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Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

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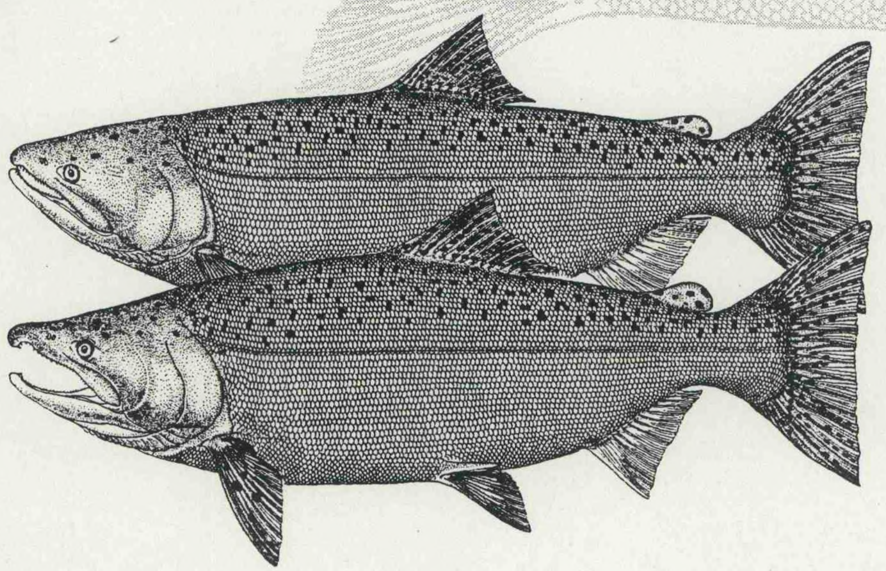

Evaluation of Juvenile Fall Chinook Salmon Passage through the McNary Dam Juvenile Fish Bypass System to Identify Areas of Delay

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Report of research by

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Northwest Fisheries Science Center
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EXECUTIVE SUMMARY

In 2001, the National Marine Fisheries Service completed the second year of a study to evaluate travel times of juvenile subyearling chinook salmon *Oncorynchus tshawytscha* in the bypass system at McNary Dam. The first year of study indicated a delay associated with passage through the juvenile fish bypass system: median residence times within the Unit 8A gatewell were 2.8 hours. During 2001, radiotelemetry receivers were deployed to determine areas of delay within the gatewell, collection channel, and separator.

River-run subyearling chinook salmon were collected and radio tagged at the McNary Dam juvenile fish collection facility, released into gatewells of three turbine units, and monitored as they passed through the bypass system.

All of the 261 radio-tagged fish released were detected as they passed through the bypass system and exited the separator. Median residence time in Gatewells 8A, 10A, and 13A was 8.6, 2.6, and 3.7 hours, respectively. This accounted for 90-98% of total travel time through the juvenile bypass system.

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INTRODUCTION

Fish diversion from turbine passage is an important component in increasing survival for juvenile salmonid migrants at hydroelectric dams in the Columbia River Basin (Iwamoto et al. 1994; Muir et al. 1995, 1996). Numerous studies have examined post-diversion survival of fish following structural or operational changes at hydroelectric dams. However, few studies have evaluated fish passage and timing through the juvenile fish bypass/collection system after diversion.

Extensive delays within juvenile fish bypass systems can affect survival and overall fish health. The McNary Dam collection facility has been shown to affect stress levels in fish (Maule et al. 1988). Stress caused by each element of the bypass system can have cumulative effects on the fish. Maule et al. (1988) concluded that the amount of time juvenile chinook salmon *Oncorhynchus tshawytscha* spend in the bypass system can have serious implications on fish health. Therefore, any reduction in delay at the gatewell, collection channel, or separator should reduce total stress experienced by the fish and diminish impacts on fish health.

Subyearling chinook salmon migrate downstream later in the season than other salmonid populations, and passage delays combined with deleterious conditions may result in higher mortality rates. In 1999, the National Marine Fisheries Service (NMFS) conducted a PIT-tag study to evaluate post-detection bypass survival for river-run subyearling chinook salmon at McNary Dam (Smith et al. 2000).

This work showed that treatment groups released into the gatewell of Turbine Unit 8 remained within the bypass system for a median time of 12 hours, with fish remaining for days in some cases. As a result, during coordination discussions with the U.S. Army Corps of Engineers concerning a second year of study, we were asked to determine potential areas of delay through the use of radiotelemetry. Results indicated that the median travel time for subyearling chinook salmon released into Gatewell 8A was 2.5 hours, with gatewell residence accounting for 97% of the observed delay (Axel et al. 2001).

Our research objectives in 2001 were 1) to use radiotelemetry methods to further evaluate juvenile subyearling chinook salmon passage and delay through the McNary Dam juvenile fish bypass system, and 2) to determine residence times of radio-tagged fish in the gatewell, collection channel, and separator.

METHODS

Study Area

McNary Dam, the fourth dam on the Columbia River, is located 471 km upstream from the river mouth. The study area was the McNary Dam juvenile fish bypass system including gatewells in Turbine Units 8, 10, and 13, the collection channel, and the separator (Fig. 1). The A intakes of each turbine unit were chosen because more water passes through these slots as a result of turbine rotation direction and conditions represent a worst-case scenario.

Radio Tags

Radio tags, purchased from Advanced Telemetry Systems Inc.,[1] were pinger-type, measuring 15 mm in length by 6 mm in diameter and weighing 1.0 g in air. The radio tags had an expected battery life of 7 days and transmitted a pulse every 2 seconds. This tag is 0.4 g lighter than the tags that are used in yearling chinook studies, and was necessary in order to tag the smaller subyearling chinook at McNary Dam. Each pinger produced its own identifiable code, which allowed us to discern separate individual fish detections.

Test Fish and Tagging Protocol

Fish used in this study were river-run subyearling chinook salmon collected from 19 June through 25 July at the juvenile collection facility in the bypass subsample at McNary Dam (Table 1). We arbitrarily removed 30-32 anesthetized fish from the sample and allowed them to recover in a 113.5-L container with flow-through water 24 hours prior to tagging. The study design called for releases of 9 radio-tagged fish per gatewell each day for a total of 27 to be released; 4-6 extra fish were collected to ensure that test fish of poor condition were not used in the study. Study fish were measured and their condition noted.

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

Table 1. Number of radio-tagged subyearling chinook salmon collected, tagged, and released within the juvenile fish bypass system at McNary Dam, 2001.

Date	Number collected	Number tagged	Number released
21-Jun	31	27	22
25-Jun	33	27	26
28-Jun	31	27	27
02-Jul	32	27	27
05-Jul	32	27	27
09-Jul	31	27	27
12-Jul	33	27	25
16-Jul	32	27	27
19-Jul	31	27	27
23-Jul	31	27	26

Table 2. Total numbers of subyearling chinook salmon radio-tagged and released for each treatment at McNary Dam, 2001.

Gatewell	Total tagged	Mortalities	Total released
08A	89	4	85
10A	85	1	84
13A	93	1	92
Totals	267	6	261

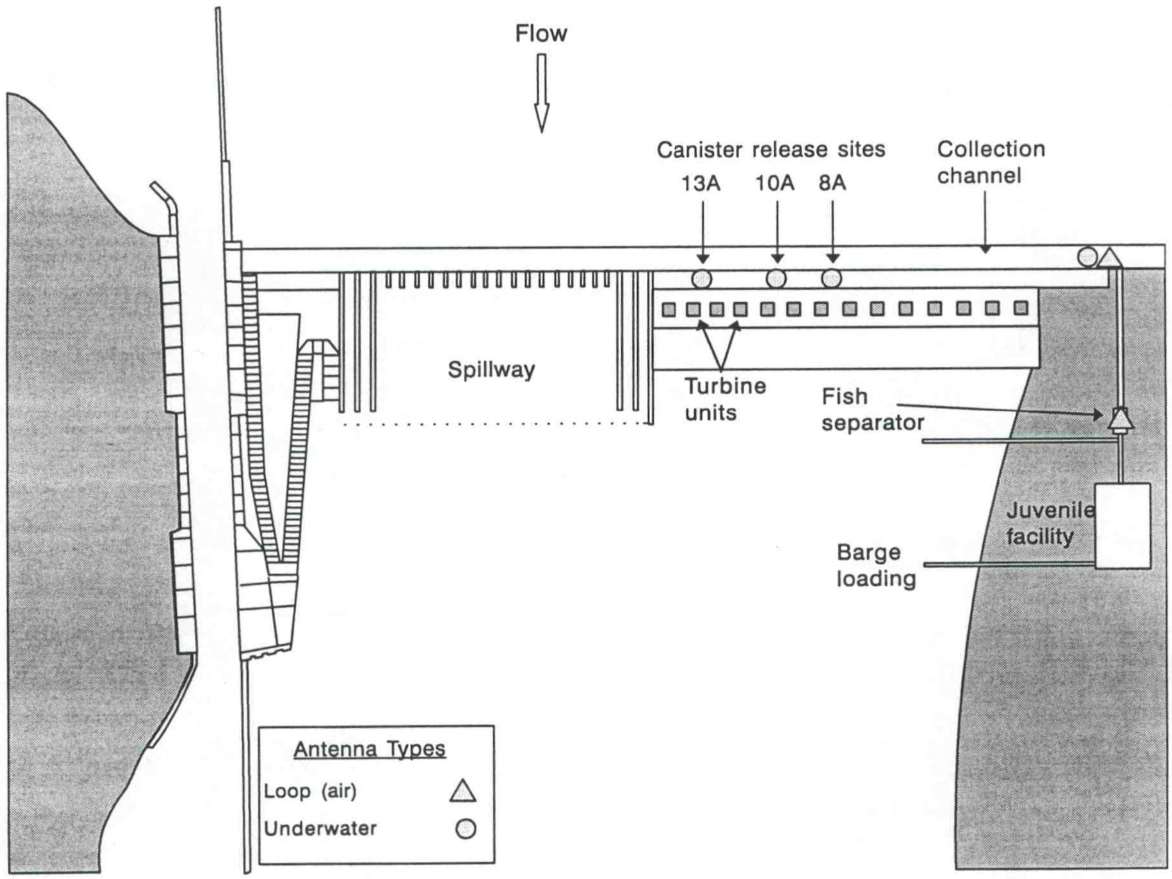

Figure 1. Locations of telemetry receivers, types of antennas, and release sites in the juvenile fish bypass system at McNary Dam, 2001.

Test fish ranged from 114 to 134 mm in length, while lengths of all subyearling chinook salmon within the sample ranged from 64 to 192 mm. We tried to maintain a 2.0% tag-to-body weight ratio throughout the study. Six mortalities were incurred from a total of 267 tagged fish for an overall mortality rate of 2.2% (Table 2).

Prior to radio tagging, fish were PIT tagged (Prentice et al. 1990) using individual, pre-sterilized syringes with a 12-gauge hypodermic needle. Used syringes were sterilized in ethyl alcohol for a minimum of 10 minutes before reloading with PIT tags.

After fish were PIT tagged, they were radio-tagged using gastric tagging techniques similar to those described by Adams et al. (1998). Fish were held ventral side up in an 8-L dishpan containing anesthetic while the transmitter was gently pushed into the stomach using a plexiglass tube (4 mm in diameter, 150 mm long). The transmitter was bent prior to implantation so that the portion protruding from the mouth pointed posteriorly.

We tagged a total of 267 subyearling chinook salmon. Individual radio-tagged fish were held in buckets containing fresh water and placed in a tank with a flow-through water system mounted on trucks for recovery and transport to the release site.

Release Protocol

We maintained a post-tagging recovery time of 22 to 24 hours. The morning after tagging, fish were transported and released into Gatewells 8A, 10A, and 13A using a release canister which was lowered to a depth of 18.3 m (Absolon and Brege in press). Releases were made between 0500 and 0600 PST into all three gatewells on each release day. Prior to release, dead fish were removed from the buckets and recorded.

Monitoring of Radio-Tagged Fish

Radiotelemetry receivers were installed at McNary Dam to monitor the gatewells, collection channel exit, and separator. We attached double-shielded coaxial antennas to the turbine-intake fish screens prior to the annual screen deployment in March. Dipole antennas and air antennas were deployed in the collection channel to increase range of detection. We placed underwater antennas in the separator to determine entrance and exit times.

Statistical Analysis

Data files were downloaded daily from telemetry receivers at McNary Dam during the study period. Downloaded files consisted of records for each time a radio-tagged fish was detected. Records included a date/time stamp and the channel and wavelength (code) of an individual transmitter. Each file was then compiled to combine and count records wherein an individual fish had been detected by the same receiver within a 5-minute interval. Compiled records were sorted by receiver location and loaded to a database. False detections were eliminated using the following criteria: 1) the number of detections on a given receiver occurred at an approximate rate of one every two seconds for a predetermined minimum number of detections (depending upon the water velocity at the site) and 2) there was an incorrect chronological progression through the bypass facility.

Residence time in the gatewell was calculated as the date/time difference between release and last detection in the gatewell. Residence time in the collection channel was calculated as the difference between last detection at the gatewell monitor and last detection at the collection channel exit. Separator residence time was determined by first and last detections on the separator receiver.

Gatewell, collection channel, and separator residence time distributions were compared with a Kaplan-Meier time-to-event model using a log-rank test statistic (Hosmer and Lemeshow 1999, Harrington and Fleming 1982). The "events" were passage out of the gatewell, collection channel, or separator; thus residence times are the "time-to-event" data.

RESULTS AND DISCUSSION

We detected all 261 fish on each of our telemetry lines. Residence times of radio-tagged subyearling chinook salmon by release group for gatewells 8A, 10A, and 13A are shown in Figure 2. Distributions of gatewell residence times are shown in Figure 3. Median residence time in Gatewells 8A, 10A, and 13A was 8.6, 2.6, and 3.7 hours, respectively. Gatewell residence contributed 90-98% of the overall travel time through the bypass system for radio-tagged fish (Fig. 4).

Distributions of passage times from the gatewell orifices (i.e., gatewell residence times) are shown in Figure 5. The distribution for Gatewell 8A was significantly longer than for 10A or 13A ($P < 0.001$), which were not significantly different from each other ($P = 0.398$). This pointed to a possible difference in operations between the units. During 2001, Unit 8 was shut down repeatedly during the subyearling chinook salmon outmigration. However, releases were made at approximately 0600 h which, on most days, gave the fish 14 or more hours to leave the gatewell during normal operation.

Beeman and Maule (2001) found that median gatewell residence time for yearling chinook salmon released into gatewell 5A was 8.9 hours. For the most part, they found that fish released during daylight hours spent prolonged periods of time within the gatewell as opposed to fish released at night. However, we found that there may be a difference between gatewells. For releases made during a unit outage, seven of the nine fish exited the gatewell before the unit came back on line.

Median collection channel travel times for fish released into Units 8, 10, and 13 were 4.5, 5.5, and 10.5 minutes, respectively. The distributions of passage times through the collection channel (i.e., collection channel residence times) are shown in Figure 6. Collection channel residence times were shorter for Unit 8A than for 10A, and in turn shorter for 10A than for 13A ($P < 0.001$).

Collection channel travel time increased with increased distance from orifice entrance (Fig. 7), with fish released into Unit 13A taking the longest time to traverse the channel. There was some evidence that these fish were able to hold in the northern end of the channel, though few detections were recorded. Regardless of the significance of differences, the time spent in the collection channel was much less than in the gatewells for all releases. The water velocity within the channel was approximately 2.1 m/s (Brad Eby, U.S. Army Corps of Engineers, Pers. commun.).

A relatively minor passage delay occurred in the vicinity of the floor dewaterer, just upstream from the collection channel exit flume. In this area, the channel widens from 2.7 to 4.3 m. In addition, the channel depth increases from 1.8 m at the north end to 4.3 m at the south end before the dewaterer. This creates a pool where subyearling chinook salmon have been observed holding for prolonged periods of time.

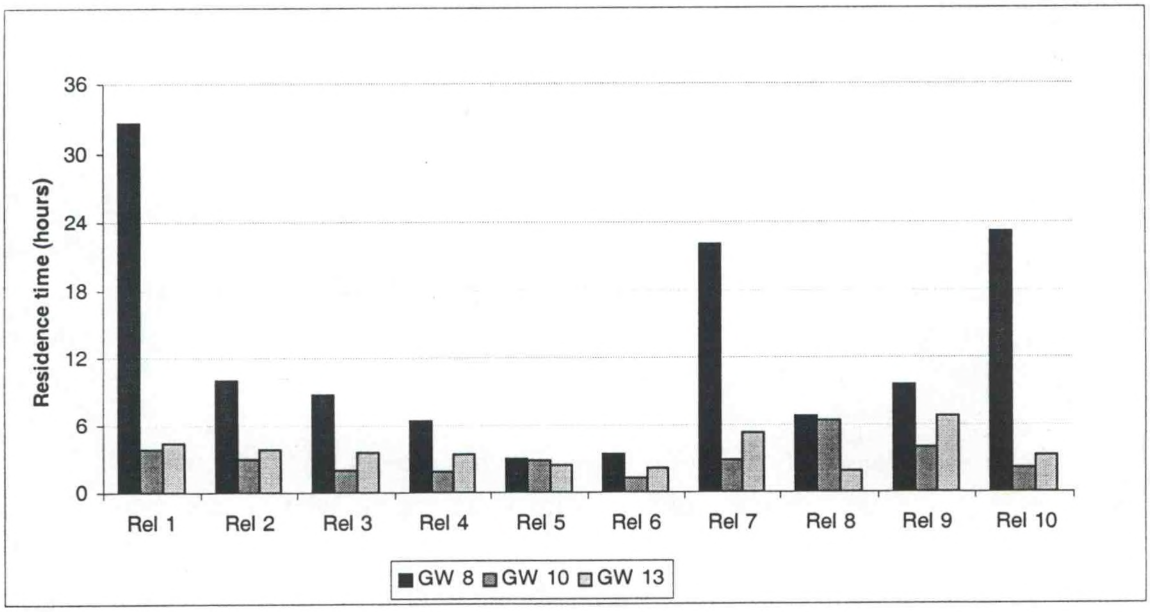

Figure 2. Residence times of radio-tagged subyearling chinook salmon by release group in Gatewells 8A, 10A, and 13A at McNary Dam, 2001.

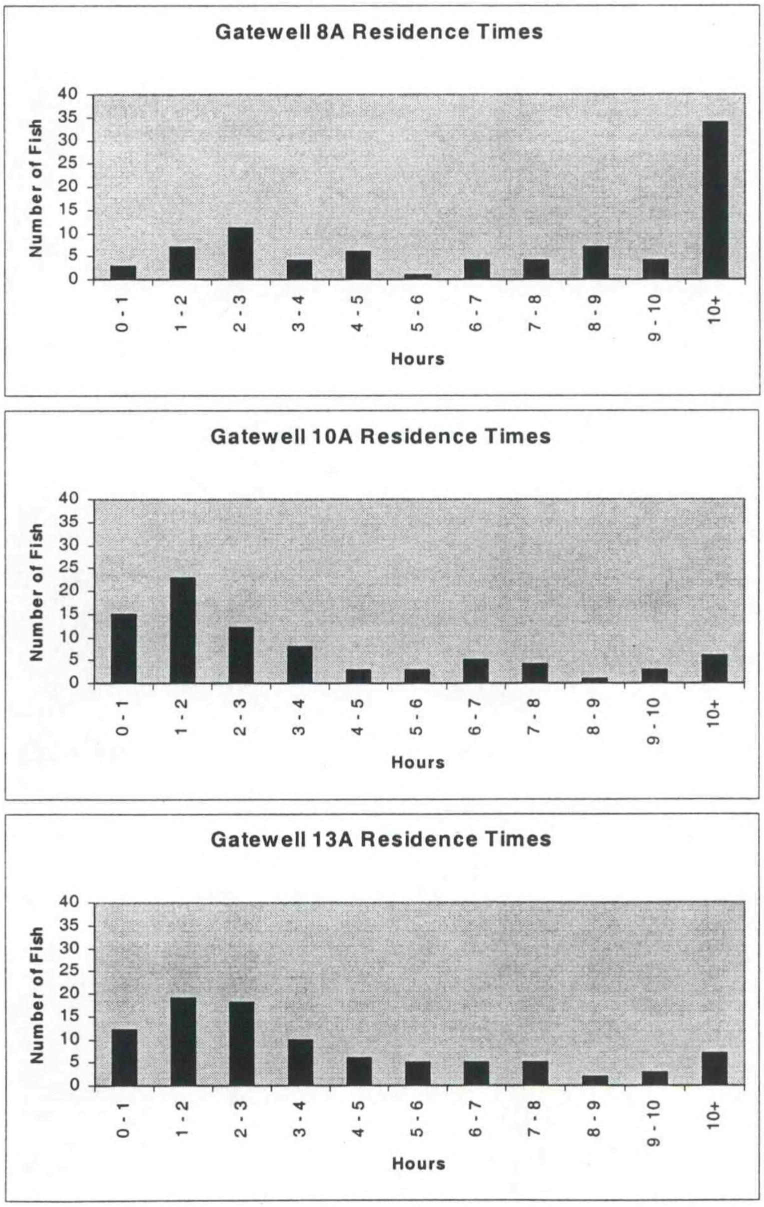

Figure 3. Residence times of radio-tagged subyearling chinook salmon in Gatewells 8A, 10A, and 13A at McNary Dam, 2001.

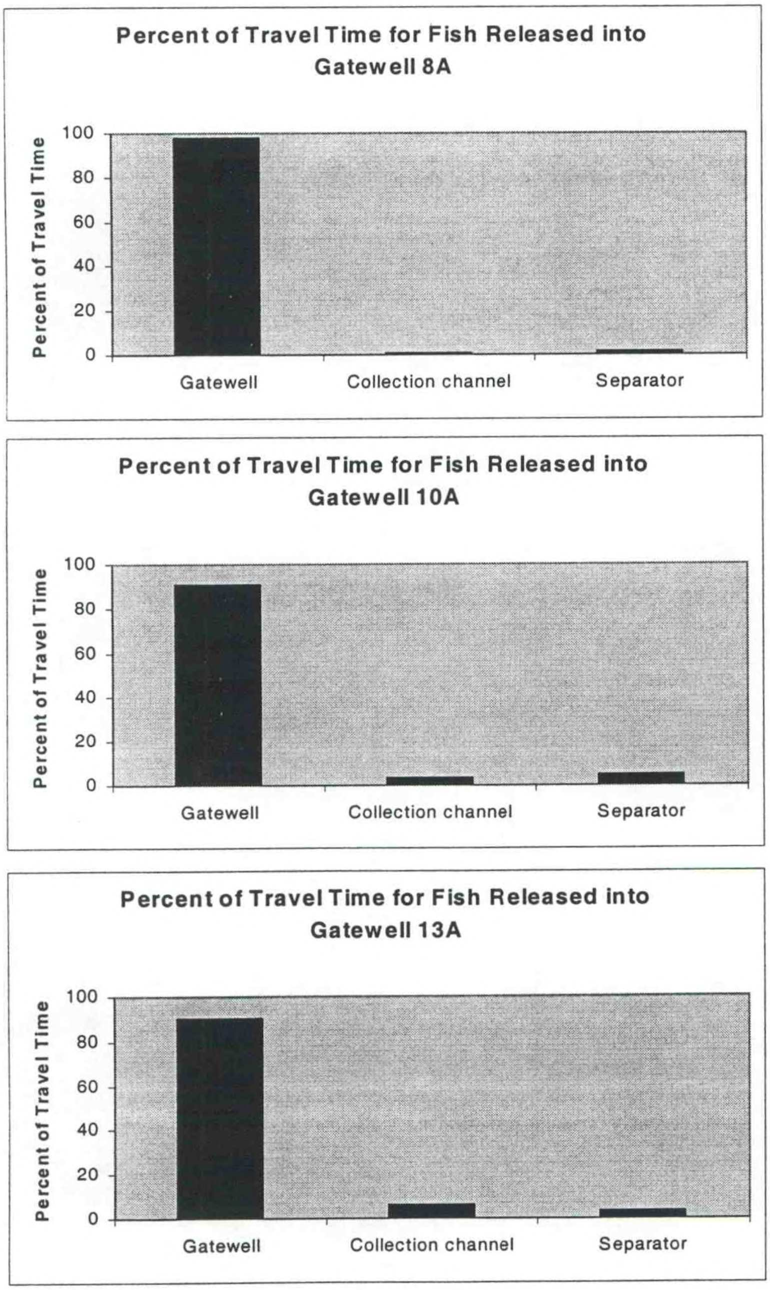

Figure 4. Percent of travel time for radio-tagged subyearling chinook salmon within the juvenile fish bypass system at McNary Dam, 2001.

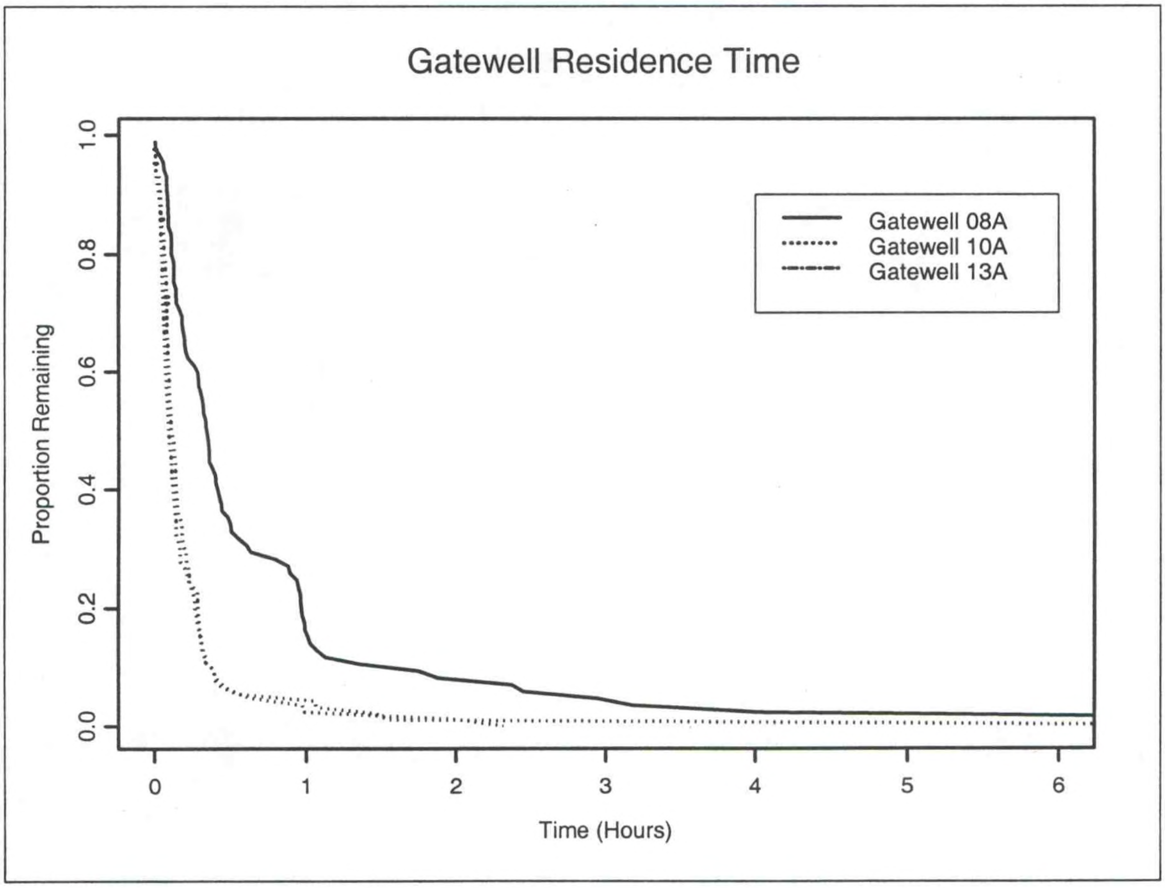

Figure 5. Curves representing the proportion of fish remaining within the gatewell vs. time at McNary Dam, 2001.

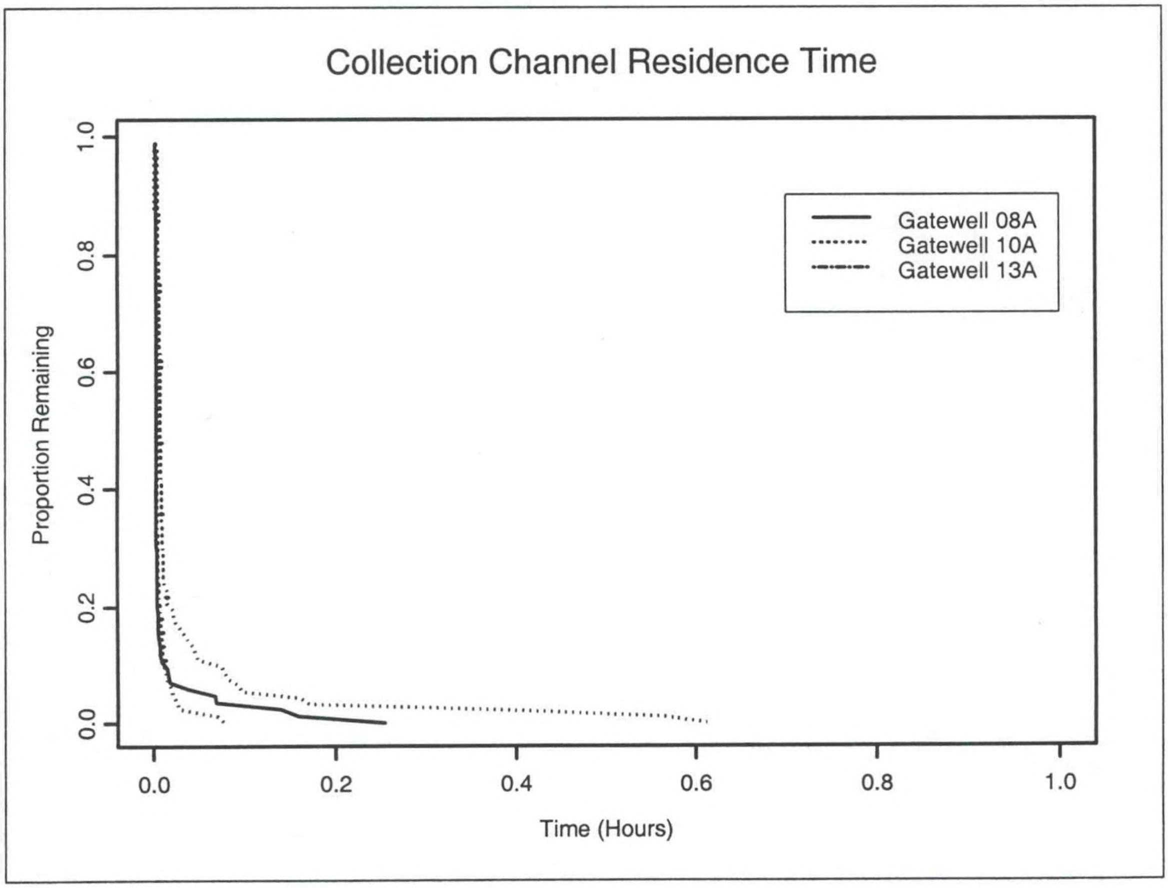

Figure 6. Curves representing the proportion of fish remaining within the collection channel vs. time at McNary Dam, 2001.

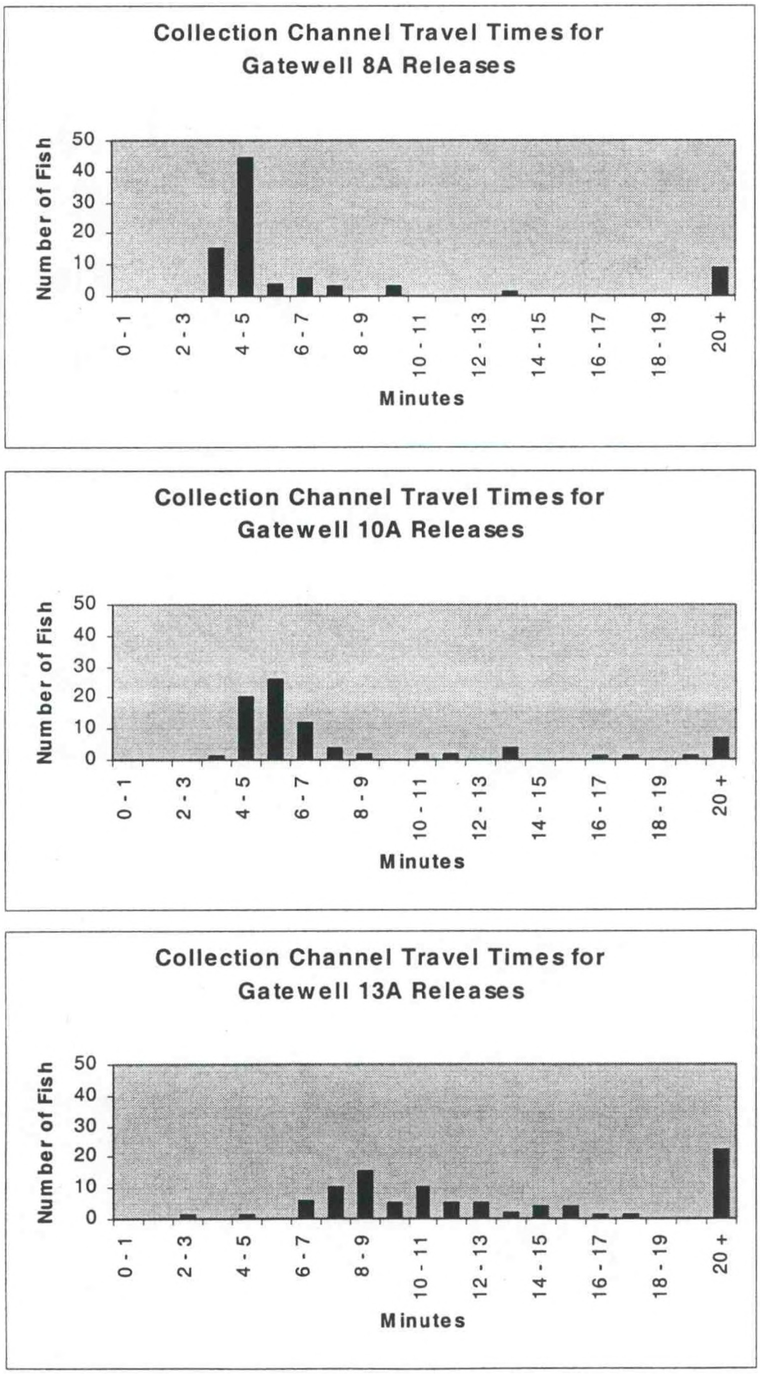

Figure 7. Collection channel travel times for radio-tagged subyearling chinook salmon released into three gatewells at McNary Dam, 2001.

Distributions of passage times through the separator (i.e., separator residence times) are shown in Figure 8. The distributions for fish released in the three gatewells were not significantly different (P = 0.180). Also, much less time was spent in the separator than in the gatewells for all releases. The median residence time, without regard to release site, was 6.5 minutes.

Water temperatures within gatewells were variable throughout the duration of the study. The highest average temperature varied among the three gatewells for each release day (Fig. 9). There was no significant correlation found between temperature and gatewell passage (P = 0.621).

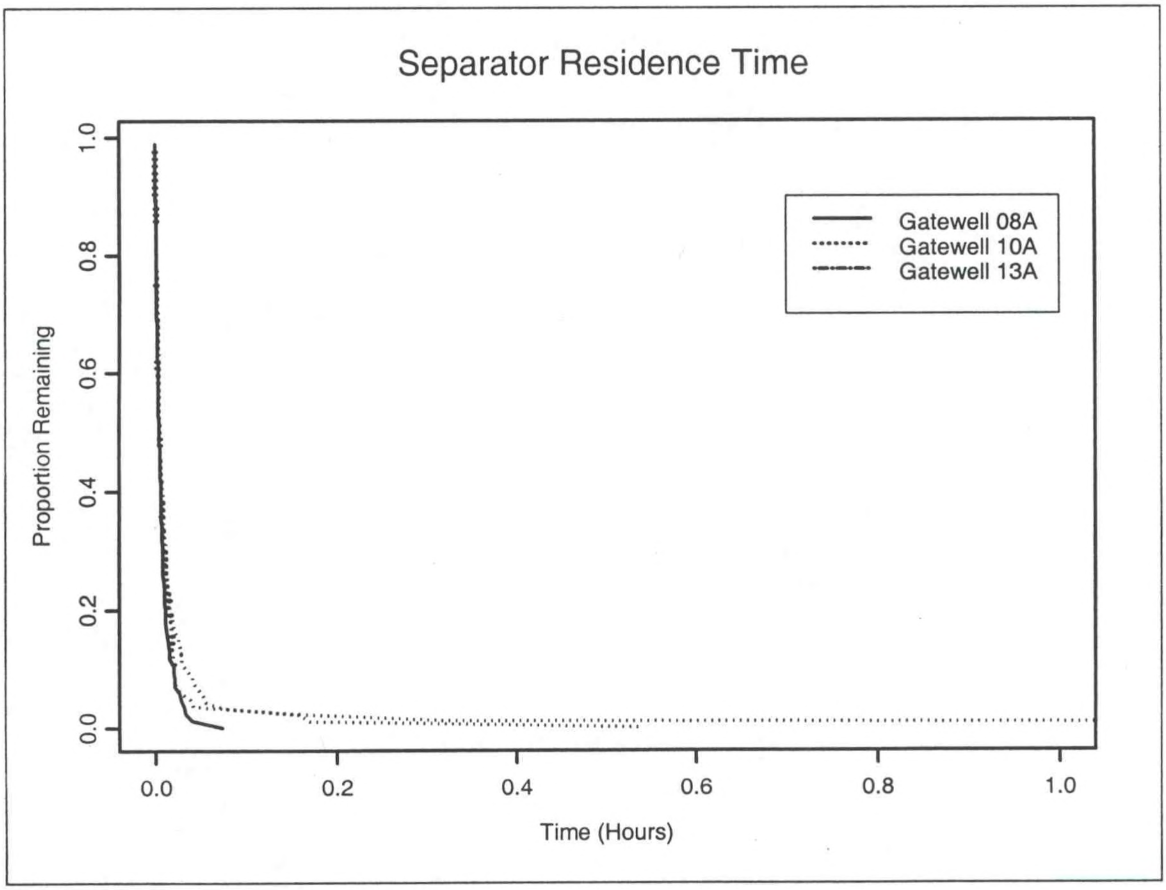

Figure 8. Curves representing the proportion of fish remaining within the separator vs. time at McNary Dam, 2001.

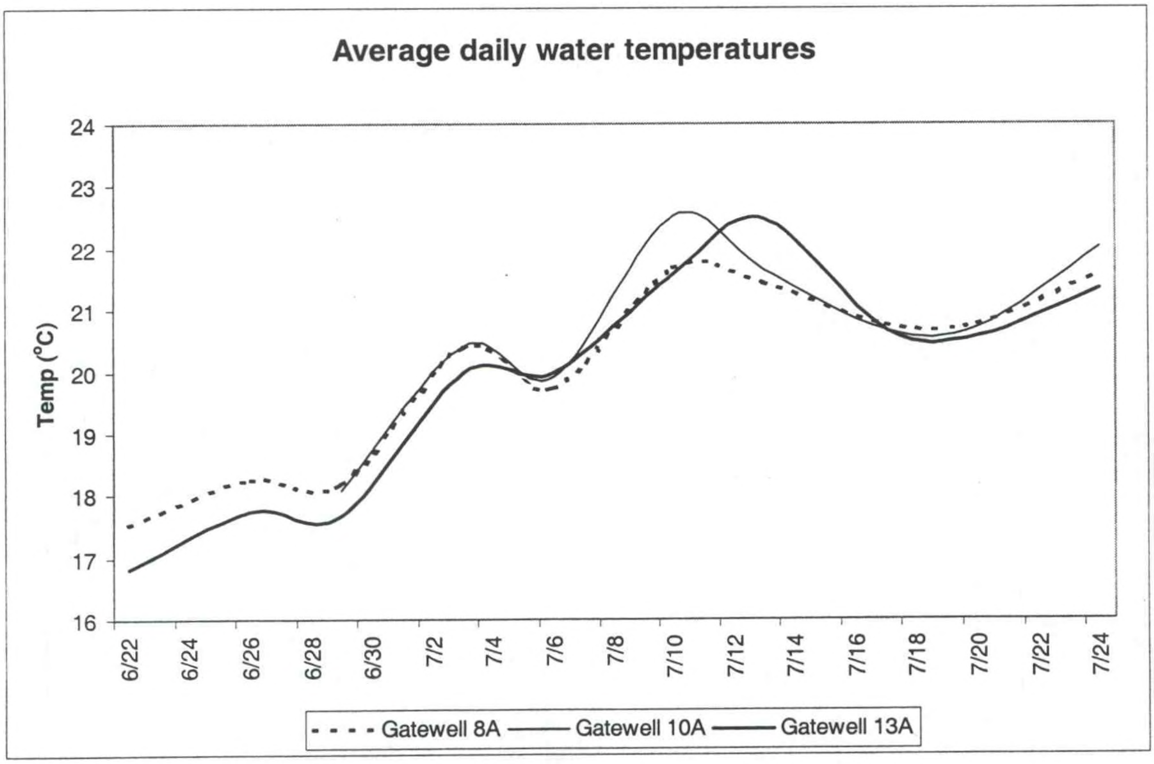

Figure 9. Average daily water temperature within three gatewells at McNary Dam, 2001.

RECOMMENDATIONS

To expedite passage of subyearling chinook salmon is particularly important to minimize descaling, injury, and stress-related impacts that may occur in the bypass system, as well as to avoid elevated water temperatures. Based on our study, gatewell residence accounted for 90-98% of the total travel time through the bypass system; therefore, the best opportunity for reducing passage delay would be to reduce gatewell residence time.

Fish released into Gatewell 8A took three to four times longer to exit the gatewell than fish released into Gatewells 10A and 13A. There appears to be some difference in the gatewell environment that causes much longer residence times in Gatewell 8A. Further evaluation is necessary to investigate differences within the gatewell environments to more fully understand factors that result in passage delay and impacts to fish health and survival at McNary Dam.

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