Effects of Turbine Operations and a Prototype Rotating Vertical Barrier Screen on Fish Condition at McNary Dam, 2005

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Report of research by

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EXECUTIVE SUMMARY

This study was initiated to evaluate the condition of juvenile salmonids during passage through the fish bypass and collection system at McNary Dam, with an emphasis on identifying guidance structures and turbine operations that may cause fish injuries. Although earlier studies at McNary Dam indicated that juvenile salmonid survival may not differ over a range of turbine discharges, the more turbulent conditions associated with higher discharges, together with debris accumulation, may require structural modifications to protect fish in the gatewells. A rotating vertical barrier screen was installed in gatewell 4A to address this issue.

Also, tests at McNary Dam in 2004 indicated that an increase in descaling during higher turbine discharges may not have been solely related to gatewell conditions. Therefore, in 2005, we released test fish just downstream from the trashrack in front of turbine unit intake gatewell 4A. We installed an orifice trap in gatewell 4A (south orifice) to recapture test fish for this portion of the study. The flume from the orifice leading to the orifice trap was fitted with PIT-tag detectors to verify that fish released just downstream from the trashrack did, in fact, pass through the test gatewell and orifice.

The study was designed as a series of paired releases during the spring and summer juvenile migrations, with turbine loads of 62 MW (standard discharge) and 80 MW (high discharge). Run-of-river fish were dip-netted from gatewells, sorted, and scanned for previous PIT-tags; fish were then tagged only if they were uninjured and not previously tagged.

PIT-tagged fish were recaptured either by the separation-by-code system in the juvenile fish facility or with the orifice trap on gatewell 4A. Fish condition was determined using standard fish descaling/injury criteria. We collected additional descaling data on run-of-river fish from the orifice trap in gatewell 4A, as well as from another orifice trap attached to gatewell 6B, which was operated at standard turbine load (62 MW). Descaling data from run-of-river fish sampled at the juvenile fish facility was also compared to these test results.

Three evaluations of descaling were made with PIT-tagged yearling Chinook salmon, for a total of eight paired releases (5 May to 6 June). Results from the first evaluation showed no significant difference in descaling by turbine load, with descaling rates of 7.7 and 8.7% at the 62 and 80 MW loads, respectively.

In the second evaluation, a significant difference in descaling was observed by location: lower descaling was observed for fish released into the gatewell and recovered at the orifice trap (6.4%) than for fish released just downstream from the trashrack and recovered at the orifice trap (8.6%) or for run-of-river fish captured in the orifice trap (9.1%). There was no difference between the latter two values.

In the third evaluation of yearling Chinook salmon, a significant difference in descaling levels was seen between run-of-river fish examined at the gatewell orifice trap (8.0%) and those examined at the juvenile fish facility (5.0%).

Numbers of juvenile subyearling Chinook salmon arriving at McNary Dam during the summer juvenile migration were limited. Therefore, a full evaluation with collection, tagging, and recapture would not have produced sufficient data for statistical analysis. Instead, we monitored the condition of run-of-river fish at the orifice traps in turbine units 4A and 6B and compared these data to the data collected from river-run fish at the juvenile fish facility.

Results indicated significant differences in descaling among these three areas; however, descaling at all locations was low, at 3.4% in the gatewell 4A orifice trap, 2.5% in the gatewell 6A orifice trap, and 1.2% in the sample from the juvenile fish facility. Because of these low rates, we were unable to ascertain whether meaningful biological differences existed between these locations in terms of their impact on fish condition.

CONTENTS

EXECUTIVE SUMMARY iii

INTRODUCTION 1

METHODS 3
- Fish Collection, Tagging, and Release 3
- Data Analysis 4

RESULTS AND DISCUSSION 7
- Preliminary Evaluations of the Orifice Trap and Flume 7
- Descaling Evaluations of Yearling Chinook Salmon 7
  - Comparison Between the 62 and 80 MW Turbine Load 9
  - Comparison Between the Trashrack, Gatewell, and Orifice Trap 11
  - Comparison Between the Gatewell 4A Orifice Trap and Juvenile Fish Facility 14
- Descaling Evaluations of Subyearling Chinook Salmon 16

CONCLUSIONS 19

ACKNOWLEDGMENTS 20

REFERENCES 21

APPENDIX: Descaling Data Tables 23

INTRODUCTION

This study was conducted as part of the McNary Powerhouse Modernization project (USACE 2005) and was designed to evaluate bypass system components in anticipation of increased turbine loading at the McNary Dam powerhouse. The study addressed turbine survival as prescribed by the National Marine Fisheries Service biological opinion for operation of the Federal Columbia River Power System (NMFS 2004 Appendix G, p. 10, section 4.8). The study was sponsored by the U.S. Army Corps of Engineers Anadromous Fish Evaluation Program.

There are numerous components to contemporary fish bypass systems. At McNary Dam and similar hydroelectric projects, extended-length submersible bar screens guide fish out of the turbine intakes into gatewells where vertical barrier screens (VBSs) confine the fish closer to submerged gatewell orifices. These orifices then efficiently draw fish out of the gatewells and into a collection channel. From the collection channel, fish can either be returned to the river below the dam or diverted to holding raceways within the juvenile fish facility (JFF) to await transport by barge or truck to downriver release sites.

The condition of juvenile anadromous salmonids that are diverted from turbines at these hydroelectric projects is an ongoing concern. If any part of the bypass system is not functioning at peak efficiency, downstream survival of juvenile salmonids can be reduced, thereby impacting future adult returns.

At McNary Dam in 2004, a program was initiated to examine the effects on fish condition of increasing turbine loads from approximately 60 MW to 80 MW. Although hampered by limited test replication, results indicated that the overall condition of PIT-tagged yearling Chinook salmon *Oncorhynchus tshawytscha* released into the gatewells of turbines operated at 80 MW was similar to that of smolts released into turbine units operated at approximately 60 MW (Absolon et al. 2005). However, the study also suggested that some degree of descaling and injury could be occurring before fish entered the gatewells of turbines operating at the higher loads. Moreover, at times during the study, daily samples of smolts collected at the JFF showed an increase in descaling that appeared to be related to the periods when the test turbines were operated at higher loads.

We continued the study during the 2005 juvenile salmonid migration to determine whether operating turbines at higher discharge rates increased descaling or injury. Our plan was to partition the fish passage corridor into two sections (from the trashrack to the gatewell entrance and within the gatewell) and to evaluate descaling in each section. Also,

a prototype rotating vertical barrier screen (R-VBS) was installed in gatewell 4A. This new style of VBS was designed to reduce the accumulation of debris on the VBS, which may improve fish condition as well as reducing seasonal maintenance needs.

We planned to use orifice traps to recapture smolts for examination to compare the two turbine loads in conjunction with the R-VBS. To isolate where descaling and injuries (if any) were occurring, we released PIT-tagged fish in two locations: 1) just downstream from the trashrack in front of the extended-length submersible bar screens, and 2) into the gatewell approximately 3 m above the top of the extended-length submersible bar screens (Figure 1).

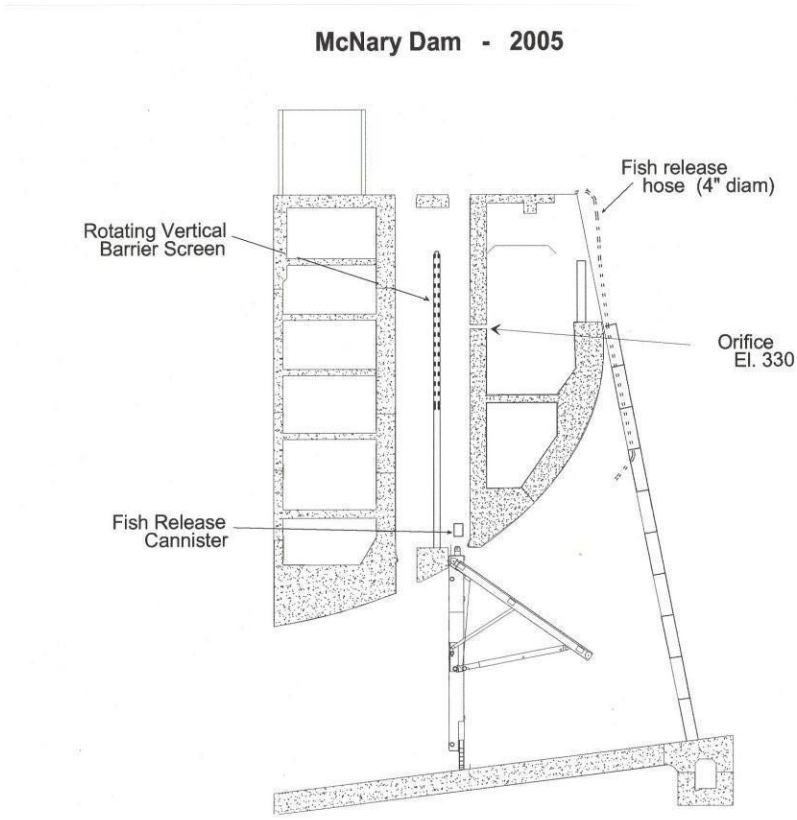

Figure 1. Cross section of a turbine intake at McNary Dam showing placement of rotating vertical barrier screen and release sites.

METHODS

Fish Collection, Tagging, and Release

Evaluations of a prototype VBS at McNary Dam in 2004 suggested that smolts may have been descaled prior to entering gatewells in a turbine operated at a higher (80 MW) discharge level. To isolate the location of possible descaling, we designed the 2005 study to release groups of PIT-tagged yearling and subyearling Chinook salmon at two points in turbine unit 4. The first release point was from a 10.1-cm-diameter (4-in) hose end located approximately 2.5 m (8 ft) downstream from the trashrack facing turbine unit intake gatewell 4A (Figure 1). The second release point was from a canister submerged directly into the gatewell (Absolon and Brege 2003).

We intended to recapture and examine fish from both release points using the separation-by-code (SbyC) system at the McNary Dam juvenile fish facility. However, every other day, the JFF was operated in primary bypass mode, which returns all fish directly to the river. Therefore, study fish could be recaptured using the SbyC system only on alternate days, when the JFF was not in primary bypass mode.

To collect fish for tagging, we dipnetted the gatewells at McNary Dam using a dipbasket similar to that described by Swan et al. (1979). We attempted to use only uninjured yearling Chinook salmon that were not previously descaled. A few study fish were selected that had minor scale loss; this information was noted for individual fish during tagging so that we could discern any new descaling or injury that occurred as the result of a specific test condition.

PIT-tagged fish were held overnight, with equal numbers of fish placed in each holding tank. Prior to release, we examined the holding tanks for lost tags and mortalities and adjusted the tag files accordingly. All other juvenile salmonids captured by dip net were routed to a recovery tank and allowed to recover from the anesthetic before being released back into the bypass system.

Our study design called for morning releases after tagging the previous evening, with subsequent recapture and examination using the SbyC system in the JFF. However, prior to recapture, we needed to confirm that fish released just downstream from the trashrack had actually entered the system through gatewell 4A. To verify that tagged fish had indeed entered the collection channel through the test gatewell, we installed a dual set of PIT-tag readers in the flume leading to the gatewell 4A orifice trap.

The study design also called for a canister release of PIT-tagged juveniles into gatewell 5A. This turbine had a standard VBS and was operated at the standard, 62 MW turbine load. This release was made only when turbine unit 4 was operated at 80 MW and was to serve as a reference group for standard turbine operation.

Recaptured fish were anesthetized and examined for descaling and injury. Descaling was evaluated using the criteria of the Fish Transport Oversight Team (Ceballos et al. 1993), where a fish that was missing 20% or more of the scales on at least one side was considered descaled. After examination, all fish were allowed to recover from anesthesia and then returned to the river.

In addition to the PIT-tag releases, we also planned to examine run-of-the-river smolts (all juvenile salmonid species) captured in the gatewell 4A orifice trap. The trap was downstream from the PIT-tag readers so that passage of our tagged fish would not be disrupted by these handling operations.

Prior to any PIT-tagged fish being released, we monitored smolt passage through the orifice trap to ensure that the trap or flume was not causing any descaling or injury. An additional orifice trap, located on the south orifice of turbine unit 6 (McComas et al. 1997) was used to collect run-of-river fish for evaluation at the 62 MW load. This trap was operated primarily during the summer juvenile migration, but some data were collected during the spring for yearling Chinook salmon as well.

Data Analysis

Each descaling value was a proportion of descaled fish from the total number recaptured. As such, the data were assumed to be binomially distributed. These data were fitted to a logistic regression model with a logit link function (McCullagh and Nelder 1983). Equations for the logistic regression models were of the form:

$$\log\left(\frac{y_{ik}}{1-y_{ik}}\right) = a + \beta_d d_i + \sum_k \beta_k F_k + \varepsilon$$

with the estimated solution for y_{ik} :

$$\hat{y}_{ik} = \frac{e^{\hat{a}+\hat{\beta}_d d_i + \sum_k \hat{\beta}_k F_k}}{1+e^{\hat{a}+\hat{\beta}_d d_i + \sum_k \hat{\beta}_k F_k}}$$

where:

y_{ik} is the proportion descaled in group k on day I,
a is a constant,
β_d is the coefficient for the day covariate, d_i,

and the summation of βs is the coefficient for a vector of one or more factors, F, with a total of k parameters (e.g. k = the product of the number of levels of each factor plus interaction levels), and ε are random multinomial-distributed errors.

Maximum likelihood estimates of the parameters were calculated by fitting the particular model using an iterative-reweighted least squares algorithm (McCullagh and Nelder 1983; Hosmer and Lemeshow 2001). We used Minitab statistical software to conduct the analyses. The deviance test for goodness-of-fit was used to indicate whether the model was over-dispersed relative to binomial variability and/or whether outliers might be present. If the test was significant and no important outlier was found, we used a quasi-likelihood method to estimate the over-dispersion parameter (Ramsey and Schafer 1997).

The interaction between factors was included in model selection. We fitted the models with and without the interaction term. If over-dispersion and important outliers were not detected (see above), we calculated the value of the log-likelihood for each. We then calculated a likelihood ratio test as twice the difference in the two log-likelihood values (Hosmer and Lemeshow 2001), that is, the drop-in-deviance statistic. This likelihood ratio test value was then compared to a chi-square distribution, with degrees of freedom equal to the difference in number of parameters between the two models. If the resulting P-value indicated no significant difference between the two models ($\alpha = 0.05$), then the reduced model (with no interaction parameter) was used.

However, if over-dispersion was detected, we used drop-in-deviance F-tests (that incorporated the over-dispersion parameter) to compare models instead of the chi-square test above (Ramsey and Schafer 1997). If important outliers were found, we attempted to find out the cause and took appropriate action (i.e., removal or explanation).

For all models, deviance residuals were visually assessed to determine significant outliers or the appropriateness of the logistic regression model.

RESULTS AND DISCUSSION

Preliminary Evaluations of the Orifice Trap and Flume

Before we began tagging study fish, we needed to evaluate the orifice trap installed in gatewell 4A to ensure that it did not contribute to smolt descaling or injury. On 29 April, we marked 178 run-of-river yearling Chinook with a partial caudal clip and released them into the test gatewell. Only uninjured fish with no previous descaling were clipped, and releases were made about 3 m below the orifice using the gatewell release canister. We released fish at 2000 PDT and monitored the orifice trap for the next 6 h. We recovered about half of these marked fish, and none showed any signs of injury or descaling. During the next few days, we took random samples of run-of-the-river smolts with turbine unit 4 operating at both 62 and 80 MW. We saw no indication of descaling or injury to these fish that could be attributed to the flume or orifice trap.

From 1700 PDT on 5 May to 0200 on 7 May, we collected and examined all fish passing through the orifice trap for a period of 24 h. Between 1700 and 2200, the descaling rate for yearling Chinook salmon was 2.2% (n = 316). From 2200 on 5 May through 0600 on 6 May, descaling was 1.8% (n = 167). On 6 May at 0600, the turbine load was increased to 80 MW, and from 0600 to 1700, descaling was 4.9% (n = 1,276).

Descaling Evaluations of Yearling Chinook Salmon

We began releasing PIT-tagged yearling Chinook salmon on 5 May and ended on 6 June. The initial release of PIT-tagged smolts was made with turbine unit 4 operating at 62 MW. The study design called for a series of 2-day blocks of 60 and 80 MW operation; however, at the onset of these tests, we encountered a period of continuous, heavy debris buildup on the trashracks, which continued for about 2 weeks. Therefore, testing was postponed until the trashracks could be maintained reasonably clear of debris.

The consequent loss of test days meant that we could not achieve sufficient replication for statistical analysis if we continued releasing marked fish only every other day. The only way to obtain sufficient numbers for analysis was to mark and recapture test fish on a daily basis.

We accomplished this by utilizing the PIT-tag readers in the flume leading to the orifice trap, rather than using the SbyC system. While this approach allowed us to mark and release the test fish on a daily basis, it also limited the number of hours we could recover some of the test groups and required study fish to be manually sorted from total catch in the orifice trap.

Using the new mark and release schedule, we PIT tagged test fish early each evening (between 1600 and 2000) and released them after 2200 the same evening. Our recovery of some PIT-tagged fish was limited when we changed the turbine load. On these days, we had only 8 hours to recover the test group, since the releases were made at 2200 and turbine operation changed the following day at 0600. Past releases have shown that PIT-tagged fish pass rapidly from the release points to initial observation within the PIT-tag identification system at McNary Dam. Therefore, we felt the shorter recovery period would not adversely impact our data collection. This was generally true for test groups released into the gatewells, but recovery for some of the trashrack releases was limited.

We also made several releases of PIT-tagged yearling Chinook salmon into gatewell 5A. We did this in an attempt to compare fish passage and condition in the test gatewell to that in a unit equipped with a standard VBS and operated at the standard 62 MW load. Use of the SbyC system in the JFF was also required to recapture and examine these fish. We made several (9) of these releases, but were unable to recover sufficient numbers with the SbyC for meaningful statistical analysis.

The initial study design was to release fish in 4-d blocks, with each block having turbines operated for 2 d at the 62 MW load and 2 d at the 80 MW load. However, this release schedule was only partially implemented (see appendix); therefore, the block design was not incorporated in the statistical analyses.

We made three separate evaluations of PIT-tagged yearling Chinook descaling using data collected during the spring juvenile migration (no tagging was done on steelhead or sockeye salmon):

1) A comparison between two turbine loads (62 and 80 MW) using data from releases via canister in gatewell 4A and via hose just downstream from the trashrack in front of gatewell 4A, with recapture and examination at the gatewell 4A orifice trap.

2) A comparison among three locations at both turbine loads using data from fish released at the trashrack and gatewell and recaptured at the gatewell 4A orifice trap as well as run-of-river fish captured and examined at the orifice trap.

3) A comparison between two locations using data from run-of-river fish collected and examined at the gatewell 4A orifice trap or collected and examined at the JFF.

All descaling data collected on yearling Chinook salmon during the 2005 study are detailed in the appendix.

Comparison Between the 62 and 80 MW Turbine Load

For the first comparison, fish were released just downstream from the trashrack in front of gatewell 4A during both 62 and 80 MW operations, and all fish were recaptured and examined at the gatewell 4A orifice trap. Data analysis was conducted using a single factor (turbine load) at two levels (62 and 80 MW, thus $k = 2$). We included test date as a covariate to account for general (linear) temporal changes in descaling.

There was no significant difference in descaling by turbine load at the gatewell 4A orifice trap ($\alpha = 0.05$). Mean descaling was 7.7% at the 62 MW load, and was only 1.0% lower than the 8.7% rate at the 80 MW load (Table 1 and Figure 2). Regression diagnostics indicated no problems with the model structure or selection, although over-dispersion of the binomial model was detected (deviance test = 2.88, $P < 0.001$) and adjusted for in the resulting significance tests and standard errors. One data point did appear to have considerable influence in the analysis, but that was primarily due to its large sample size and not an anomalous value (5.0%).

Inference on descaling differences between the two turbine load levels was made based on this first analysis because it contained the largest sample size (number of tests).

Table 1. Logistic regression results from comparing descaling at the gatewell 4A orifice trap during two turbine load levels with a rotating VBS in turbine unit 4 at McNary Dam, 2005. There was significant over-dispersion above binomial variance, so *F*-tests were used to test coefficient significance.

	Predictor				Mean
	coefficient	SE	**F**	*P*	descaling (%)
Constant	-5.817	1.122	---	---	
Day	0.024	0.008	---	---	
Turbine load					
62 MW*	0	---	---	---	7.7
80 MW	0.145	0.166	0.77	0.390	8.7
Log-likelihood = -1651.656			Over-dispersion = 2.88		$P < 0.001$

* Model used one level of each factor set to zero.

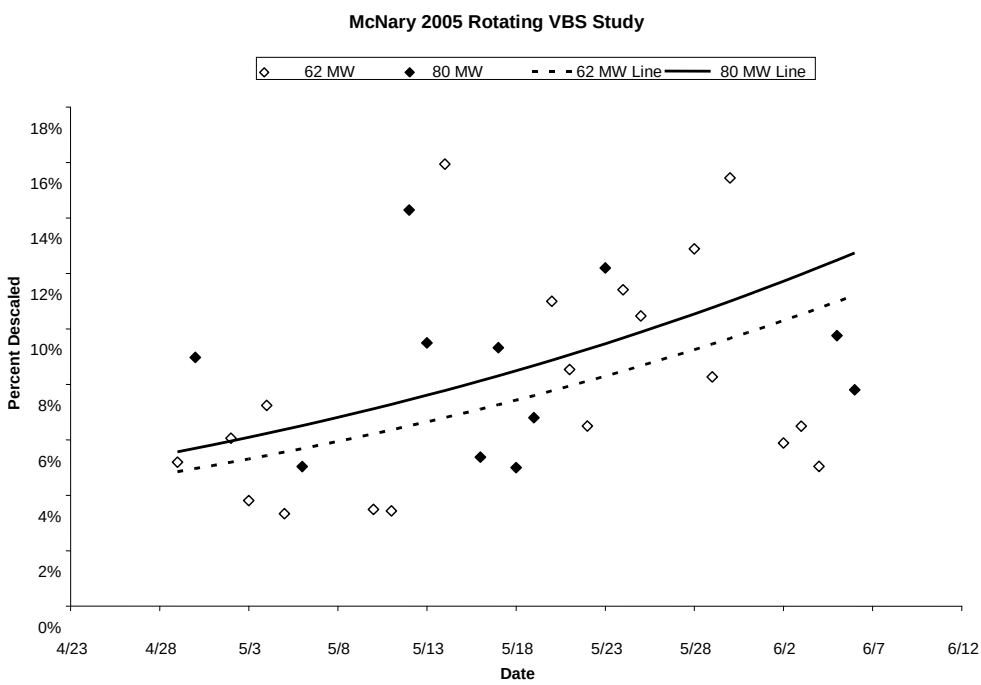

Figure 2. Data and logistic regression results for comparing descaling at the gatewell 4A orifice trap during two turbine load levels with a rotating VBS in turbine unit 4 at McNary Dam, 2005.

Comparison Between the Trashrack, Gatewell, and Orifice Trap

For the second evaluation, we used descaling data from fish released just downstream from the trashrack in front of gatewell 4A and from the canister in gatewell 4A, with both releases recovered at the 4A orifice trap. These data were compared to data from run-of-river fish captured at the 4A orifice trap. Releases were made during both 62 and 80 MW turbine load operations.

A two-factor analysis was conducted, with the two levels of turbine load (62 and 80 MW) and three levels of location (trashrack, gatewell, and orifice trap). Again, we included test date as a covariate to account for temporal changes in descaling. Although we did not evaluate turbine load directly in this analysis, turbine load was included as a factor to determine whether significant interaction could be detected between turbine load and location.

For the full model with interaction between day and location, as well as load and location, the Deviance test showed a highly significant lack of goodness-of-fit ($P = 0.001$) and examination of the deviance residuals found two values that appeared to be important outliers. Both descaling values were usually low and were associated with the 5 May date, which occurred 11 days before all other tests. Therefore, this result was most likely related to early-season smolt condition (i.e., early season fish are less smolted and thus tend to descale less easily than later, more-smolted fish) and was not a good indicator of differences between locations. Also, the load for 5 May was 60 MW, and no commensurate test at 80 MW was conducted during the same time. We analyzed the dataset both including and excluding 5 May data.

If these two outliers were included, the log-likelihood was -1417.269, and for the model with no interaction, it was -1419.834. A likelihood ratio test comparing the two was

$$\chi^2 = 2 \times (\text{LL of model with no interaction - LL of full model}) = 5.13,$$

with 4 df (for removing 4 parameters). The *P*-value was 0.274; therefore, there was no evidence of interaction between day and location or between load and location, and the reduced model was used. Regression diagnostics indicated no problems with the model structure or selection other than the outliers discussed above.

There were statistically significant differences when we compared the descaling rates of the gatewell 4A releases (6.4%) to those of both the trashrack (8.6%) and 4A orifice trap (9.1%) releases. However, there was no difference in descaling between fish released to the trashrack and run-of-river fish captured in the orifice trap (Table 2a and Figure 3a).

Table 2a. Logistic regression results for comparing trashrack, gatewell, and orifice trap descaling at two turbine load levels in unit 4A with a rotating VBS at McNary Dam, 2005. Data from 5 May were used in the analysis.

	Predictor				Mean
	coefficient	SE	*Z*	*P*	descaling (%)
Constant	-2.563	0.910	---	---	
Day	0.001	0.006	---	---	
Load					
62 MW*	0	---	---	---	---
80 MW	0.215	0.104	---	---	---
Location					
Trashrack*	0	---	---	---	8.6
Gatewell	-0.315	0.150	-2.10	0.035	6.4
Orifice trap	0.073	0.122	0.60	0.551	9.1
Log-likelihood = -1419.834					

* Model used one level of each factor set to zero.

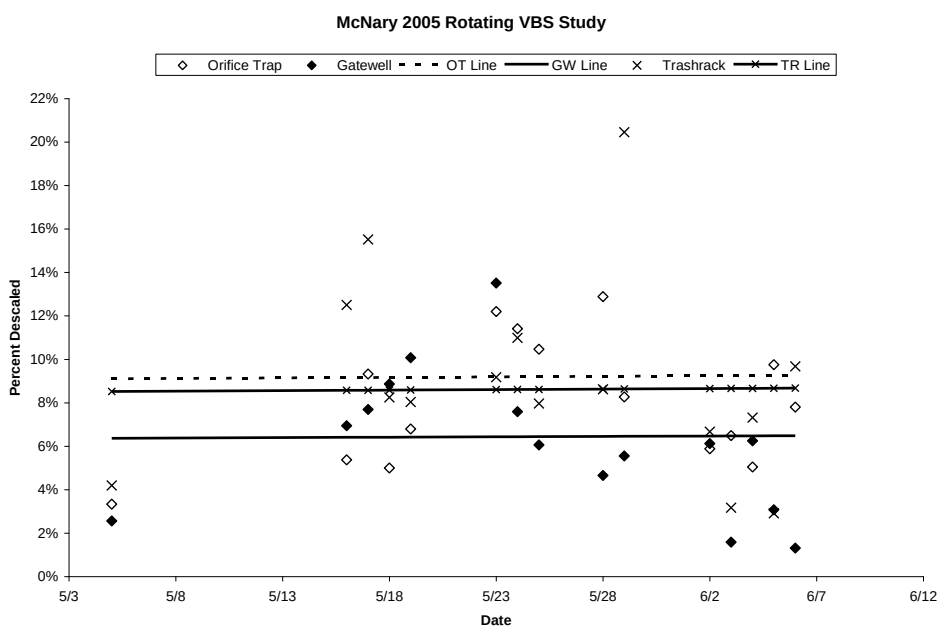

Figure 3a. Data and logistic regression results for comparing trashrack, gatewell, and orifice trap descaling at two turbine loads in unit 4A with a rotating VBS at McNary Dam, 2005. Data from 5 May were used in the analysis.

If the 5 May data were excluded, the log-likelihood was –1343.145; for the model with no interaction, it was –1346.805. A likelihood ratio test comparing the two was $\chi^2 = 7.32$, with 4 df (for removing 4 parameters). The *P*-value was 0.120; therefore, there was no evidence of interaction between day and location or load and location, and the reduced model was used. Regression diagnostics indicated no problems with the model structure or selection other than the outliers discussed above.

There were statistically significant differences when we compared the descaling rates of the gatewell 4A releases (6.4%) to those of both the trashrack (8.3%) and 4A orifice trap (9.4%) releases. However, there was no difference in descaling between fish released to the trashrack and run-of-river fish captured in the orifice trap (Table 2b and Figure 3b).

Table 2b. Logistic regression results for comparing trashrack, gatewell, and orifice trap descaling at two turbine load levels in unit 4A with a rotating VBS at McNary Dam, 2005. Data from 5 May were excluded from analysis.

	Predictor				Mean
	coefficient	SE	*Z*	*P*	descaling (%)
Constant	1.993	1.414	---	---	
Day	-0.029	0.002	---	---	
Load					
62 MW*	0	---	---	---	---
80 MW	-0.063	0.122	---	---	---
Location					
Trashrack*	0	---	---	---	8.3
Gatewell	-0.280	0.154	-1.81	0.070	6.4
Orifice trap	0.039	0.124	0.32	0.753	9.4
Log-likelihood = -1346.805					

* Model used one level of each factor set to zero.

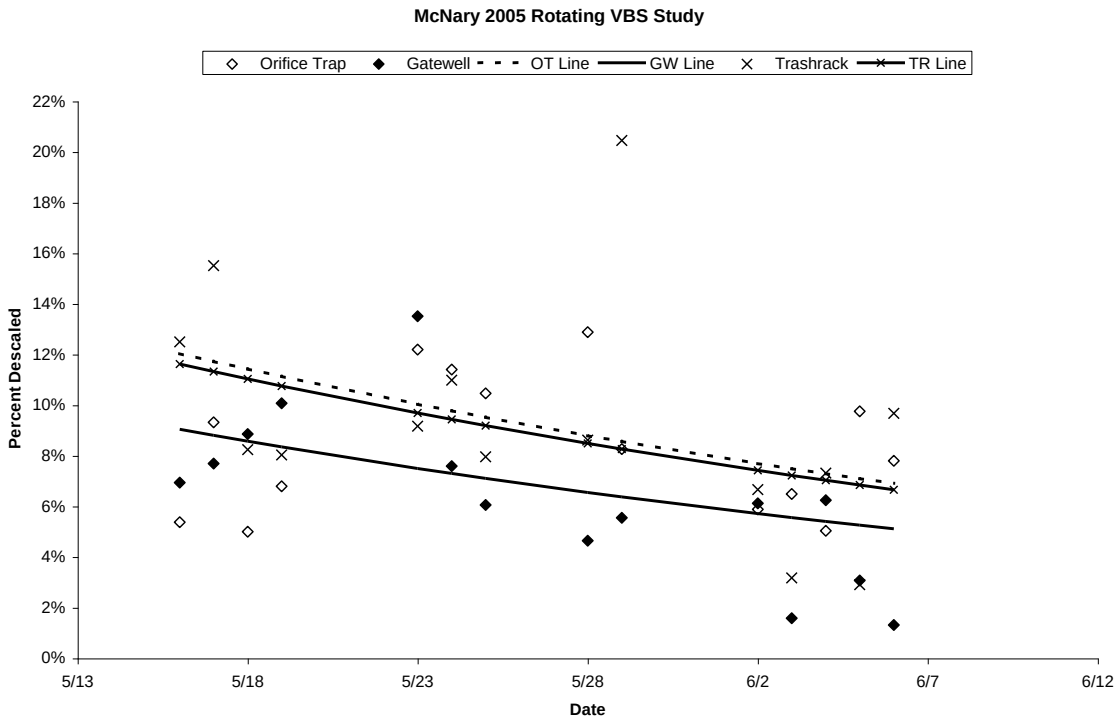

Figure 3b. Data and logistic regression results for comparing trashrack, gatewell, and orifice trap descaling at two turbine loads in unit 4A with a rotating VBS at McNary Dam, 2005. Data from 5 May were excluded from analysis.

Comparison Between the Gatewell 4A Orifice Trap and Juvenile Fish Facility

As in the second evaluation, turbine load was included as a factor in the third evaluation to determine whether significant interaction could be detected between turbine load and location. The third analysis was a two-factor (turbine load and location), with each factor having two levels (62 and 80 MW/orifice trap and JFF). We again included test date as a covariate to account for temporal changes in descaling.

For the full model with interaction, significant over-dispersion relative to the binomial model was detected (deviance test = 2.28, $P < 0.001$) and tests and standard errors were appropriately adjusted. For the model with interaction, the log-likelihood was -4711.411. For the model with no interaction, the log-likelihood was -4712.589. These two ratios were compared using the drop-in-deviance F-test,

$$F = 2 \times (\text{LL of model with no interaction - LL of full model})/(2*2.28) = 0.52$$

With 2 and 43 degrees of freedom (for removing 2 parameters), $P = 0.598$; therefore, the model with no interaction was used. Regression diagnostics indicated no additional problems with the model structure or selection.

There was a highly significant difference in descaling and injury by location (3.0%, $P < 0.001$) between the JFF and orifice trap for run-of-river fish (Table 3 and Figure 4).

Table 3. Logistic regression results for orifice trap descaling of juvenile yearling Chinook salmon in unit 4A, fitted with a rotating VBS at two turbine load levels, compared with descaling of river-run fish collected at the McNary Dam juvenile fish facility (JFF), 2005.

	Predictor coefficient	SE	**F**	*P*	Mean descaling (%)
Constant	-5.030	0.605	---	---	
Day	0.018	0.005	---	---	
Turbine load					
62 MW*	0	---	---	---	
80 MW	0.121	0.094	---	---	
Location					
Orifice trap*	0	---	---	---	8.0
JFF	-0.477	0.097	23.4	<0.001	5.0
Log-likelihood = -4712.589			Over-dispersion = 2.28		$P < 0.001$

* Model used one level of each factor set to zero.

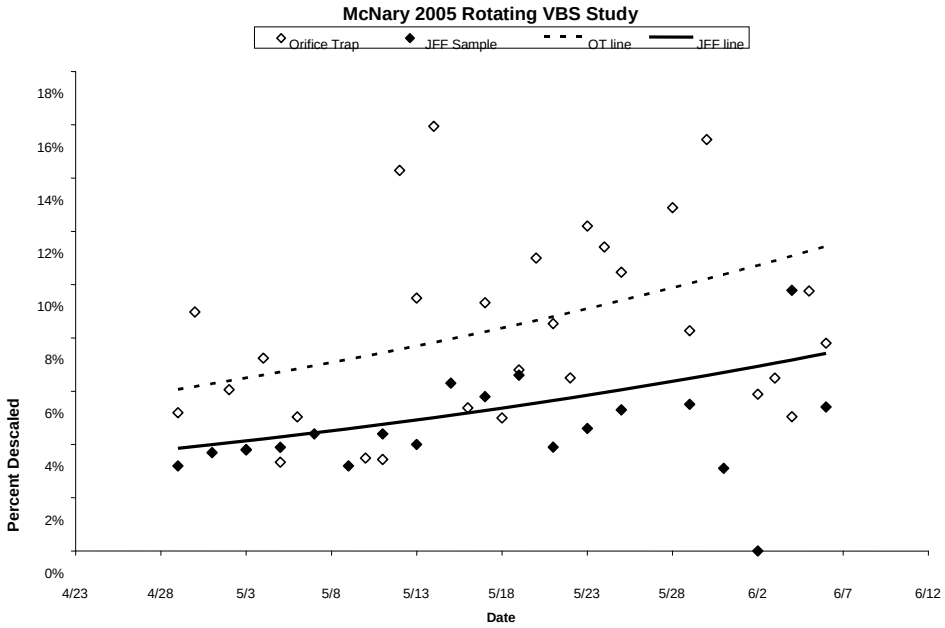

Figure 4. Data and logistic regression results for comparing descaling in the gatewell 4A orifice trap with descaling in fish sampled from the juvenile fish facility at McNary Dam, 2005. The gatewell was fitted with a rotating VBS and tested during operations with both a 62 and 80 MW turbine load.

Descaling Evaluations of Subyearling Chinook Salmon

During the summer juvenile migration, higher water temperatures limited the safe handling and tagging of subyearling Chinook salmon arriving at McNary Dam. Therefore, a full evaluation involving collection, tagging, and recapture would not have produced sufficient data for statistical analysis. We were able to examine run-of-river fish at the orifice traps in turbine units 4A and 6B and compare the condition of these fish to that of run-of-river fish collected at the juvenile fish facility.

Analysis of descaling data for subyearling Chinook salmon was similar to that used during spring testing for yearling Chinook salmon, but with only one factor (location) at three levels (JFF, 4A orifice trap, and 6B orifice trap).

Results from logistic regression are shown in Table 4. For the model with interaction, significant over-dispersion relative to the binomial model was detected (deviance test = 2.12, $P < 0.001$), and tests and standard errors were appropriately adjusted.

For the model with interaction, the log-likelihood was –2656.630; for the model with no interaction, the log-likelihood was –2658.524. These two ratios were compared using the drop-in-deviance *F*-test, ($F = 0.89$, with 2 and 33 degrees of freedom, $P = 0.420$); therefore, the model with no interaction was used. Regression diagnostics indicated no additional problems with the model structure or selection.

Mean descaling was 1.2% in the juvenile fish facility, 2.5% in the gatewell 6B orifice trap, and 3.4% in the gatewell 4A orifice trap. Descaling was significantly different in comparisons by location between the JFF and gatewell 4A orifice trap ($P < 0.001$) and gatewell 6B orifice trap ($P < 0.001$). The difference between gatewell 6B and 4A orifice traps was not significant ($P = 0.137$).

Table 4. Results of logistic regression comparing descaling for subyearling Chinook salmon in the gatewell 4A orifice trap, gatewell 6B orifice trap, and juvenile fish facility (JFF) sample at McNary Dam, 2005. Study day was included as a covariate.

	Predictor				Mean
	coefficient	SE	*F*	*P*	descaling (%)
Constant	-5.593	1.993	---	---	
Day	0.0126	0.012	---	---	
Location					
4A orifice trap*	0	---	---	---	3.4
6B orifice trap	-0.344	0.227	2.32	0.137	2.5
JFF	-1.072	0.173	31.25	<0.001	1.2
JFF vs. 6B	---	---	13.26	<0.001	
Log-likelihood = -2658.524			Over-dispersion = 2.12 $P < 0.001$		

* Model used one level of each factor set to zero.

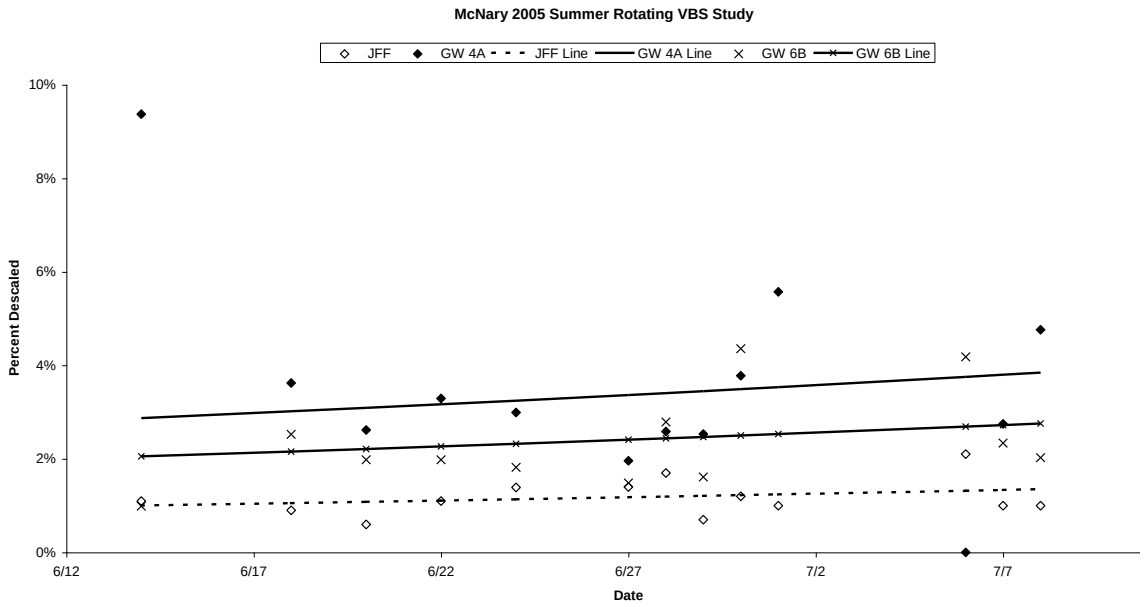

Figure 5. Data and logistic regression results for comparing descaling in the gatewell 4A and 6B orifice traps with descaling in subyearling Chinook salmon sampled from the juvenile fish facility at McNary Dam, in summer 2005. The gatewells were fitted with a rotating VBS and tested during operations at a 62 MW turbine load.

CONCLUSIONS

1. For gatewell-released fish, there was no significant statistical difference in descaling rates for yearling Chinook salmon when the two turbine loads of 62 (7.7%) and 80 MW (8.7%) were compared.

2. There were significant differences in descaling rates between the 4A gatewell release (6.4%) and both the 4A trashrack release (8.6%) and 4A orifice trap collection (9.1%), but there was no difference between the latter two rates.

3. There was a significant difference in descaling between yearling Chinook salmon collected at the 4A orifice trap (8.0%) and those in the JFF sample (5.0%).

4. Descaling for subyearling Chinook salmon showed a significant difference when each orifice trap (4A and 6B) was compared to the JFF sample, but the descaling rates for each area were only 3.4, 2.5, and 1.2%, respectively. Therefore, the tests provide little or no evidence as to whether or not meaningful biological differences exist among these sites.

5. Due to significant debris accumulations, descaling estimates were most likely biased high to an unknown degree on several days during the middle of the study. We chose not to include data derived from 26 and 17 May tests, which were the two worst days for this problem.

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APPENDIX

Descaling Data Tables

Appendix Table 1. Descaling data collected for yearling Chinook salmon during the spring juvenile migration for the rotating vertical barrier screen study at McNary Dam, 2005.

		4A orifice trap			4A gatewell			4A trashrack			5A gatwell			Juvenile fish facility		
			Descaled			Descaled			Descaled			Descaled			Descaled	
Date	MW	Number examined	No.	(%)	Number examined	No.	(%)	Number examined	No.	(%)	Number examined	No.	(%)	Number examined	No.	(%)
4-29	62	77	4	5.2										1,346	43	3.2
4-30	80	78	7	9.0												
5-01	62													3,328	123	3.7
5-02	62	99	6	6.1												
5-03	62	105	4	3.8										2,239	85	3.8
5-04	62	304	22	7.2												
5-05	80	90	3	3.3	195	5	2.6	143	6	4.2				1,748	68	3.9
5-06	80	1,191	60	5.0												
5-07	62													2,296	101	4.4
5-09	62													563	18	3.2
5-10	62	401	14	3.5												
5-11	80	407	14	3.4										614	27	4.4
5-12	80	133	19	14.3												
5-13	62	358	34	9.5										350	14	4.0
5-14	62	138	22	15.9												
5-15	80													651	41	6.3
5-16	80	93	5	5.4	72	5	6.9									
5-17	80	311	29	9.3	39	3	7.7	116	18	15.5	85	0	0.0	1,121	65	5.8
5-18	80	40	2	5.0	79	7	8.9	97	8	8.2						

Appendix Table 1. Continued.

		4A orifice trap			4A gatewell			4A trashrack			5A gatwell			Juvenile fish facility		
			Descaled			Descaled			Descaled			Descaled			Descaled	
Date	MW	Number examined	No.	(%)	Number examined	No.	(%)	Number examined	No.	(%)	Number examined	No.	(%)	Number examined	No.	(%)
5-19	62	103	7	6.8	129	13	10.1	112	9	8.0	60	5	8.3	394	26	6.6
5-20	62	100	11	11.0												
5-21	62	82	7	8.5										436	17	3.9
5-22	80	200	13	6.5												
5-23	62	410	50	12.2	148	20	13.5	109	10	9.2				174	8	4.6
5-24	62	149	17	11.4	79	6	7.6	91	10	11.0						
5-25	80	172	18	10.5	132	8	6.1	113	9	8.0				963	51	5.3
5-26	80	550	119	21.6	111	30	27.0	124	15	12.1	75	0	0.0			
5-27	62	234	49	20.9										452	29	6.4
5-28	62	225	29	12.9	86	4	4.7	116	10	8.6						
5-29	62	266	22	8.3	72	4	5.6	44	9	20.5				563	31	5.5
5-30	62	123	19	15.4												
5-31	62													161	5	3.1
6-01	62															
6-02	62	68	4	5.9	49	3	6.1	60	4	6.7				63	0	0.0
6-03	62	77	5	6.5	63	1	1.6	63	2	3.2						
6-04	80	119	6	5.0	32	2	6.3	41	3	7.3				92	9	9.8
6-05	80	82	8	9.8	65	2	3.1	103	3	2.9						
6-06	80	141	11	7.8	76	1	1.3	62	6	9.7				222	12	5.4

Appendix Table 2. Descaling data collected from run-of-river subyearling Chinook salmon during the summer juvenile migration during biological evaluations of a rotating vertical barrier screen at McNary Dam, 2005.

	Turbine load	4A orifice trap			Juvenile fish facility			6B orifice trap		
		Number	Descaled		Number	Descaled		Number	Descaled	
Date	(MW)	examined	Number	(%)	examined	Number	(%)	examined	Number	(%)
6-14	62	96	9	9.4	546	6	1.1	202	2	1.0
6-18	62	138	5	3.6	3,000	27	0.9	198	5	2.5
6-20	62	191	5	3.6	2,670	16	0.6	202	4	2.0
6-21	62	139	9	6.5				153	2	1.3
6-22	62	243	8	3.3	1,640	18	1.1	202	4	2.0
6-23	62	211	4	1.9						
6-24	62	167	5	3.0	4,825	67	1.4	220	4	1.8
6-25	62	104	4	3.8	4,667	56	1.2	214	5	2.3
6-26	62				1,360	23	1.7			
6-27	62				2,500	35	1.4			
6-28	62	232	6	2.6	3,471	59	1.7	251	7	2.8
6-29	62	316	8	2.5	2,857	20	0.7	434	7	1.6
6-30	62	344	13	3.8	2,417	29	1.2	436	19	4.4
7-01	62	341	19	5.6	2,400	24	1.0	26	4	15.4
7-02	62	208	7	3.4	600	6	1.0			
7-03	62				666	6	0.9			
7-04	62				470	7	1.5			
7-05	62	463	18	3.9	700	7	1.0			
7-06	62	53	0	0.0	1,190	25	2.1	213	6	2.8
7-07	62	182	5	2.7	1,000	10	1.0	342	8	2.3
7-08	62	42	2	4.8	1,000	10	1.0	296	6	2.0