A Study to Evaluate Latent Mortality Associated with Passage through Snake River Dams, 2007

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EXECUTIVE SUMMARY

During spring 2007, the National Marine Fisheries Service tagged yearling hatchery Chinook salmon *Oncorhynchus tshawytscha* to evaluate latent (extra) mortality associated with their passage through Snake River Dams. This was the third year of juvenile tagging for the study. We also monitored adult returns from fish tagged in 2005 and 2006 for the same evaluation.

For the 2007 tagging season, we changed our study design. In our original design, fish detected at McNary Dam were used to form our three study groups. This allowed us to avoid having to estimate the number of fish in each group. Because of concerns about our ability to tag the large number of fish needed (301,000), and the impact tagging such a large number would have on the run in general, we decided to use estimates of the number of fish arriving at McNary Dam tailrace for each group instead. This change allowed us to sharply reduce the number of fish needed for the study: from 301,000 to a minimum of 111,222 fish. Due to recent low smolt-to-adult returns (SARs), we decided to set our 2007 tagging goal at 120,000.

Due to changes in Snake River dam operations during spring 2007 (a delayed start of collection and transportation), we had to postpone the start of our tagging period from 23 April to 2 May. Because hatchery Chinook salmon pass Lower Granite Dam in a compressed time frame, our fish collection "window" began to close less than two weeks after we started tagging. Therefore, our tagging period ended on 15 May, as originally planned. This resulted in four of the ten replicates not being marked (a total loss of 48,000 fish).

From 2 to 15 May, we released a total of 72,098 hatchery spring/summer Chinook salmon. Of these fish, 16,751 were transported by truck and released below Ice Harbor Dam and 23,843 were transported by truck and simultaneously released into the Lower Granite Dam tailrace. An additional 31,504 fish were released into the Lower Granite Dam tailrace as a reference group (no transportation).

Estimated survival to McNary Dam was 89.3, 75.2, and 75.5% for the Ice Harbor Dam, Lower Granite Dam, and reference fish groups, respectively. Based on these survival estimates, we estimate that 14,998, 17,915, and 23,742 tagged fish reached the McNary Dam tailrace from the three respective groups. The detection rates based on release numbers were 35.5, 34.8, and 37.1% for the Ice Harbor Dam, Lower Granite Dam, and reference groups, respectively.

Adults from 2007 releases will begin returning in 2008 (jacks), with complete adult returns in 2010. At the Bonneville Dam ladders, we detected 35 age-2-ocean adults and 172 jacks from our 2005 and 2006 tagging years, respectively, while detections at Lower Granite Dam were 32 and 159 adults and jacks, respectively.

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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 (FCRPS) (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), coincident with installation of structural improvements and operational changes at dams (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 (Schaller et al. 2007).

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 FCRPS (Budy et al. 2002). This hydropower-related latent mortality was hypothesized 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 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, 2007).

Evidence from the spawner and recruit data of Schaller et al. (1999, 2007) and Deriso et al. 2001) 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, 2007) 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 (SARs) 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

Our original study design required using only those fish detected at McNary Dam (Marsh et al 2007). Because detection probability at McNary Dam was only 0.25, we had to tag 301,000 fish for release upstream from the dam to have a chance of detecting the 58,100 fish needed to create our three study groups. Based on our 2006 tagging program (Marsh et al. 2007), concerns were raised about our ability to tag the 301,000 fish needed under our original study design, and the effects attempting to tag such a large number of hatchery spring/summer Chinook salmon would have on the general population of fish passing Lower Granite Dam. In light of the concerns raised, we decided to change our study design to use an estimate of the number of juveniles reaching the tailrace of McNary Dam for 2007 instead of the actual number.

For 2007, we planned to collect and PIT-tag hatchery Snake River spring/summer Chinook salmon at Lower Granite Dam from 22 April to 15 May 2007. This timetable was based on our previous experience with hatchery spring/summer Chinook salmon that showed this group of fish passed Lower Granite Dam beginning around 20-25 April and ending by mid-May.

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 Dam (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 Dam (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 SARs, that is, SAR_{LG}/SAR_{IH}, or (LG/IH ratio). 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 the comparison of transported to inriver fish below Bonneville Dam. An LG/IH ratio significantly less than 1.0 would 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 1.0, or the confidence interval of the true natural-log-transformed LG/IH, ln(LG/IH), did not contain zero. 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

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

and

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

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:

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

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	333	22,200	27,750	49,950

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 our 2006 study year, and accounting for fish removed for transportation, we estimated the proportion of fish remaining alive and in the river in McNary Dam tailrace as 0.830 for fish released into Ice Harbor Dam tailrace and 0.657 for fish released into Lower Granite Dam tailrace.

Thus, to realize the necessary number of study fish detected at McNary Dam required releasing approximately 26,747 fish (22,200/0.83) into Ice Harbor Dam tailrace and 42,237 fish (27,750/0.657) into Lower Granite Dam tailrace. An additional 42,237 non-transported fish were required for release directly into Lower Granite Dam tailrace to serve as reference fish for comparisons to determine potential transport effects. Therefore, the total tagging requirement was 111,222 fish. Because of the low SARs experienced over the past several years, we decided to increase the release number to 120,000.

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 2010 for 2007 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

Our plans were to begin tagging on 23 April. However, on 18 April, the regional managers informed us that we were not allowed to begin collection and tagging until 2 May. Tagging at Lower Granite Dam began on 2 May and finished on 15 May 2007. This resulted in only six releases being made, instead of the planned ten. We were unable to make up for the lost tagging days due to logistical constraints including:

- The compressed passage pattern of hatchery spring/summer Chinook salmon
- Hiring of fewer personnel to mark fish due to the anticipated reduction in the number of fish tagged per day
- Lower collection numbers due to 24-hour spill at Lower Granite Dam
- Having to provide hatchery spring/summer Chinook salmon for another study, which ran concurrently with this study (and which required 400-500 fish/day)
- The need to finish tagging by 1600 hours to prevent our truck drivers from exceeding their allowable number of hours on the road

From 2 to 15 May, we tagged 72,349 hatchery yearling spring/summer Chinook salmon and released a total of 72,098 (Table 1). Fish were divided into three groups, with 16,751 released below Ice Harbor Dam (IH), 23,843 released into Lower Granite Dam tailrace after being transported by truck for an equal amount of time (LG), and 31,504 released as reference fish into Lower Granite Dam tailrace with no transportation (LN).

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 0.59, with daily values ranging from 0.43 to 0.82. This rate was similar to that observed in past tagging programs using hatchery spring/summer Chinook salmon at Lower Granite Dam. Mortalities were examined for any obvious injury that would indicate problems with tagging technique (e.g., punctured kidney or other organ damage). We also checked the condition at tagging and observed that 2.9% of mortalities had been described as descaled at the time of tagging, while only 0.4% 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 at Lower Granite Dam.

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 2007. Numbers of fish released are also shown.

Collection date	Tag date	Release date	Number of fish released	Release number per 2-d block
1 May	2 May	3 May	8,060	
2 May	3 May	3 May	7,576	15,636
3 May	4 May	5 May	5,619	
4 May	5 May	5 May	6,503	12,122
6 May	7 May	8 May	3,600	
7 May	8 May	8 May	4,560	8,160
8 May	9 May	10 May	4,799	
9 May	10 May	10 May	6,932	11,731
10 May	11 May	12 May	4,942	
11 May	12 May	12 May	9,306	14,148
13 May	14 May	15 May	4,584	
14 May	15 May	15 May	5,717	10,301

Estimated survival to McNary Dam was 89.3, 75.2, and 75.5% for the Ice Harbor Dam transport (IH), Lower Granite Dam transport (LG), and Lower Granite Dam reference (LN) groups, respectively (Table 2). Based on these survival estimates, we estimate that 14,998, 17,915, and 23,742 tagged fish reached McNary Dam tailrace from the IH, LG, and LN groups, respectively. These juvenile numbers will be used to determine SARs when adult returns are complete for comparisons of the three groups.

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 2007. Survival from release to McNary Dam and the estimated number of fish arriving in the tailrace of McNary Dam are also shown.

Release group	Number released	Survival to McNary Dam (%)	Estimated number to McNary Dam tailrace
Lower Granite	23,843	75.2	17,915
No transport	31,504	75.5	23,742
Ice Harbor	16,751	89.3	14,998

Survival rates, while higher this year compared to last year, for the Lower Granite Dam trucked (LG) and non-transport (LN) release groups indicate that, similar to results from 2006 tagging, transporting fish in a truck had little or no effect on juvenile survival through the hydropower system. We await adult returns to determine if there are any impacts of trucking on SARs. Adults from 2007 releases will begin returning in 2008 (jacks), with complete adult returns expected in 2010.

During 2007 adults continued returning from previous marking years (Marsh et al. 2007). From our 2005 marking year, 35 age-2-ocean adults were observed ascending the Bonneville Dam adult ladder and 32 were detected at Lower Granite Dam. Jack returns from our 2006 numbered 172 to Bonneville Dam and 159 to Lower Granite Dam. When complete adult returns are complete, we will conduct analyses to compare SARs between treatment groups.

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