. 2010).

Results from 2007 were based on the modified study design, which used estimated numbers of juveniles arriving in the McNary Dam tailrace rather than detections at McNary Dam. Comparison of SARs based on this design have shown a significantly higher adult return rate for reference fish than for dam-passage fish groups. In other words, fish transported and released below Ice Harbor Dam survive at much higher rates than fish released at Lower Granite Dam to pass Little Goose, Lower Monumental, and Ice Harbor Dams before reaching McNary Dam. However, comparisons between the dam-passage and truck-effects groups have not shown that trucking significantly affected SARs.

Juvenile tagging for this project was completed in 2011, and a rigorous, multi-year analysis of SARs will be possible in 2014, when adult returns are complete for all release years. This analysis will separate timing effects from other potential causes of latent mortality and will thus address the issue of variability introduced by an earlier arrival at McNary Dam for Ice Harbor releases than for Lower Granite releases (with the early arriving fish being expected to return at a greater rate; Scheuerell et al. 2010).

ACKNOWLEDGMENTS

We thank the U.S. Army Corps of Engineers (USACE) for their cooperation with this study. In particular, we thank Mike Halter and staff at Lower Granite Dam, and John Bailey for his help in obtaining the use of USACE fish transport tanker trucks. We also thank Scott Davidson of NMFS Pasco Field Station shop for his help in preparing the tankers for our use, for coordinating the trucking contract, and for conducting the release operations at Ice Harbor Dam. This study (and many other studies we have conducted) would not have been possible without personnel of the Pacific States Marine Fisheries Commission, including D. Marvin, who operates and maintains the Columbia Basin PIT-tag Information System. Finally, we thank Gene Matthews who helped develop the original study design.

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APPENDIX A:

Data for Hatchery Spring/Summer Chinook Salmon Tagged and Released in 2007

Appendix Table A1. Totals by treatment of hatchery spring/summer Chinook salmon tagged at Lower Granite Dam in spring 2007. After tagging, truck-effects fish were held 24-h prior to release in the tailrace, dam-passage fish were transported halfway to Ice Harbor Dam and back prior to release in Lower Granite tailrace, and reference fish were transported and released to Ice Harbor Dam tailrace.

2007	Truck-effects group		Dam-passage group (trucked to Lower Granite Dam)		Reference group (trucked to Ice Harbor Dam)	
release dates	Tagged	Released	Tagged	Released	Tagged	Released
3 May	8,102	8,050	4,302	4,298	3,283	3,280
5 May	5,655	5,617	3,980	3,979	2,525	2,525
8 May	3,576	3,600	2,425	2,421	2,141	2,141
10 May	4,843	4,792	4,130	4,130	2,818	2,812
12 May	4,879	4,842	5,735	5,718	3,596	3,584
15 May	4,603	4,583	3,317	3,311	2,409	2,408

Appendix Table A2. Total numbers of hatchery spring/summer Chinook salmon released at Lower Granite Dam and detected at McNary Dam in spring 2007. After tagging, truck-effects fish were held 24-h prior to release in the tailrace, dam-passage fish were transported halfway to Ice Harbor Dam and back prior to release in Lower Granite tailrace, and reference fish were transported and released to Ice Harbor Dam tailrace.

2007	Truck-effects group		Dam-passage group (trucked to Lower Granite Dam)		Reference group (trucked to Ice Harbor Dam)	
Release date	Released	Detected	Released	Detected	Released	Detected
3 May	8,050	2,193	4,298	1,064	3,280	1,083
5 May	5,617	1,471	3,979	1,029	2,525	768
8 May	3,600	878	2,421	595	2,141	702
10 May	4,792	1,364	4,130	1,119	2,812	912
12 May	4,842	1,454	5,718	1,538	3,584	1,060
15 May	4,583	1,362	3,311	924	2,408	789

Appendix Table A3. Estimated numbers of hatchery spring/summer Chinook salmon arriving in McNary Dam tailrace in spring 2007 after release at Lower Granite and Ice Harbor Dam. After tagging, truck-effects fish were held 24-h prior to release in the tailrace, dam-passage fish were transported halfway to Ice Harbor Dam and back prior to release in the Lower Granite tailrace, and reference fish were transported and released to the Ice Harbor tailrace.

2007	Truck-effects group		Dam-passage group (trucked to Lower Granite Dam)		Reference group (trucked to Ice Harbor Dam)	
release dates	Released	Arrived in tailrace	Released	Arrived in tailrace	Released	Arrived in tailrace
3 May	8,050	6,638	4,298	3,626	3,280	2,892
5 May	5,617	4,405	3,979	2,925	2,525	2,360
8 May	3,600	2,615	2,421	1,805	2,141	1,907
10 May	4,792	3,428	4,130	2,972	2,812	2,550
12 May	4,842	3,458	5,718	4,210	3,584	3,261
15 May	4,583	3,238	3,311	2,474	2,408	2,087

APPENDIX B

Estimated Variance of Smolt-to-Adult Return Ratios

In this study, ratios of the proportion of smolts that returned as adults (SARs) were estimated between paired treatment groups. The estimated variance of SARs ratios has been calculated for NMFS transport studies over many years using Equation 2. This method is widely used to estimate variance in ratios, for example, in relative survival estimates. In most studies, release numbers of smolts are known, and thus assumed to be "fixed," with no variation. However, in this study, release numbers were estimated. Therefore, variance of the estimation process must be incorporated into the variance of the proportions (SARs) and ratios, to reflect the added uncertainty resulting from "non-fixed" release numbers. The derivation shown below in Equations 1 and 2 can be applied to any general pair of treatment groups.

From Mood, Graybill, and Boes (1974, p. 181), using the Delta Method for independent x and y,

$$V\left(\frac{x}{y}\right) \approx \left(\frac{\mu_x}{\mu_y}\right)^2 \left(\frac{V(x)}{\mu_x^{\,2}} + \frac{V(y)}{\mu_y^{\,2}}\right) \tag{1}$$

For $R = SAR_1/SAR_2$, assuming the SARs are binomially-distributed, and using estimated values, this becomes:

$$\hat{V}(\hat{R}) \approx \hat{R}^2\left(\frac{1}{n_1} - \frac{1}{N_1} + \frac{1}{n_2} - \frac{1}{N_2}\right) \tag{2}$$

since,

$$\frac{\hat{V}(S\hat{A}R_1)}{S\hat{A}R_1^{\,2}} = \frac{S\hat{A}R_1(1 - S\hat{A}R_1)}{N_1 S\hat{A}R_1^{\,2}} = \frac{1 - S\hat{A}R_1}{N_1 S\hat{A}R_1} = \frac{1}{n_1} - \frac{1}{N_1} \tag{3}$$

and similarly for SAR_2.

If, however, N_1 and N_2 are calculated from R_1S_1 and R_2S_2, where the R is the release number and S is survival from release to some location, then from (1):

$$\hat{V}(\hat{R}) \approx \hat{R}^2\left(\frac{\hat{V}(S\hat{A}R_1)}{S\hat{A}R_1^{\,2}} + \frac{\hat{V}(S\hat{A}R_2)}{S\hat{A}R_2^{\,2}}\right) \tag{4}$$

Now, $$\hat{V}(S\hat{A}R_1) = \hat{V}\left(\frac{n_1}{N_1}\right) = \hat{V}\left(\frac{n_1}{R_1\hat{S}_1}\right) = \left(\frac{1}{R^2}\right)\hat{V}\left(\frac{n_1}{\hat{S}_1}\right)$$

$$= \left(\frac{1}{R^2}\right)\left(\frac{n_1}{\hat{S}_1}\right)^2\left(\frac{\hat{V}(n_1)}{n_1^{\,2}} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}}\right) \tag{5}$$

by (1) and, $$S\hat{A}R_1^{\,2} = \left(\frac{n_1}{N_1}\right)^2 = \left(\frac{1}{R^2}\right)\left(\frac{n_1}{\hat{S}_1}\right)^2 \tag{6}$$

So from (5) and (6), and assuming the SARs are binomially distributed,

$$\frac{\hat{V}(S\hat{A}R_1)}{S\hat{A}R_1^{\,2}} = \frac{\hat{V}(n_1)}{n_1^{\,2}} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}} = \frac{N_1 S\hat{A}R_1\left(1 - S\hat{A}R_1\right)}{n_1^{\,2}} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}}$$

$$= \frac{n_1\left(\frac{N_1 - n_1}{N_1}\right)}{n_1^{\,2}} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}} = \frac{N_1 - n_1}{n_1 N_1} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}} = \frac{1}{n_1} - \frac{1}{N_1} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}} \tag{7}$$

Then from (4) and (7) and substituting the estimators for N_1 and N_2,

$$\hat{V}(\hat{R}) \approx \hat{R}^2\left(\frac{1}{n_1} - \frac{1}{R_1\hat{S}_1} + \frac{1}{n_2} - \frac{1}{R_2\hat{S}_2} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}} + \frac{\hat{V}(\hat{S}_2)}{\hat{S}_2^{\,2}}\right) \tag{8}$$

For this study, R is the ratio of Treatment 1 SAR to Treatment 2 SAR from McNary Dam (MCN) as juveniles to Bonneville Dam as adults, R_1 and R_2 are the release numbers for the two treatments, N_1 and N_2 are the numbers of the two treatments estimated alive in the MCN tailrace, n_1 and n_2 are the adult return numbers, and S is the survival from release to MCN. The hat notation means that the quantities/parameters are estimated using Cormack/Jolly Seber (CJS) methods.

Data that were ratios of binomial proportions were assumed to be log-normally distributed. Therefore, confidence intervals for this study were calculated as ±2 SEs (for $\alpha = 0.05$, the multiplier is approximately 2) around the natural log-transformed ratio. These endpoints were back-transformed to the original scale. The standard error of the ratio on the log-scale is:

$$\hat{V}(\ln(\hat{R})) \approx \hat{R}^2\hat{V}(\hat{R}) \approx \left(\frac{1}{n_1} - \frac{1}{R_1\hat{S}_1} + \frac{1}{n_2} - \frac{1}{R_2\hat{S}_2} + \frac{\hat{V}(\hat{S}_1)}{\hat{S}_1^{\,2}} + \frac{\hat{V}(\hat{S}_2)}{\hat{S}_2^{\,2}}\right) \tag{9}$$