Evaluation of a High-Velocity Induction/Release System for Testing Turbine-Related Injuries to Juvenile Salmonids at Hydroelectric Projects

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EXECUTIVE SUMMARY

The National Marine Fisheries Service (NMFS) was contracted to test the induction/release portions of a high-velocity induction system during fall 1998. The system was designed for a 1999 U.S. Army Corps of Engineers study to monitor the condition of migrating juvenile salmonids after they pass through the turbines at McNary Dam.

The system was tested at NMFS Pasco Field Station, where the induction/release portions of the system were installed. During late October and early November 1998, we released and monitored a total of 99 juvenile hatchery fall chinook salmon. We saw no indication of descaling or other injury to any of the test animals. We also monitored the fish with an underwater video camera as they exited the system. We determined that fish exited the system in a variety of orientations, either head or tail first, and that a few of the fish appeared to be tumbling rather than swimming at exit.

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INTRODUCTION

The U.S. Army Corps of Engineers (COE) is developing procedures to more effectively evaluate injury and/or mortality rates of juvenile salmonids that pass through low-head Kaplan turbines. Preliminary testing is scheduled to begin at McNary Dam during the spring outmigration of 1999. During fall 1998, the National Marine Fisheries Service (NMFS) was asked to examine methods to place migrating juvenile salmonids at selected areas within the turbine intake. An induction/release system under consideration for this purpose was constructed and tested at NMFS Pasco Field Station in October-November 1998.

The system, which was designed to release juvenile salmonids into the turbine at McNary Dam, is composed of a 20.3-cm-diameter polyvinyl chloride (PVC) pipe that ends with a concentric nozzle 20.3-15.2 cm in diameter and 45.7 cm in length. The pipe will extend from the main deck of the dam down through a gatewell to selected release sites within the turbine intake. Total length of the system will approach 70 m.

Velocities at the test pipe exit were designed to match turbine intake velocities, approximately 6 m/sec. Limited amounts of space and water at the Pasco Field Station allowed us to test only the induction (placing fish into the high-velocity pipe) and the release (observing how fish exited the concentric nozzle) portions of the overall system. The primary objective of our testing was to determine if either the induction or release sections would contribute to injury or mortality. A secondary objective of monitoring tagged fish was added after we had begun our tests.

APPROACH

The Pasco Field Station has three concrete raceways, each of which is 2.6 m wide by 1.2 high and 20.1 m long. There is also a reservoir that is 1.8 m wide by 1.2 m high and 6.1 m long. The reservoir is adjacent to the raceways and is supported by pilings, so that the bottom is 1.8 m above ground level. We connected a 20.3-cm PVC pipe to the reservoir and extended it to a smaller holding tank positioned above one of the concrete raceways (Fig. 1). The smaller tank was 1.2 m wide by 1.5 m high and 1.2 m long and was used as the fish induction area (see Fig. 1). We then attached a 90° PVC sweep (1.1 m long) to the bottom of the small tank and extended this line 4.9 m where it terminated with the concentric nozzle. The PVC line between the two tanks had a valve and an in-line flow meter. The PVC line to the concentric nozzle was equipped with a pinch valve 1.2 m from the nozzle.

In the induction tank a 20.3-cm PVC standpipe 1.2 m in height provided water to the PVC exit line. The bottom 40.6 cm of the standpipe was perforated, so that with the proper water level in the tank, vortices would not be created. This standpipe was capped,

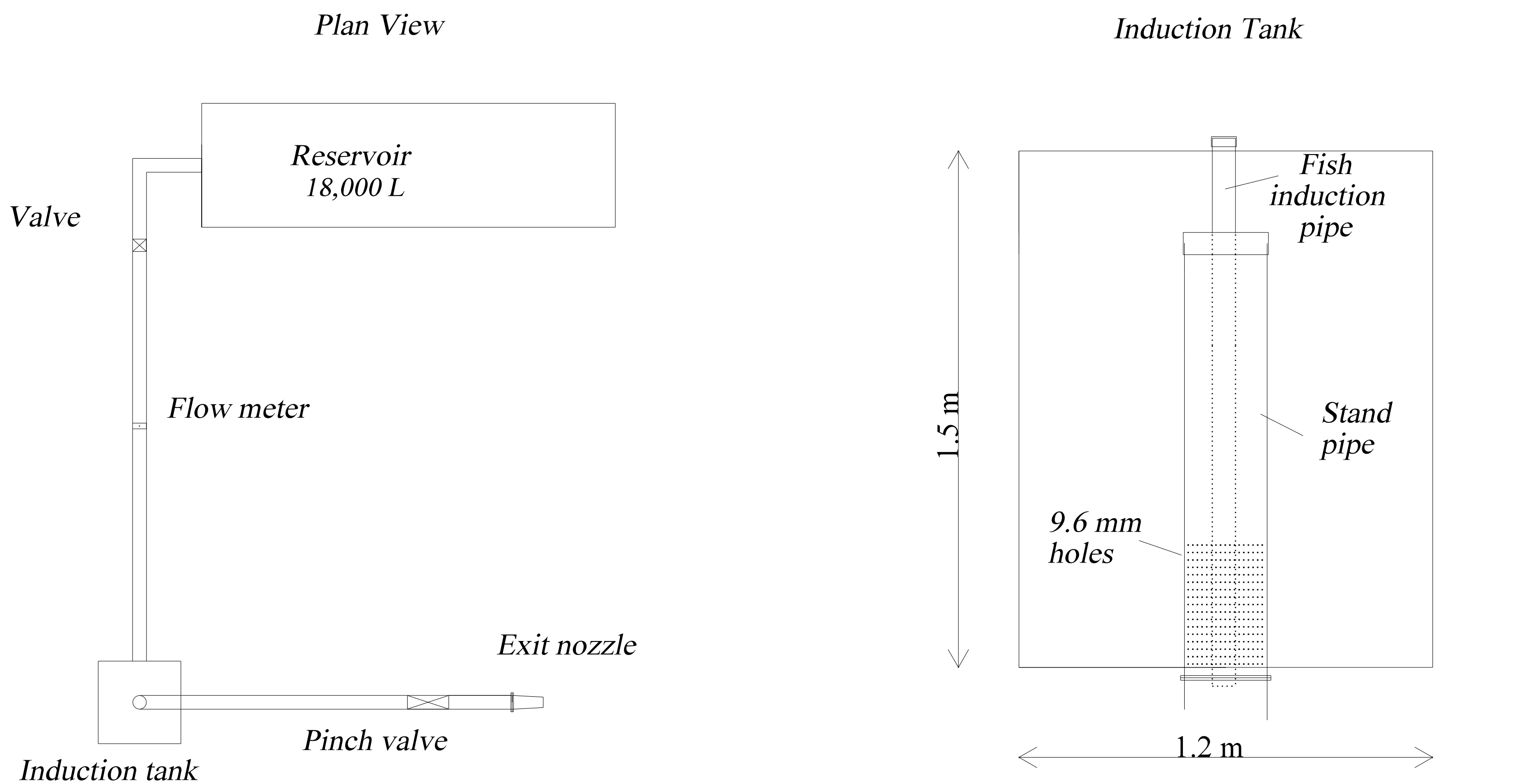

Figure 1. Plan view of test area and close-up view of fish induction tank used for the high-velocity induction/release tests at NMFS Pasco Field Station, fall 1998.

and a 10.2-cm PVC line was inserted through the cap and extended into the tank outlet (Fig. 1). The 10.2-cm PVC line was used as the fish induction line. Initially, we tried to run the system at a "steady state" (with the fish induction line always open) and simply placed test fish into the smaller PVC line for induction into the system. We found this was not possible because air was continually entrained through the 10.2-cm line, and we could not monitor fish exiting the nozzle.

To reduce air entrainment it was necessary to use the pinch valve. The operating steps were 1) close the pinch-valve, 2) remove the cap from the 10.2-cm induction pipe and fill the small tank to 1.2 m, 3) place fish into the 10.2-cm line and re-cap, and 4) open the pinch valve. This head (surface of induction tank to surface of raceway) of 2.6 m provided an exit velocity at the nozzle of approximately 4.6 m/second into a static tank.

We used non-smolted, hatchery fall chinook salmon for test fish (fork length averaged about 170 mm). The fish were transported to NMFS Pasco Field Station and held in net-pens prior to testing. Initially, we used untagged fish and monitored their condition before and after passage through the induction/release system. We used underwater cameras (low-light charge-coupled device (CCD)) to videotape fish as they exited the concentric nozzle. We observed fish exiting in a variety of orientations and reported these observations to the COE. Plans were then developed to release tagged fish through the system to determine if the induction/release system caused problems with the tags or the method used to attach the tags to the fish, and to view tagged fish as they exited the nozzle.

Both tagged and untagged fish were individually released into the induction pipe. Fish were tagged by Normandeau Associates[1] personnel just prior to release. The primary tags used were a small radio-tag and two "Hi-Z-Turb'n Tags" developed by Normandeau Associates (Fig. 2). All fish were examined upon recapture for signs of descaling/injury and then placed in separate holding areas (separated by test group). Fish were held for at least 5 days to monitor delayed mortality.

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

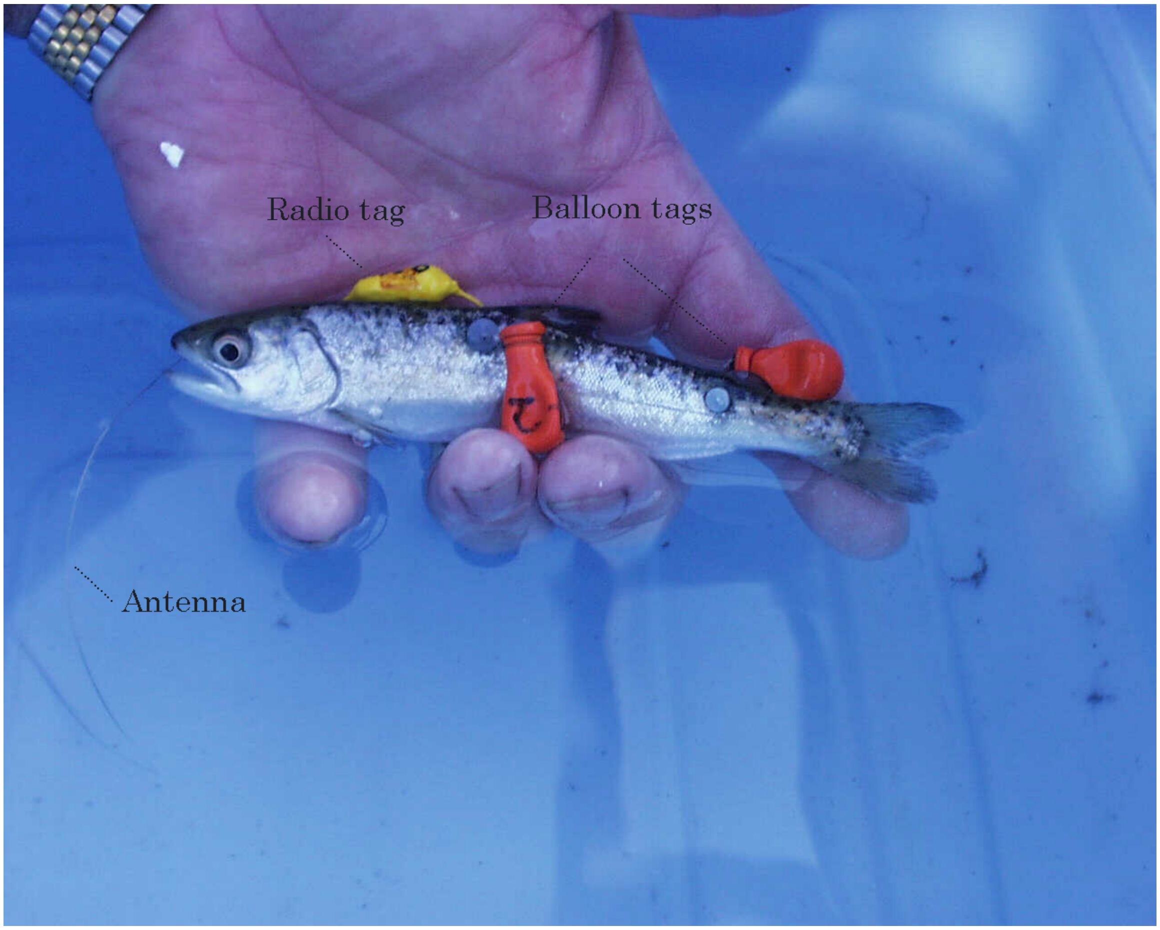

Figure 2. A tagged juvenile chinook salmon used in tests at NMFS Pasco Field Station during fall 1998. The balloon tags are the "Hi-Z Turb'n Tags" (non-inflated), and the lighter colored tag is a radio-tag (with antenna).

RESULTS

During a 2-week period in late 1998, a total of 99 hatchery fall chinook salmon were released through the prototype induction/release system. All fish were examined both prior to and after testing for descaling/injury. There was one mortality during the post-test holding period. This fish was examined internally, but no obvious areas of trauma were found, and we concluded that the fish was probably injured during the recapture process after testing. We found no indication that the induction/release portions of the system would cause fish-passage problems through injury or descaling to the fish, although the fact that these were non-smolted juvenile salmonids may limit the usefulness of the descaling data. We also saw no indication of injury problems caused by tags or the methods used to attach them (Table 1).

Although the pinch valve eliminated most of the entrained air, a small amount entered the system with each test fish. This air was usually purged through the nozzle before fish exited, but at times the air and fish exited together, though with no obvious adverse effect on the fish.

We also released a small number of fish (five) during an evening test. This was done to simulate the dark conditions found in a turbine intake. We attached a small chemical light stick in place of one of the balloon tags so that we could identify when fish exited the concentric nozzle, and we did not use radio tags on these fish. The light stick was one typically used by fishermen as an attractant and was about 2.5 cm in length and 0.8 cm in diameter. However, the videotapes showed only a streak of light when fish exited. It was impossible to even determine whether the fish exited head or tail first.

Although the scope of this study did not include evaluation of the swimming capabilities of test fish, we believe some comments on this subject are pertinent. The videotapes showed that fish exited the system under a variety of orientations, from horizontal to nearly vertical, and either head- or tail-first. Appendix Table 1 shows the orientation of test fish as they exited the concentric nozzle. Some tagged fish appeared to exit the nozzle in a “tumbling” orientation. We could not determine whether this was caused by the tags (the additional weight/flow resistence or a reaction to the tagging process) or simply by the inability of an individual fish to “right itself” over the fairly short distance under high-velocity flow. However, we noted that not all of the untagged fish exited in what could be called an “in-control” orientation.

Table 1. Release data and recovery condition for juvenile chinook salmon tested with the high velocity turbine release system, Pasco Field Station 1998.

Date of release	Number tagged/untagged	Recovery condition	Delayed condition
22 October	20 Untagged	Good[a]	Good
24 October	24 Untagged	Good	Good
5 November[b]	10 Tagged	Good	Good
5 November	10 Tagged	Good	Good
5 November[c]	5 Tagged	Good	Good
6 November	8 Tagged	Good	Good
6 November	8 Untagged	Good	Good
6 November	7 Tagged	Good	Good
6 November	7 Untagged	Good	Good

[a] Indicates that no obvious external injury or descaling was visible on the fish.

[b] One fish from this group died within the first 24-hour post-test period. It is thought the fish was injured during recovery within the raceway.

[c] These fish were tagged with one balloon tag and one chemical light stick.

CONCLUSIONS

The tests we conducted were specifically designed to monitor the general condition of juvenile salmonids after passage through the high-velocity induction/release system to be tested at McNary Dam during the 1999 outmigration. We found no evidence of descaling or gross external injuries immediately after testing or during a 5-day post-test holding period. Our test system was designed to duplicate induction flows into the high-velocity system and exit flows at the concentric nozzle. Therefore, while the orientation of test fish as they exited the nozzle was variable, we cannot say how this system may (or if it will) affect the spring tests. Our data indicated that of the recorded fish, 1 of 32 untagged and 7 of 33 tagged fish appeared to be tumbling as they exited the nozzle.

APPENDIX

Appendix Table 1. Orientation of the test fish as they exited the concentric nozzle during tests at the Pasco Field Season, fall 1998.

Date	Tagged/Untagged	Orientation
Oct 22	Untagged	Attempted using static flow (steady-state) condition. Could not view fish because of bubbles.
	Total 20 fish	
Oct 22	Untagged	Head first, level, swimming
		Vertical, head down, tumbling/swimming
		Tail first, level, swimming/turning
		Tail first, slightly head up, swimming
		Tail first, level, swimming
		Tail first, slightly head up, swimming/turning
		Head first, slightly head down, swimming
		Head first, slightly head down, swimming
		Vertical, head up, swimming
		Head first, level, swimming
		Tail first, level, swimming
		Tail first, level, swimming/turning
		Head first, level, swimming
		Head first, slightly head down, swimming
		Head first, level, swimming
		Tail first, level, swimming
		Tail first, level, swimming/turning
		7 fish were not recorded
	Total 24 fish	
Nov 5	Tagged	Head first, slightly head up, swimming
		Head first, slightly head up, swimming/turning
		Head first, level, swimming
		Head first, level, tumbling
		Tail first, slightly head up, swimming/turning
		Tail first, slightly head up, swimming/turning
		Tail first, slightly head up, swimming
		Head first, level, swimming
		Tail first, slightly head up, swimming
		Tail first, slightly head up, swimming
	Total 10 fish	

Appendix Table 1. Continued.

Date	Tagged/Untagged	Orientation
Nov 5	Tagged	Tail first, level, swimming
		Head first, level, swimming
		Tail first, level, swimming
		Head first, slightly head up, swimming
		Cross-wise, slightly head up, tumbling
		Tail first, upside down, level, tumbling/turning
		Tail first, level, swimming
		Cross-wise, level, tumbling
		2 fish were not recorded
	Total 10 fish	
Nov 5	Tagged	Streak from the light bar
		Streak from the light bar
		Streak from the light bar
		Streak from the light bar
		Streak from the light bar
	Total 5 fish	
Nov 6	Tagged	Cross-wise, vertical, head down, tumbling
		Tail first, swimming
		Tail first, turning/swimming
		Cross-wise, vertical, head up, turning
		Cross-wise, vertical, head up, swimming
		Tail first, level, tumbling
		Head first, level, swimming
		Tail first, level, swimming
	Total 8 fish	

Appendix Table 1. Continued.

Date	Tagged/Untagged	Orientation
Nov 6	Untagged	Head first, level, swimming
		Tail first, level, turning/swimming
		Tail first, slightly head up, swimming
		Tail first, slightly head down, swimming
		Head first, level, swimming
		Tail first, slightly head up, swimming
		Head first, level, swimming
		Head first, level, swimming
	Total 8 fish	
Nov 6	Tagged	Tail first, slightly head up, swimming
		Head first, head up, swimming
		Head first, level, swimming
		Head first, level, swimming
		Cross-wise, vertical, head up, tumbling
		Tail first, level, swimming
		Tail first, level, swimming
	Total 7 fish	
Nov 6	Untagged	Head first, level, swimming
		Head first, level, swimming
		Head first, nearly vertical, head down, turning/swimming
		Tail first, level, swimming
		Head first, level, swimming
		Tail first, level, swimming
		Head first, level, swimming
	Total 7 fish	