A Study to Evaluate Latent Mortality Associated with Passage through Snake River Dams, 2006

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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. 24575, Project 2003-041-00
for performance period February through September 2006

December 2006

EXECUTIVE SUMMARY

During spring 2006, the National Marine Fisheries Service tagged yearling hatchery Chinook salmon to evaluate latent (extra) mortality associated with the passage of these fish as smolts through Snake River Dams. This was the second year of the study, and we also monitored adult returns (jacks) from fish tagged in 2005 for the same evaluation.

Fish tagging began at Lower Granite Dam on 21 April and finished on 13 May 2006. During this time, we released a total of 190,274 hatchery spring/summer Chinook salmon. Of these fish, 38,599 were transported by truck and released below Ice Harbor Dam and 57,176 were transported by truck and released simultaneously into the Lower Granite Dam tailrace. An additional 94,499 fish were released into the Lower Granite Dam tailrace as a reference group (no transportation).

Our study designed called for respective release sizes of 71,480, 114,800, and 114,800 for the Ice Harbor transport, Lower Granite transport, and reference groups. We were unable to tag these numbers of fish, in part due to unusually large numbers of hatchery steelhead arriving at the dam during the tagging period. These large numbers, combined with the need to limit the length of tagging days, greatly reduced the number of fish that could be processed each tagging day. Tagging days were shortened in order to avoid causing truck drivers to exceed the number of legally allowed driving hours per day.

Estimated survival to McNary Dam was 85.0, 68.2, and 70.3% for the Ice Harbor, Lower Granite, and reference fish groups, respectively. Based on these survival estimates, we estimate that 32,801, 39,012, and 66,436 tagged fish reached the McNary Dam tailrace from the three respective groups. Detection at McNary Dam for these fish was 34.0, 19.7, and 19.9% for the Ice Harbor, Lower Granite, and reference groups, respectively.

Adults from 2006 releases will begin returning in 2007 (jacks), with complete adult returns in 2009. One jack from the 2005 tagging year was detected at the Bonneville Dam ladder but was not detected above Bonneville Dam.

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INTRODUCTION

Snake River spring/summer Chinook salmon *Oncorhynchus tshawytscha* abundance decreased precipitously after completion of the Federal Columbia River Hydropower System (Raymond 1979; Schaller et al. 1999). The initial decline occurred in the early 1970s as Lower Granite, Little Goose, Lower Monumental, and John Day Dams were added to the existing hydropower system. This decline was roughly proportional to direct mortality suffered by smolts during downstream migration through the completed system.

Direct smolt mortality has decreased considerably over the past 2 decades (Williams et al. 2001), coincidental with installation of structural improvements at dams to facilitate juvenile passage, and with initiation of operational procedures (e.g., spill) designed to enhance downstream passage survival (Williams and Matthews 1995). However, despite substantial improvements in direct smolt survival, adult return rates of Snake River spring/summer Chinook salmon have not increased to levels that existed prior to dam construction.

One of the most important and enigmatic questions currently facing regional managers is whether or not migration through the hydropower system, as currently configured, causes mortality to anadromous salmonids that is not expressed until after they have passed through the system. This hydropower-related latent mortality was hypothesized during the multi-agency process known as the Plan for Analyzing and Testing Hypotheses. Latent mortality was offered as a possible explanation for the relative change in productivity calculated for populations of spring/summer Chinook salmon from the Snake River compared to those downstream from McNary Dam after construction of John Day, Lower Granite, Little Goose, and Ice Harbor Dams (Schaller et al. 1996).

Evidence from the spawner and recruit data of Schaller et al. (1999) indicated that productivity declined more for upriver stocks, which were most affected by hydropower development, and that this reduction occurred primarily after completion of the three final dams on the Snake River. Further, the differential decline was greater than could be explained by differences in direct mortality caused by the additional dams. Schaller et al. (1999) argued there was little evidence that factors unrelated to the hydropower system could account for the differences in productivity and survival between upstream and downstream stocks.

On the other hand, Zabel and Williams (2000) and Hinrichsen (2001) have questioned this conclusion and provided evidence that several other factors could be at least partially responsible for observed differences in productivity between salmon populations from the two areas. The scientific debate surrounding this issue will continue unresolved in the absence of experimental data.

Therefore, the goal of this study is to determine whether migration through Snake River dams and reservoirs causes latent mortality in Snake River yearling Chinook salmon smolts. Specifically, the study will determine if smolt-to-adult return rates of yearling Chinook salmon passing McNary Dam are significantly higher for fish released into Ice Harbor Dam tailrace than for their counterparts released into Lower Granite Dam tailrace and passing three additional dams and reservoirs.

METHODS

Sampling and Tagging of Juveniles

We collected and PIT-tagged hatchery Snake River spring/summer Chinook salmon at Lower Granite Dam from 20 April to 13 May 2006. Collection and handling techniques, including use of a re-circulating anesthetic water system, followed the methods of Marsh et al. (1996, 2001). Tagging for each of 10 replicates was conducted in 2-d blocks over 20 total days. On the first day of each 2-d block, fish for the Lower Granite Dam reference group (LN) were tagged and sent to a holding tank for 24-h. On the second day of the block, we tagged two groups: one for the Ice Harbor Dam transport group (IH), and one for the Lower Granite Dam transport group (LG). All tagging was completed by 1600 each day because truck drivers were required to limit the number of driving hours per day (for safety reasons). This allowed the driver releasing 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. Ice Harbor (IH) fish were released upon arrival at Ice Harbor Dam (approximately 2000) into the juvenile fish facility bypass pipe. A circuitous route was devised for the Lower Granite (LG) release group so that the truck carrying these fish returned to Lower Granite Dam at the same time the IH truck was arriving at Ice Harbor Dam. These fish were then released through a pipe that runs along the top of the Lower Granite Dam juvenile fish facility bypass pipe. Immediately following release of the LG group, the LN group was released through the same pipe.

Evaluation will be based on annual ratios of smolt-to-adult return rates (SARs), that is, SAR_{LG}/SAR_{IH}, or (LG/IH). Note that as a ratio of SARs, LG/IH is a measure of differential "post-McNary" survival: as such, it is analogous to the differential mortality parameter, *D*, which has been computed for transported fish below Bonneville Dam. An LG/IH ratio significantly less than 1.0 will indicate significant latent mortality for fish that passed through the hydropower system between Lower Granite and Ice Harbor Dams.

Sample sizes for each year of this study were designed to provide an 80% probability ($\beta = 0.20$) of detecting a significant difference from 1.0 using a one-sided hypothesis test at $\alpha = 0.05$. Thus, differences will be detectable if the true LG/IH is less than or equal to 0.80 (i.e., survival is at least 20% lower for fish released at Lower Granite Dam) and SAR_{IH} is at least 1.5% (see below).

Required sample sizes were derived by determining the required precision around the estimated LG/IH such that the one-sided confidence interval on the true LG/IH did not contain the value 1, or the confidence interval of the true natural-log-transformed LG/IH, ln(LG/IH), did not contain 0. If the confidence interval does not contain 1.0, then we can reject the null hypothesis, that there is no difference between rates of survival to adulthood for LG and IH fish, and that the true value of LG/IH is thus 1.0. Therefore, for a desired $\alpha = 0.05$ and $\beta = 0.20$, the number of fish needed to determine the true LG/IH was

$$\ln\left(\frac{LG}{IH}\right) - (t_\alpha + t_\beta) \times SE\left[\ln\left(\frac{LG}{IH}\right)\right] \approx 0$$

and

$$SE\left[\ln\left(\frac{LG}{IH}\right)\right] \approx \sqrt{\left(\frac{1}{n_{IH}} + \frac{1}{n_{LG}}\right)} = \sqrt{\frac{2}{n}}$$

where n is the number of adult returns per treatment, and $n_{IH} = n_{LG}$ (n for Ice Harbor Dam and Lower Granite Dam tailrace groups set equal for simplicity). The previous two statements imply that the required number of adults is:

$$n \approx \frac{2(t_\alpha + t_\beta)^2}{\left(\ln\left(\frac{LG}{IH}\right)\right)^2}$$

Again, as we set $\alpha = 0.05$ and $\beta = 0.20$, and if we expect SAR_{IH} to be at least 1.5%, then the number of detections needed at McNary Dam are listed as follows:

True LG/IH	n	N_{IH}	$N_{LG} = N_{IH}/(LG/IH)$	N_{Total}
0.80	249	16,600	20,750	37,350

were N denotes the number of juveniles

These calculations provide the sample size for the number of juvenile detections required at McNary Dam. Such "samples" are obtained by releasing tagged fish upstream from McNary Dam and including only the proportion detected at the dam. However, some mortality occurs before released groups arrive at McNary Dam, and only a portion of the fish arriving are detected. Thus, greater numbers of tagged fish are required for release than for determining differences among SARs. To determine the total tagging requirements, we used an assumed probability of survival to and detection at McNary Dam for each of the LG and IH groups.

Based on survival estimates from previous years, we assumed survival probabilities from Ice Harbor Dam tailrace to McNary Dam of 0.93 and from Lower Granite Dam tailrace to McNary Dam of 0.72. In 2000, the detection probability in the collection system at McNary Dam for yearling Chinook salmon smolts was 0.30. Therefore, we conservatively assumed a detection probability of 0.25 for study smolts passing McNary Dam.

Thus, to realize the necessary number of study fish detected at McNary Dam required releasing approximately 71,475 fish (16,600/0.929/0.25) into the Ice Harbor Dam tailrace and 114,799 fish (20,750/0.723/0.25) into the Lower Granite Dam tailrace. An additional 114,799 non-transported fish were required for release directly into the Lower Granite Dam tailrace to serve as reference fish for comparisons to determine potential transport effects. Therefore, the total tagging requirement was 301,073 fish.

Recovery of Adult Study Fish at Bonneville Dam and Data Analyses

Bonneville Dam will serve as the principal adult recovery site for this study. Using this site for adult recovery will maximize study SARs by avoiding losses from passage mortality and mainstem fisheries upstream from the dam. Data acquired from other areas will be considered ancillary. To analyze results, statistical tests will be applied when adult returns for the study are complete (in 2009 for 2006 releases). For each year of releases, the study will provide LG/IH ratios based on estimates of juvenile detection and survival to McNary Dam. Confidence intervals for this LG/IH will be calculated using the ratio (survival) estimate (Burnham et al. 1987) and its associated empirical variance.

RESULTS AND DISCUSSION

Tagging at Lower Granite Dam began on 21 April and finished on 13 May 2006. During this time, we tagged 192,302 hatchery yearling spring/summer Chinook salmon. Of these 192,302 fish, we released a total of 190,274 hatchery spring/summer Chinook salmon. Fish were divided into three groups, with 38,599 released below Ice Harbor (IH), 57,176 released into Lower Granite Dam tailrace after being transported by truck for an equal amount of time (LG), and 94,499 released as reference fish into the Lower Granite Dam tailrace with no transportation (LN).

Our study design called for release sizes of 71,480, 114,800, and 114,800 for the Ice Harbor, Lower Granite, and reference groups, respectively. We were unable to tag the necessary number of fish in part due to the unusually large numbers of hatchery steelhead arriving at the dam during our tagging period. These large numbers required us to process many more steelhead than expected, and the additional time required to process these fish was considerable. Tagging numbers were also curtailed by the necessity of having to shorten tagging days to avoid forcing the truck drivers to work beyond their permitted number of hours on the road per day.

Post-tagging mortality was determined using the reference group (LN) which was held for 24-h prior to release. Average post-tagging mortality for the entire tagging period was 1.00 and ranged from 0.35 to 1.63 per tagging day. This rate was similar to that observed in past tagging programs using hatchery spring/summer Chinook salmon. Mortalities were checked for obvious causes (e.g., punctured kidney or other organ damage) that would indicate problems with tagging technique. We also checked the condition at tagging of the mortalities and observed that 14.0% of them had been described as descaled at the time of tagging, while only 2.6% of the entire tagging population was so described. This effect of descaling on post-tagging mortality was similar to that found in previous studies using hatchery spring/summer Chinook salmon.

Estimated survival to McNary Dam was 85.0, 68.2, and 70.3% for the Ice Harbor transport (IH), Lower Granite transport (LG), and Lower Granite reference (LN) groups, respectively. Based on these survival estimates, we estimate that 32,801, 39,012, and 66,436 tagged fish reached the McNary Dam tailrace from the IH, LG, and LN groups, respectively.

Our study design is based on the LG/IH ratios of fish detected at McNary Dam, so juvenile fish were monitored as they migrated downstream after release (Table 2). Detection at McNary dam was 34.1, 19.8, and 20.1% for the IH, LG, and LN groups, respectively. The purpose of the LN group was to test for potential effects of trucking.

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 2006. Numbers of fish released are also shown.

Collection date	Tag date	Release date	Number of fish released	Release number per 2-d block
20 April	21 April	22 April	3,939	
21 April	22 April	22 April	3,458	7,397
23 April	24 April	25 April	6,524	
24 April	25 April	25 April	9,619	16,143
25 April	26 April	27 April	3,480	
26 April	27 April	27 April	8,450	11,930
27 April	28 April	29 April	12,832	
28 April	29 April	29 April	12,614	25,446
30 April	1 May	2 May	10,587	
1 May	2 May	2 May	9,360	19,947
2 May	3 May	4 May	12,114	
3 May	4 May	4 May	7,655	19,769
4 May	5 May	6 May	9,734	
5 May	6 May	6 May	9,733	19,467
7 May	8 May	9 May	11,877	
8 May	9 May	9 May	11,052	22,929
9 May	10 May	11 May	13,045	
10 May	11 May	11 May	11,466	24,511
11 May	12 May	13 May	11,480	
12 May	13 May	13 May	12,686	24,166

Table 2. The number of PIT-tagged hatchery yearling spring/summer Chinook salmon released at Lower Granite Dam after trucking (LG), released at Lower Granite Dam without trucking (LN), and at Ice Harbor Dam (IH) for evaluation of latent mortality in 2006. The number and percent detected at McNary Dam and the estimated number of fish arriving in the tailrace of McNary Dam is also shown.

Release group	Number released	Number detected at McNary Dam	Percent detected at McNary Dam	Estimated number to McNary Dam tailrace
Lower Granite	57,176	11,306	19.77	39,801
No transport	94,499	19,035	20.14	66,436
Ice Harbor	38,599	13,146	34.06	32,801

Survival and detection rates for the Little Goose (LG) and non-transport (LN) release groups indicate that, similar to results from last year's tagging, transporting fish in a truck had little or no impact on juvenile survival through the hydropower system. We await adult returns to determine if there are any impacts of trucking on SARs. Adults from 2006 releases will begin returning in 2007 (jacks), with complete adult returns expected in 2009. One jack from our 2005 marking year was observed ascending the Bonneville Dam adult ladder, but was not detected at any site above Bonneville Dam.

ACKNOWLEDGMENTS

We thank the U.S. Army Corps of Engineers (USACE) for their cooperation with this study. In particular, we thank Mike Halter and his staff at Lower Granite Dam, and John Bailey and Dave Hurson for their help in obtaining the use of USACE fish transport tankers. We also thank Scott Davidson of our Pasco shop for his help in preparing the tankers for our use and for conducting the release operations at Ice Harbor Dam. Finally, we thank the Pasco shop personnel for implementing upgrades to the tagging facility based on our experiences with the new facility in 2005.

REFERENCES

Hinrichsen, R. A. 2001. The importance of influence diagnostics: examples from Snake River Chinook salmon spawner-recruit models. Canadian Journal of Fisheries and Aquatic Sciences 58:551-559.

Marsh, D. M., J. R. Harmon, , K. W. McIntyre, K. L. Thomas, N. N. Paasch, B. P. Sandford, D. J. Kamikawa, and G. M. Matthews. 1996. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1995. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla, Walla, Washington

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2001. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 2000. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla, Walla, Washington.

Raymond, H. R. 1979. Effects of dams and impoundments on migrations of Chinook salmon and steelhead from the Snake River, 1966-1975. Transactions of the American Fisheries Society 90:58-72.

Schaller, H. A., C. E. Petrosky, and O. P. Langness. 1996. Contrasts in stock recruitment patterns of Snake and Columbia River spring and summer Chinook. In Plan for analyzing and testing hypotheses (PATH): final report of retrospective analysis for fiscal year 1996. Compiled and edited by D. R. Marmorek and 21 coauthors. ESSA Technologies, Ltd., Vancouver, B.C.

Schaller, H. A., C. E. Petrosky, and O. P. Langness. 1999. Contrasting patterns of productivity and survival rates for stream-type Chinook salmon (*Oncorhynchus tshawytscha*) populations of the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences 56:1031-1045.

Williams, J. G., S. G. Smith, and W. D. Muir. 2001. Survival estimates for downstream migrant yearling juvenile salmonids through the Snake and Columbia Rivers Hydropower System, 1966-1980 and 1993-1999. North American Journal of Fisheries Management 21:310-317.

Williams, J. G. and G. M. Matthews. 1995. A review of flow and survival relationships for spring and summer Chinook salmon, *Oncorhynchus tshawytscha*, from the Snake River basin. Fishery Bulletin, U.S. 93:732-740.

Zabel, R. W., and J. G. Williams. 2000. Comments on "contrasting patterns of productivity and survival rates for stream-type Chinook salmon (*Oncorhynchus tshawytscha*) populations of the Columbia and Snake rivers" by Schaller et al. (1999). Canadian Journal of Fisheries and Aquatic Sciences 57:1739-1741.