Overview of the Performance of PIT-Tag Interrogation Systems for Adult Salmonids at Bonneville and McNary Dams, 2002

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EXECUTIVE SUMMARY

During the winter of 2001, the U.S. Army Corps of Engineers and Bonneville Power Administration installed a prototype orifice-based PIT-tag interrogation system into the Washington Shore Ladder at Bonneville Dam (BWSL). NOAA Fisheries (NMFS) tagged and released salmonids during 2001 to determine tag-reading efficiencies for different salmonid populations. The BWSL system detected 97% of spring chinook salmon, but in fall it was discovered that coho and fall chinook salmon used weir overflows at a much higher rate and thus avoided detection. During 2001, technology advances led to the development of significantly larger antennas (2 × 6 ft). Thus, it became feasible to design interrogation systems for ladder locations where all fish would have to go through the antennas.

Although the orifice-based systems appeared less effective for some salmonid populations, the decision was made to proceed with installations planned for Bonneville and McNary Dams because valuable data would still be collected. In addition, a prototype system was installed into the counting-window area in the McNary Oregon Ladder (MOL) where its performance could be directly compared to the orifice-based system in the same ladder. This overview provides information on how PIT-tag interrogation systems at Bonneville and McNary Dams performed during 2002.

Tag-Reading Performances of Counting-Window and Orifice-Based Interrogation Systems in the McNary Oregon Ladder

The orifice-based and counting-window interrogation systems in the MOL became operational on 9 April 2002. The prototype counting-window system underwent several developmental improvements over the season and was finalized on 14 August. From 15 August through 31 October, radiotelemetry and PIT-tag data yielded 743 radio- and PIT-tagged salmonids whose final ascent was via MOL.

The two PIT-tag systems together detected 717 fish or 96.5% of the 743 double-tagged fish. Most (22/26) of the undetected fish were steelhead. The counting-window system detected 95.2% and the orifice-based system detected 96.0% of the double-tagged fish. On a relative scale, both systems detected above 98.5% of the double-tagged fish. The orifice-based system probably detected more fish because it had 16 antennas compared to 2 for the prototype counting-window system.

From 15 August through 31 October, 1,034 river-run migrating adult salmonids were detected by one or both PIT systems. Each system independently detected over 98.5%, and fall chinook salmon and steelhead were detected in equal proportions by both systems.

For spring chinook salmon later detected at Lower Granite Dam, the orifice-based system detected 83% of the 2-year old jacks; the counting-window system detected 94%.

For adult chinook, the orifice-based system detected 99.9% and the counting-window system 96%. A similar trend was seen for fall chinook jacks and adults. Therefore, it appeared that both interrogation systems detected adult chinook salmon better than jacks.

The reading efficiency for the orifice-based system decreased to less than 90% during July. This may have been because the transceivers experienced temperatures above their optimum operating maximums or it may have been due to fish behavior (i.e., summer chinook using the weir overflows).

We recommend using counting-window or vertical-slot based systems in future installations.

Reading Efficiencies of the Orifice-Based System in the Bonneville Washington Shore Ladder

In 2002, NMFS tagged 216 fall chinook salmon, 157 coho salmon, and 250 steelhead at Bonneville Dam. Reading efficiencies for BWSL were 72.7, 79.0, and 90.4% for fall chinook, coho, and steelhead, respectively. Of the fish not detected at Bonneville Dam, a significant number of fall chinook salmon and steelhead were detected at McNary Dam. Overall detection rates were 88.0, 79.6, and 96.0% for fall chinook, coho, and steelhead, respectively.

The BWSL-only reading efficiency results in 2002 compared to 2001 were much lower for fall chinook (2001-90.3%), slightly lower for steelhead (2001-94.8%), and about the same for coho salmon (2001-75.9%). Based on the results for 2001 and 2002, the proportions of test fish that primarily used the orifices (those fish detected in at least seven of the eight weirs) appeared to directly correlate to the reading efficiencies for the different salmonid populations.

As with the results in 2001, it must be emphasized that the primary cause for the lower reading efficiencies for fall chinook and coho was fish behavior (i.e., weir overflow use) and not the failure of orifice-based antennas to detect fish transiting them.

Orifice Passage Behavior in Fish Ladders at Bonneville and McNary Dam

A 25% difference in detection rates of fall chinook salmon between BWSL and MOL in 2002 (72.7 and 99.6% respectively) made us question whether fish behavior was significantly different between ladders. Each of the fish ladders at Bonneville and McNary Dams is designed differently. To look at the impact of ladder design on the level of orifice use by fish, we analyzed the proportions of river-run migrating adult salmonids that primarily used the orifices (those fish detected in at least seven of the eight weirs) as they ascended each ladder.

Results for ladders at both dams strongly suggested that fall chinook salmon might use the weir overflows more in ladders that have partial overflows than ladders with full overflows.

The orifice-based system in MOL detected all salmonid populations at higher rates than the system in BWSL because a higher proportion of each salmonid population primarily used the orifices in that ladder. At least 90% of each salmonid population primarily used the orifices in the MOL, while the proportion of primary use in the BWSL ranged from 40 to 80%.

As was observed at McNary Dam, the orifice-based systems at Bonneville Dam missed more chinook jacks than adults. Despite being active only about half of the day, the flume-based system in the Adult Fish Facility at Bonneville Dam detected 7% more spring/summer chinook jacks than were detected by the orifice-based system, while all adults detected by the flume-based system were also detected by the orifice-based system.

Reading Efficiencies based on Radio-Tagged and PIT-Tagged Salmonids

Radiotelemetry data for spring/summer chinook, fall chinook salmon, and steelhead that were radio and PIT tagged in 2002 have been processed by the University of Idaho to determine migration routes through Bonneville and McNary Dams. Because both types of detection systems missed some fish ascending ladders, we established final ascent information for each individual using both radiotelemetry and PIT-tag data. We also analyzed spring and summer chinook separately because most double-tagged summer chinook were from the Upper Columbia River and were therefore ocean-type salmon instead of stream-type salmon. Results showed that stream-type and ocean-type salmonids behaved differently in fish ladders and consequently were detected at different rates by orifice-based PIT-tag interrogation systems.

The orifice-based systems in all of the fish ladders detected more than 97% of the stream-type spring/summer chinook, while only one system (Bradford B branch) detected more than 95% of the ocean-type summer chinook. The interrogation system in the BWSL performed poorest (53.8%) in detecting ocean-type summer chinook for the upper eight-weir section, and this system also had the poorest performance for fall chinook salmon (also ocean-type; 62.2%). However, in all other ladders, fall chinook were detected at rates above 93%, in contrast to their detection rates for ocean-type summer chinook.

Visual Fish Counts vs. PIT-Tag Detections

Over the years, people have questioned the accuracy of fish counts at counting windows. With PIT-tag systems at both Bonneville and McNary Dams, we compared how well PIT-tag detections and fish counts matched. The 2002 fish count for adult spring chinook salmon at McNary Dam was 48.1% of the total detected at Bonneville Dam. The PIT-tag systems at McNary Dam detected 52.5% of Snake River spring chinook adults detected at Bonneville Dam. Thus, for spring chinook adults, the two approaches yielded similar proportions.

Performance of Orifice Antennas Containing Moisture

In April 2002, around 25% of the fiberglass orifice antenna housings that were installed in 2002 were identified as probably containing moisture. Three times during the season, PSMFC tested all of the antennas with a megohmmeter. These tests showed that most antennas remained consistent over all sets of measurements, but others did change their moisture status. Over the entire 2002 season, around 20% of antennas installed into fish ladders consistently measured as containing moisture.

We compared the median number of reads/fish at BWSL for April 2001 and 2002. The comparison showed that the performance of the antennas containing moisture in April 2002 was equal to or better than it was in April 2001. Therefore, it appeared that the antennas containing moisture had not degraded over time. Furthermore, a nonparametric statistical test comparing the number of reads/fish in BWSL antennas with and without moisture showed the difference was not significant. Thus, there did not appear to be any difference in the ability of antennas to read tags based on moisture content.

Analyses conducted during the rest of the year (May-September) on all of the ladders demonstrated that whenever a median value for the reads-per-fish went below five, then that antenna was missing fish occasionally. Of the nine orifice antennas that averaged less than five reads/fish, only two were from the list of antennas mostly containing moisture; none was from the definite group of antennas containing moisture. Therefore, there are other reasons besides having some moisture in the antennas for these systems to miss detecting fish. It needs to be emphasized that these are new systems and we are still learning how to improve their performances.

No antennas failed during 2002. Analyses of all of the antennas using number of reads/fish, weir counts, and transceiver current and voltages did not consistently identify any single antenna that was weak. Thus, the decision was made in mid September not to replace any of the antennas during the 2002-2003 dewatering period.

CONTENTS

INTRODUCTION

During winter 2001, the U.S. Army Corps of Engineers (Corps) and Bonneville Power Administration (BPA) installed a prototype orifice-based PIT-tag interrogation system into the Washington Shore Ladder at Bonneville Dam (BWSL). Detectors were installed into 12 weirs: 4 downstream (Weirs 334-337) and 8 upstream (Weirs 352-359) from the fish release point (i.e., the exit ladder for the Adult Fish Facility).

NOAA Fisheries (National Marine Fisheries Service – NMFS) tagged and released salmonids during 2001 to determine tag-reading efficiencies for different salmonid populations (Downing et al. 2004). Data analyses focused on the upper eight weirs. The 2001 tagging results for spring chinook salmon indicated that having detectors in four consecutive weirs would have been sufficient to yield a reading efficiency of 95%; the overall reading efficiency was 97%. The BWSL orifice-based system performed well until the coho and fall chinook salmon migrations began. Coho and fall chinook salmon appeared to use the weir overflows, and thus avoid detection, at much higher rates than biologists expected.

During 2001, technology advances in the transceiver technology led to the development of significantly larger antennas than had been available earlier, and thus it was possible to build antennas of approximately 2 × 6 ft. Consequently, it became feasible to design interrogation systems for ladder locations where <u>all</u> fish would have to go through the antennas and thus could not avoid detection by using the weir overflows (Fig. 1). Destron Technologies by Digital Angel[†] designed a prototype interrogation system with two antennas. The system was installed into the counting-window area in the Oregon Ladder at McNary Dam, where its performance could be directly compared to that of the orifice-based system in the same ladder.

Although the orifice-based systems appeared less effective than the fisheries community wanted for fall chinook and coho salmon, the decision was made to proceed with installations planned for Bonneville and McNary Dams because valuable data would still be collected. During the winter of 2002, the Corps and BPA installed PIT-tag interrogation systems into the Bradford Island and Cascades Island Fish Ladders at Bonneville Dam and into the Washington and Oregon Ladders at McNary Dam. Like BWSL in 2001, these ladders had eight weirs (16 orifices) outfitted with fiberglass antennas. Douglas County Public Utility District also installed an orifice-based system into its ladders at Wells Dam, but they were able to use weirs with no overflow sections wherein all fish had to swim through the orifice antennas. Thus, 2002 was the first year that the fisheries community had PIT-tag detection of adult salmonids at Bonneville, McNary, Wells, and Lower Granite Dams (Fig. 2). This overview will provide information on how well the systems at Bonneville and McNary Dams performed.

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

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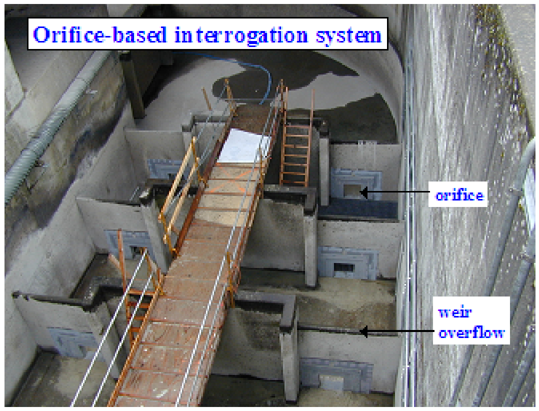

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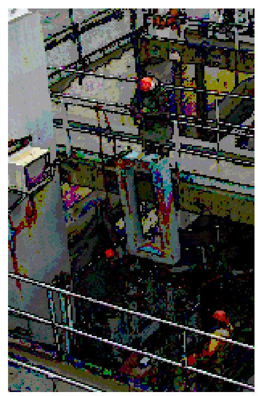

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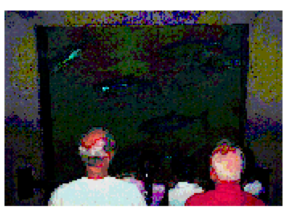

Figure 1. The orifice-based interrogation system at Bonneville Dam (a), antennas being installed at the counting window at McNary Dam (b), and a fish viewing window (c) that is similar to the counting windows in fish ladders at these dams.

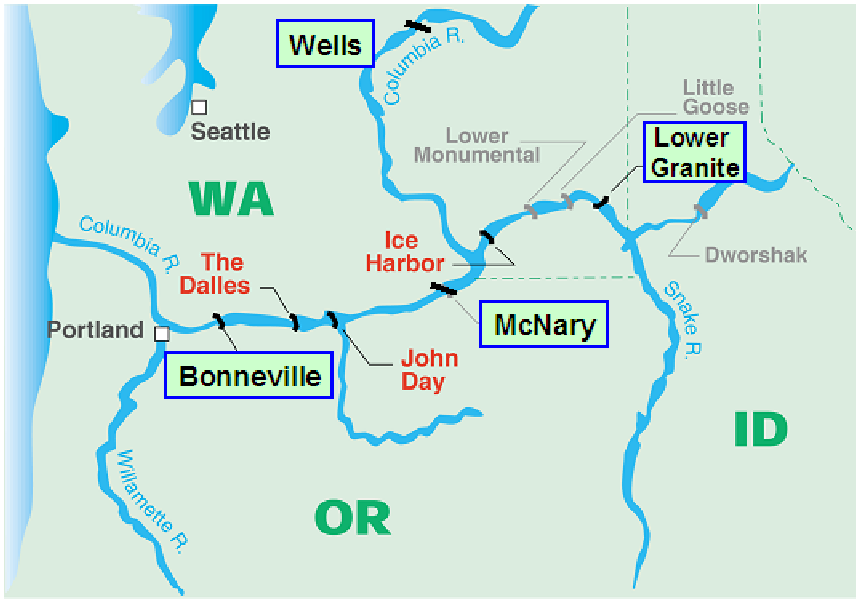

Figure 2. The four dams that had interrogation systems for PIT-tagged adult salmonids in 2002.

For this overview, we had six objectives:

1) Compare tag-reading performances of the counting-window and orifice-based interrogation systems in the McNary Oregon Ladder using three groups of salmonids.
2) Determine reading efficiencies of the orifice-based system in the Washington Shore Ladder at Bonneville Dam using salmonids tagged in the Adult Fish Facility (direct evaluation).
3) Compare salmonid behavior regarding orifice use in all ladders at Bonneville and McNary Dam.
4) Determine reading efficiencies of the individual ladders at Bonneville and McNary Dams using radio-tagged and PIT-tagged salmonids (direct evaluation).
5) Compare proportions of fish counts for Bonneville and McNary Dams using numbers reported from the counting windows and the PIT-tag data.
6) Determine how the antennas identified as containing moisture read tags and maintained tune relative to antennas without moisture.

Although the numbers reported in the following evaluations may change slightly as more data are processed, we do not anticipate significant changes in the overall trends described.

TAG-READING PERFORMANCES OF COUNTING-WINDOW AND ORIFICE-BASED INTERROGATION SYSTEMS IN THE MCNARY OREGON LADDER

Introduction

The counting-window and orifice-based interrogation systems in the McNary Oregon Ladder (MOL) became operational on 9 April 2002. The prototype interrogation system at the counting window underwent several developmental improvements over the season. Initially, the two large antennas (inside dimensions were 19.5 × 63 in) appeared to detune randomly. An investigation determined that because the Corps periodically adjusted water flow conditions during April; the water level in the ladder varied by a few inches, and these fluctuations affected the tune of the antennas. This was not a concern once the reason for the detuning was identified because the water adjustments stopped soon after.

Other initial changes included Pacific States Marine Fisheries Commission (PSMFC) running a ground strap from the AC duplex outlet ground to the transceiver enclosure back panel to reduce the sensitivity to slight vibrations caused by people walking around the site. The grating and handrails of the outside metal walkway were also secured better to reduce the vibrations. Also, Destron Technologies installed new analog boards in the transceivers. Analysis of the PIT-tag data during May demonstrated that fish were being missed primarily during the afternoon, and it was concluded that the sun was heating the fiberglass antenna housings and the enclosed polypropylene capacitors, which caused the antennas to be detuned (Downing 2002). Destron Technologies covered the antenna housings with Styrofoam on 22 May to reduce the large increases in temperature; this significantly reduced the problem.

On 31 July, Destron Technologies installed copolymer-polypropylene antennas with mica capacitors without dewatering the MOL--a task that would not have been possible for the orifice-based system because it is designed for such maintenance work to be conducted during the winter dewatering period. On 14 August, Destron Technologies then replaced the mica capacitors, which had decayed significantly during the first 2 weeks, with ceramic capacitors, which appeared to handle temperature changes better than the other types of capacitors tested in the laboratory (Sean P. Casey, Destron Technologies, Personal communication). As shown by the analysis reported below, these modifications definitely improved performance. However, even in May, prior to any major modifications, performance was very good considering this was a prototype system that consisted of only two antennas.

No more changes were made to the counting-window system after 14 August; therefore, we compared tag-reading performance between the counting-window and orifice-based interrogation systems in MOL from 15 August until 31 October. After the end of October, the counting station was closed and the picketed leads were raised; therefore, fish using the ladder would no longer have to pass through the counting-window antennas. To compare tag-reading performance, three different groups of adult salmonids were used: adults double tagged with radio and PIT tags, adults with PIT tags recorded in the PIT-Tag Information System (PSMFC 1996), and migrating salmonids that were detected at Lower Granite Dam in 2002 (and thus should have been previously detected at Bonneville and McNary Dams).

Radio-Tagged and PIT-Tagged Salmonids

As part of a joint project between University of Idaho and NMFS, adult chinook salmon and steelhead were radio tagged in the Adult Fish Facility that is connected to the BWSL. Radio tags were gastrically implanted, and fish were scanned for PIT tags. Fish were then PIT tagged only if no existing PIT tag was detected. The double-tagged salmonids were then released at various sites below and above Bonneville Dam and tracked as they migrated up the Columbia River. At each dam, radiotelemetry systems use many more antennas than PIT-tag interrogation systems to cover all of the possible migration pathways (i.e., fish ladders and navigation locks).

We used radiotelemetry data to confirm that double-tagged fish had indeed ascended MOL when they were missed by either the orifice or counting-window PIT-tag interrogation systems or both systems. For this analysis, we could only utilize data from double-tagged fish with 134.2-kHz PIT tags because both interrogation systems are 134.2-kHz systems (i.e., they are not designed to and will not read 400-kHz tags).

There are radiotelemetry antennas throughout the MOL so that fish can be tracked entering the ladder, transiting the middle of the ladder (where the orifice antennas are), and leaving the ladder (just above the counting window; Fig. 3). At the top of the ladder, one radiotelemetry antenna is located below the counting window and two are located above it. Radiotelemetry data needs to be hand checked to ensure that the passage route of each fish is correctly categorized because there can be false detections at individual receive antennas.

By January 2003, only the spring/summer chinook data had been checked and completely processed. Fall chinook data were processed in April 2003, and steelhead data were not finalized until March 2004. This late date was due to discrepancies between the PIT-tag and radio-tag data systems for the species designations of some fish. Consequently, we revised the 2003 draft of this document to include final data from all of our analyses.

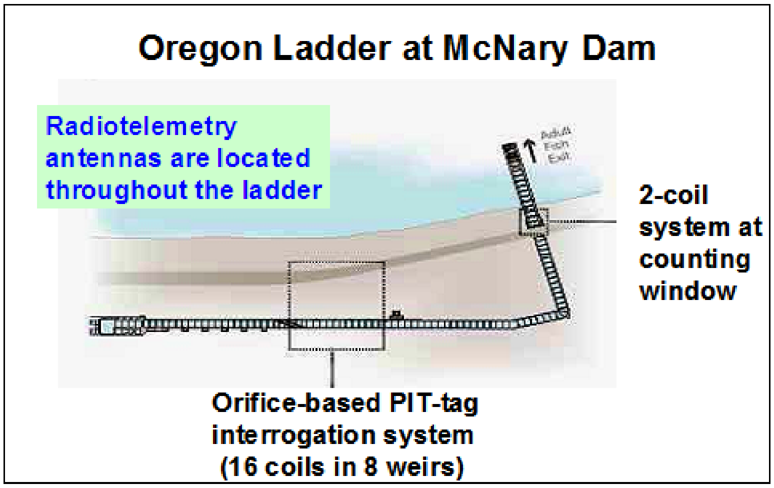

Figure 3. McNary Oregon Ladder showing locations of the two PIT-tag systems.

Tag-Reading Efficiencies

We know that some PIT-tagged fish were missed by the counting-window system while Destron Technologies was making changes to improve the performance of the prototype. Therefore, the fairest evaluation to compare tag-reading performances between the two systems was to use data collected after 14 August when the last change was made to the counting-window system (Table 1). From 15 August through the end of October, the radiotelemetry data contained records of 743 double-tagged salmonids having passed McNary Dam via MOL (these included 520 steelhead, 221 fall chinook salmon, and 2 summer chinook salmon).

Of the 743 double-tagged salmonids that ascended MOL, the two PIT-tag systems together detected 717 fish, or 96.5% (Table 1). Twenty-two of the 26 or 84.6% of the undetected fish were steelhead. To make it easier to compare the PIT-tagged and radio-tagged fish to other groups of fish that are just PIT tagged, we included a category that employs a more conservative definition for ascension than mere presence in the ladder. To count as definitely ascending the ladder, fish had to be last detected on one of the three uppermost weirs with orifice-based antennas. Results showed that the counting-window system detected 95.2% and the orifice-based system detected 96.0% (six more fish) of all double-tagged fish. On a relative scale, the two systems both detected over 98.5% of the double-tagged fish.

Table 1. Numbers, direct and relative reading efficiencies (%) of double-tagged fish that ascended the McNary Oregon Ladder between 15 August and 31 October 2002 based on radiotelemetry data.

PIT-tag system	Detections N	Detections %	Relative %
Total number ascending MOL	743	100.0	
Orifice and counting window	717	96.5	100.0
Counting window	707	95.2	98.6
Orifice--all detections	715	96.2	99.7
Orifice--definitely ascending MOL	713	96.0	99.4

For other purposes, researchers or managers may only want to know whether a fish was detected at a dam or in a ladder. There were a few cases wherein a double-tagged fish was detected only once in the MOL, but was subsequently detected upstream. If these fish had not been radio-tagged, we would not have definitively known that the fish had continued up the ladder because they could have descended and then used the navigation lock to pass the dam.

One reason the orifice-based system probably detected more fish was that it had 16 antennas, while the prototype counting-window system had 2 antennas. The technical group for Adult PIT-Tag Oversight Committee has stressed that future counting-window systems or systems installed into vertical slots need a minimum of three and preferably four antennas to ensure high tag-reading efficiency rates. Additional antennas are also necessary because a PIT-tagged fish that lingers near a single antenna in the counting-window system will prevent the detection of other tagged fish by that antenna (this was observed in 2002).

Effect of Summer Heat on Tag-Reading Performance

Looking at the month-by-month breakdown, one notes that most double-tagged fish were missed by the orifice-based system in July and by the counting-window system in August (Table 2). During July, the orifice-based system transceivers experienced daytime temperatures that were above their optimum operating maximums. Such high temperatures can cause internal electromagnetic noise levels to rise significantly, which detunes the transceivers and reduces the longevity of the electronic equipment. Detuning caused by high temperatures seems like the most important variable for explaining why the orifice-based transceivers missed a number of double-tagged fish during July (reading efficiency decreased to <90%); however, fish behavior might be a factor.

Table 2. Numbers, direct and relative reading efficiencies (%) by month of PIT-tagged and radio-tagged salmonids detected by the counting-window and orifice PIT-tag systems in the McNary Oregon Ladder, 2002.

	April-May			June			July			Aug			Sept			Oct		
PIT-tag system	N	%	Rel.%	N	%	Rel.%	N	%	Rel.%	N	%	Rel.%	N	%	Rel.%	N	%	Rel.%
Total number	207			73			76			101			408			252		
Orifice and counting window	207	100.0	100.0	72	98.6	100.0	73	96.1	100.0	100	99.0	100.0	398	97.5	100.0	243	96.4	100.0
Counting window	197	95.2	95.2	68	93.2	94.4	70	92.1	95.9	93	92.1	93.0	394	96.6	99.0	240	95.2	98.8
Orifice--all detections	207	100.0	100.0	69	94.5	95.8	66	86.8	90.4	98	97.0	98.0	397	97.3	99.7	243	96.4	100.0
Orifice--definitely ascending MOL	206	99.5	99.5	69	94.5	95.8	65	85.5	89.0	98	97.0	98.0	396	97.1	99.5	242	96.0	99.6

To try to reduce the high air temperatures, PSMFC pumped compressed air into the transceiver enclosures, but this solution was only partially successful. Transceivers for the counting-window system are mounted indoors, where air conditioners help maintain a stable environment, and so they did not experience any heat problems (the antennas and their enclosed capacitors had experienced heat problems in early May, but this was successfully corrected by covering them with Styrofoam).

Partly because measures to reduce the impact of heat on the outdoor transceivers at MOL during summer 2002 were only partially successful, the BPA and its subcontractors requested that temperature-controlled boxes be used for the installations at Ice Harbor and Lower Granite Dams scheduled for early 2003. Furthermore, PSMFC is considering installing air-conditioned outbuildings to house the transceivers at MOL in the future.

Performance of the counting-window system was poorest (93%) during August (Table 2). A further breakdown of the data indicated that the counting-window system performed at its worst during the first half of August, when the mica capacitors, which had been temporarily installed into the new antennas, rapidly decayed over the short period before ceramic capacitors could be installed (Table 3). After installation of the new capacitors, the reading efficiency returned to levels above 95%.

Table 3. Numbers and relative reading efficiencies (%) of PIT-tagged and radio-tagged salmonids detected by counting-window and orifice-based PIT-tag detection systems in the McNary Oregon Ladder during August 2002.

	1-14 August		15-30 August	
PIT-tag system	N	%	N	%
Orifice and counting window	26	100.0	74	100.0
Counting window	22	**84.6**	71	95.9
Orifice--all detections	25	96.2	73	98.6
Orifice--definitely ascending MOL	25	96.2	73	98.6

The monthly breakdown in Table 2 also provides information for researchers who want to know how the systems were performing when their study fish passed McNary Dam. Overall, both interrogation systems performed well over the entire year.

River-Run Adult Migrants

The second group of salmonids used to compare reading efficiencies between the orifice-based and counting-window systems in the MOL were river-run migrant adults that ascended between 15 August and 31 October, and that had been detected by one or both PIT-tag systems. In contrast to the evaluation using double-tagged salmonids, this evaluation was indirect: we could not directly account for fish that were missed by both systems. With this indirect method, all jacks were omitted from analysis, and adults were omitted if their detection histories indicated that they were ultimately heading down the MOL.

Both the counting-window and orifice-based systems detected more than 98.5% of the 1,934 adult salmonids that met the criteria for analysis (Table 4). Four fish (0.2%) were detected only by the orifice-based system in the lower or middle orifice weirs; these fish had no other records of PIT-tag detection at McNary Dam. Two of these four were later detected at Lower Granite or Wells Dam. One of the four had been released as a juvenile directly downstream from McNary Dam, which helps explain why it did not completely ascend the ladder. In fact, PIT-tag data collected over the full year showed a recurring pattern for a small fraction of fish that explored, but did not fully ascend the MOL, and that eventually homed to a hatchery downstream from McNary Dam.

Steelhead (n = 1,384) and fall chinook salmon (n = 512) were the two main species migrating at this time. Unlike with the double-tagged salmonids, where most undetected fish were steelhead, in this analysis, both salmonid populations were detected in equal proportions by both PIT-tag interrogation systems (Table 5). Furthermore, there were no temporal patterns (daily or seasonal) for when the two species were missed by the interrogation systems.

Table 4. Detection numbers and relative reading efficiencies (%) for the orifice-based and counting window systems in the MOL between 15 August and 31 October 2002. Detections were of PIT-tagged migrating adult river-run salmonids.

	15 August-31 October	
PIT-tag system	N	%
Orifice and counting window	1,934	100.0
Counting window	1,907	98.6
Orifice--all detections	1,923	99.4
Orifice--definitely ascending MOL	1,919	99.2

Table 5. Detection numbers and relative reading efficiencies (%) for the orifice-based and counting window systems in the MOL between 15 August and 31 October 2002. Detections were of PIT-tagged migrating adult steelhead and fall chinook salmon.

	Steelhead		Fall chinook	
PIT-tag system	N	%	N	%
Orifice and counting window	1,384		512	100.0
Counting window	1,364	98.6	505	98.6
Orifice--all detections	1,377	99.5	509	99.4
Orifice--definitely ascending MOL	1,373	99.2	509	99.4

Fish Detected at Lower Granite Dam

The third group of salmonids used to compare reading efficiencies of the two PIT-tag systems were PIT-tagged salmonids later detected at Lower Granite Dam. We chose this group because having been detected at Lower Granite Dam, they should have passed both Bonneville and McNary Dams during their migration. To ensure that these groups had passed a downstream dam, we used only fish that had records that showed evidence of detection or transport below Bonneville or McNary Dam during their juvenile or adult migration. We analyzed spring and fall chinook salmon tagged with 134.2-kHz ISO tags. Although we recognize that the counting-window system was still undergoing changes during the spring chinook analysis, we feel it is important that the fisheries community be made aware of the trend in jack detections shown by these comparisons.

We observed a significant difference in reading efficiencies between 2-year-old jacks and adult spring chinook (Table 6). Of the 134 jacks at McNary Dam, PIT-tag systems in both ladders combined detected 130 or 96.7%. Of the jacks detected by PIT-tag systems, 114 ascended MOL: 83% of these were detected in the orifice-based system and 92.9% in the counting-window system. For a subsample of 922 adult spring chinook, PIT-tag systems in both ladders detected 918 or 99.6% (two of the missed fish were also radio tagged; radiotelemetry data confirmed they ascended the McNary Washington Ladder).

Of adults detected by the PIT-tag systems, 724 ascended MOL where the orifice-based system detected 99.9% and the counting-window system detected 96.0% (most were missed in early May when sun heating the antennas was causing transceiver tune problems). Therefore, it appeared that for spring chinook, behavior was different between jacks and adults in terms of the use of orifices and weir overflows. Jacks apparently used the weir overflows more than adults, and consequently the orifice-based system did not detect the jack population as well as the counting-window system.

Table 6. Reading efficiencies (%) at McNary Dam by the counting-window and orifice-based systems in MOL for spring chinook salmon that were later detected at Lower Granite Dam, 2002. Fish were 2-year-old jacks (n = 114) and 3-year-old adults (n = 724).

PIT-tag system	Jacks	Adults
Counting window (MOL)	93.9	96.0
Orifice (MOL only; all detections)	**83.3**	99.9

A similar analysis was done with 123 2-year-old jacks and 35 3-year-old fall chinook salmon adults that were later detected at Lower Granite Dam. These data were all collected after 1 September or after the counting-window system had been finalized. Of the 109 jacks detected by the MOL PIT-tag systems, the counting-window system detected 97.2% and the orifice-based system detected 95.4% (Table 7). All 25 adults that ascended MOL were detected by both systems. For fall chinook salmon, there did not appear to be a dramatic difference in behavior between jacks and adults, but the younger fish were still detected in slightly lower proportions.

Table 7. Reading efficiencies (%) at McNary Dam by the counting-window and orifice-based systems in MOL for fall chinook salmon that were later detected at Lower Granite Dam, 2002. Fish were 2-year-old jacks (n = 109) and 3-year-old adults (n = 25).

PIT-tag system	Jacks	Adults
Counting window (MOL)	97.2	100.0
Orifice (MOL only; all detections)	95.4	100.0

Summary and Conclusions

In summary, both the prototype counting-window and orifice-based interrogation systems installed in MOL performed very well, with above 98% relative reading efficiencies of all groups analyzed after 15 August. It is important to note that the two systems combined failed to detect 3.5% of the double-tagged fish ascending MOL between 15 August and 31 October. Both interrogation systems detected adult chinook salmon at higher efficiencies than jacks. This was true to a greater degree with the orifice-based system, which detected 10% fewer spring jacks than the counting-window system. High ambient temperatures during July appeared to negatively impact the outdoor transceivers in the orifice-based system; however, the reduced performance may also have been due to fish behavior. With the improvements already made to the counting-window system, and with plans to house the orifice-based transceivers in air-conditioned buildings, the high performance shown by these two systems in 2002 can be expected to improve in the future.

Although the two systems detected adult salmonids well in this ladder, we recommend using counting-window or vertical-slot based systems in future installations. These systems should cost substantially less to install, and they have higher reading efficiencies for jacks and for adults in ladders where fish tend to use the overflows. The main shortcoming of the counting-window design is that some fish are potentially missed whenever the picketed leads are raised for cleaning (the time between when this task is done varies from daily to weekly, depending on debris load) or when the counting stations are closed at the end of October.

Therefore, we recommend that where possible, antennas be installed permanently into vertical slots. Alternatively, a second set of picketed leads could be installed which could then be dropped into the ladder during the cleaning time (suggestion made by David Hurson, Fisheries Biologist for the Corps) and the picketed leads could be left in place for the entire winter at ladders with counting-window interrogation systems.

READING EFFICIENCIES OF THE ORIFICE-BASED SYSTEM IN THE BONNEVILLE WASHINGTON SHORE LADDER

Introduction

As in 2001, NMFS tagged and released fish in the Adult Fish Facility (AFF), and the results reported here are only from fish detected in the upper eight weirs of the Bonneville Washington Shore Ladder (BWSL). We PIT tagged fish in August and September 2002 to determine tag-reading efficiencies with a known number of fish. This permitted a comparison to the results from tagging in 2001 and provided information to help fish managers evaluate whether it would be necessary to install interrogation systems into the counting-window areas or the vertical slots at Bonneville Dam in order to increase overall tag-reading efficiency for the entire dam.

Unlike in 2001, all ladders at Bonneville Dam had orifice-based systems installed during 2002, as did the two ladders at McNary Dam. Therefore, it became possible to get more definitive information on tagged fish that were not detected in BWSL. Without detection systems in the other ladders in 2001, there had been some speculation that undetected fish had died, had gone downstream using the overflows, had been tagged twice, or had been tagged at bad angles. However, in both years, fish were hand scanned before and after tagging to help avoid tagging any test fish twice. We also recorded the rare instance when we thought a fish might have been tagged at a bad angle so we could see if the tag angle impacted the tag-reading results.

Tag-Reading Efficiencies

In August and September 2002, we tagged 216 fall chinook salmon, 157 coho salmon, and 250 steelhead at the Bonneville AFF. The proportion of fall chinook salmon that primarily used the orifices (fish detected in at least seven of the eight weirs) was 41%, which was essentially the same as the 40% proportion displayed by the river-run population (river-run meaning fish that were PIT-tagged as juveniles and are now returning as adults). Test fish from other salmonid populations also displayed a similar degree of orifice use relative to their river-run counterparts. Thus, it appears that the passage behavior of fish we tagged was similar to that of the river-run population. Tag-reading efficiencies in the BWSL were 72.7, 79.0, and 90.4% for fall chinook, coho, and steelhead, respectively (Table 8). Only two fish undetected in the BWSL were detected ascending other Bonneville Dam ladders; we assume these fish descended the BWSL and then ascended these other ladders.

A significant number of fall chinook salmon and steelhead not detected at Bonneville Dam were detected at McNary Dam (Table 8). It should be pointed out that most coho salmon home to locations downstream from McNary Dam and thus would not be detected in its ladders. At Lower Granite and Wells Dam, there were no detections of fish that had not been previously detected downstream. Thus, the overall detection rates for all Bonneville and McNary ladders combined were 88.0, 79.6, and 96.0% for fall chinook, coho, and steelhead, respectively.

Table 8. Reading efficiencies (percent detected) for the direct evaluation of the Bonneville Washington Shore Ladder (BWSL) using salmonids tagged and released in the Adult Fish Facility during the fall of 2002. Reading efficiencies are also given for fish detected in the rest of the ladders at Bonneville and for Bonneville and McNary Dams combined.

Salmonid population	BWSL only	All Bonn. Ladders	All Bonn. & McNary Ladders*
Fall chinook salmon	**72.7**	73.1	**88.0**
Coho salmon	**79.0**	79.0	79.6
Steelhead B-run	90.4	90.8	96.0

* No additional detections at Lower Granite or Wells Dam

Reading-efficiency results for BWSL alone were much lower for fall chinook salmon in 2002 than in 2001, slightly lower for steelhead, and about the same for coho salmon (Table 9). To determine if fish behavior explained some of the similarities and differences between results for the 2 years, we examined the proportions of test fish that primarily used the orifices (fish detected in at least seven of the eight weirs).

Table 9. Reading efficiencies (percent detected) from evaluations of the Bonneville Washington Shore Ladder using salmonids tagged and released in the Adult Fish Facility during 2001 and 2002.

Salmonid population	2001	2002
Spring chinook salmon	97.2	NA *
Summer chinook salmon	94.4	NA
Fall chinook salmon	90.3	72.7
Coho salmon	75.9	79.0
Steelhead B-run	94.8	90.4

* No spring or summer chinook salmon were tagged in 2002

For steelhead, the proportion of test fish that primarily used the orifices was a little lower in 2002 than in 2001 (Table 10), as was the reading-efficiency value (Table 9). For coho, the proportion of test fish that primarily used the orifices was basically the same in both years (42% in 2001 and 45% in 2002), as were the reading efficiencies. These similar proportions were observed despite the fact that many more coho salmon migrated in 2001 than in 2002 (Table 11 and Fig. 4). Since coho salmon are surface-oriented, they may have continued to use the overflows at the same rate, regardless of fish density in the ladder. There was a large decrease in the proportion of fall chinook salmon that primarily used the orifices in 2002 (41%) compared to 2001 (57%), which reflected the 17% difference in reading efficiencies for fall chinook between the two years.

Table 10. Proportions of the tagged test fish that primarily used the orifices (i.e., were detected in at least seven of the eight weirs) as they ascended the Washington Shore Ladder (BWSL) at Bonneville Dam in both 2001 and 2002.

Year	Fall chinook	Coho	Steelhead B-run
2001	57	42	75
2002	41	45	70

In 2002, we tagged fish on two days when the number of adult fall chinook salmon passing Bonneville Dam was greater than 10,000, while this number was below 10,000 on all days we tagged in 2001 (Table 11). However, on these two days, we tagged mostly steelhead at the request of other researchers using the facility. In fact, we only tagged 26 fall chinook on those two days, and thus most fall chinook were tagged on days when similar numbers of fall chinook were migrating in both years.

The significantly lower number of adult coho migrating during 2002 may have affected the behavior of fall chinook salmon: with less crowding in the overflows, fall chinook may have opted to use them more frequently (Fig. 4). In 2002, the proportions of fish that primarily used the orifices were similar for fall chinook (41%) and coho salmon (45%), and so were their reading efficiencies (72.7 and 79.0%). It appeared that to attain a minimum reading efficiency of 90% in this ladder, 60% of a population needed to primarily use the orifices.

Some of the difference in the reading efficiencies for fall chinook salmon between the 2 years might also be normal year-to-year variation; this is something we will be able to distinguish as we tag more fish over the next few years. As with the results in 2001, it must be emphasized that the primary cause for the lower detection rates for fall chinook and coho was fish behavior (i.e., weir overflow use) and not that the orifice-based antennas were failing to read fish transiting them. On average, the number of detections per fish was 10-14 during transits of the orifice-based system in the BWSL; only a single read is required for a fish to be recorded as being present.

Table 11. Numbers of adult fall chinook salmon, coho salmon, and steelhead passing Bonneville Dam on days fish were tagged in 2001 and 2002.

Calendar day	Date	Fall chinook	Steelhead	Coho
		2001		
261	09/18	7,299	7,688	14,815
262	09/19	4,700	6,334	9,589
268	09/25	2,586	2,841	1,289
269	09/26	2,452	2,756	1,128
		2002		
240	08/28	10,235	4,625	447
241	08/29	17,621	4,895	588
259	09/16	7,872	5,395	1,655
260	09/17	7,576	4,582	1,828
269	09/26	2,985	3,445	1,456
270	09/27	2,335	3,400	1,376

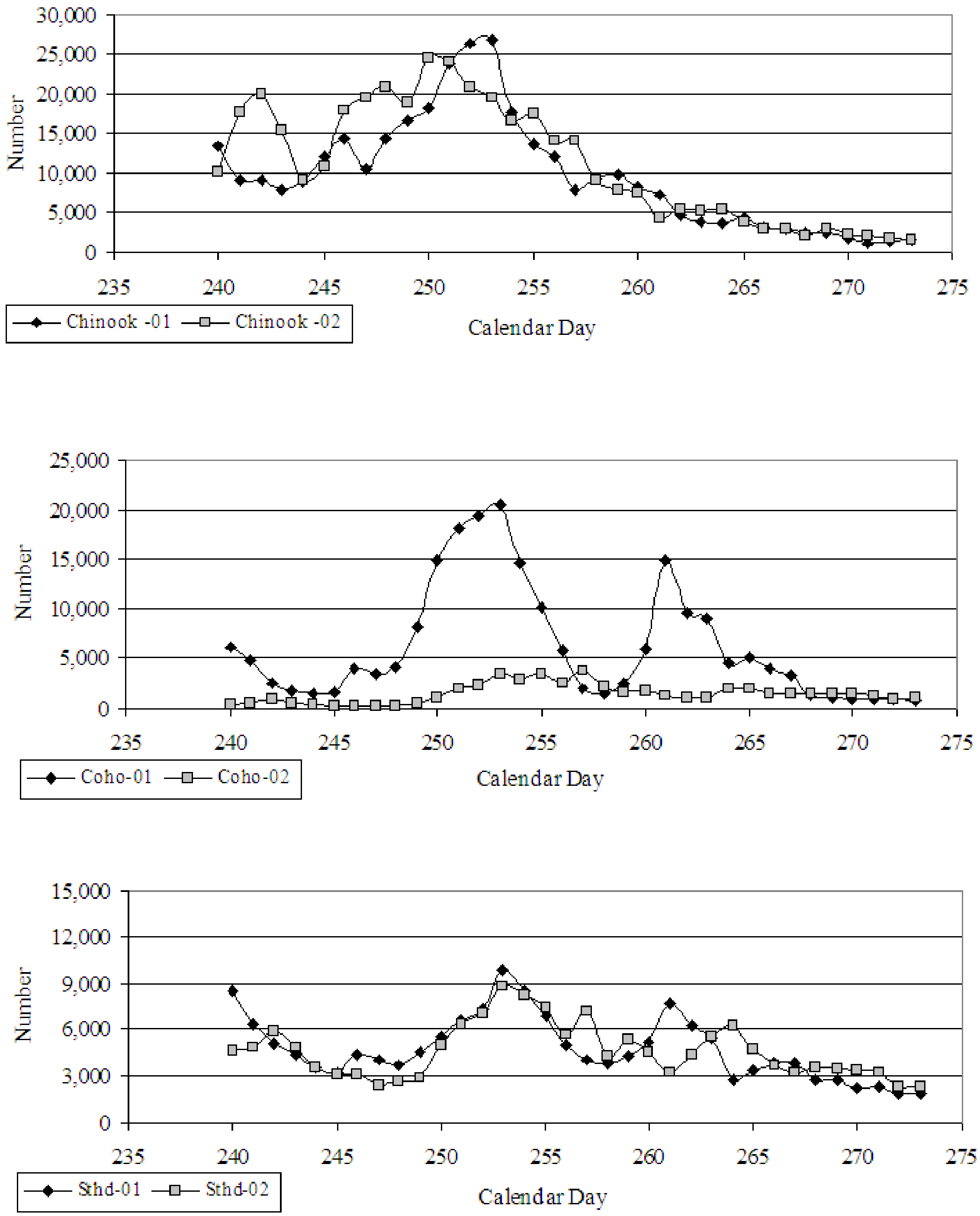

Figure 4. Numbers of adult fall chinook salmon (top), coho salmon (middle), and steelhead (bottom) passing Bonneville Dam each day between 28 August (Day 240) and 30 September (Day 273) of 2001 and 2002.

Summary and Conclusions

In summary, the proportions of test fish that primarily used the orifices (fish detected in at least seven of the eight weirs) appeared to correlate directly to the reading efficiencies for the different salmonid populations ascending the orifice-based interrogation system in the BWSL. It appeared that to attain a minimum reading efficiency of 90%, that 60% of a population needed to primarily use the orifices. The low reading efficiencies in 2002 for fall chinook and coho salmon support the need to install an interrogation system into the counting-window or vertical-slot areas at Bonneville Dam if the overall PIT-tag reading efficiency is to be raised to meet the requirements of the fisheries community.

However, it should also be pointed out that spring chinook salmon are the primary salmonid populations that are tagged as juveniles and detected as adults (in addition, many of its stocks are ESA listed) and that the orifice-based system detects these populations well because spring chinook tend to use orifices (Tables 9 and 12). Another solution to consider in improving the information on coho salmon and other stocks that home downstream from McNary Dam would be to install adult interrogation systems into The Dalles or John Day Dams.

Table 12. The population distributions (numbers and proportions) for juvenile salmon that were PIT tagged and released in 2002, and for PIT-tagged adult salmon detected at Bonneville Dam for 2002.

	Juveniles tagged and released, 2002		Adults detected, 2002	
Salmonid population	N	%	N	%
Spring chinook salmon	888,277	74.2	4,298	80.0
Fall chinook salmon	260,438	21.8	935	17.4
Coho salmon	48,582	4.1	142	2.6
Totals	1,197,297		5,375	

ORIFICE PASSAGE BEHAVIOR IN FISH LADDERS AT BONNEVILLE AND MCNARY DAMS

Introduction

We determined reading efficiencies for the different salmonid populations for MOL using the double-tagged fish (Table 13). The radio- and PIT-tagged chinook salmon that were tagged at Bonneville Dam by University of Idaho were divided by run type using dates defined by the Corps for Bonneville Dam. Therefore, all chinook migrating before 1 June were classified as spring run, those migrating between 1 June and 31 July were summer run, and all migrating after 1 August were fall chinook. Other fish PIT-tagged as juveniles were classified using the run designated by the researchers that had tagged them. Coho salmon were excluded from this evaluation because none were radio tagged and because most coho home to locations downstream from McNary Dam and thus would not be detected in its ladders.

If a fish ascended the fish ladders multiple times at McNary Dam, we only analyzed the final passage route for each individual. Furthermore, since the picketed leads were raised on 1 November and some steelhead that were tagged in 2002, migrated in 2003, we used 31 October 2002 as the cutoff date for all populations.

Table 13. Numbers and reading efficiencies (%) of PIT-tagged and radio-tagged salmonids from four salmonid populations that were detected by the PIT-tag systems in the MOL (McNary Oregon Ladder).

	Chinook salmon							
	Spring		Summer		Fall		Steelhead	
PIT-tag system	N	%	N	%	N	%	N	%
Total number ascending MOL	247	--	88	--	228	--	613	--
Orifice and counting window	245	99	87	99	227	100	591	96
Counting window	232	94	79	90	225	99	578	94
Orifice-all detections	244	99	79	90	227	100	586	96
Orifice-definitely ascending MOL	243	98	78	89	227	100	585	95

There were three notable observations based on the reading efficiencies calculated for MOL (Table13). First was that the entire interrogation system (both systems combined) for the ladder detected all of the salmonid populations at levels higher than 96% and mostly closer to 99%. Another was that summer chinook salmon were the only population in which the orifice-based system detected fewer than 95%. As indicated before, we believe the lower reading efficiency rate for summer chinook was mostly due to the transceivers being exposed to high temperatures in the orifice-based system (which detuned the transceivers), but since the counting-window system, where the transceivers are housed in a temperature-controlled environment, also had a lower reading efficiency for summer chinook, fish behavior might be a significant factor. We will need to monitor this situation in future years to determine if the trend continues, and if it does, to determine the best explanation.

The third notable observation was the 25% difference in the detection rates of fall chinook salmon between BWSL and MOL in 2002 (72.7 and 99.6% respectively), which made us question whether fish behavior was significantly different between ladders. If fish behavior in terms of orifice and overflow usage were different, this would definitely affect how well the orifice-based interrogation systems performed in different ladders. Therefore, we spent some time examining fish behavior regarding orifice use in the ladders at Bonneville and McNary Dams.

Each of the fish ladders at Bonneville and McNary Dams is designed differently (Table 14). The orifices and pools are different sizes, and some ladders utilize a partial overflow design while others utilize a full overflow design.

Table 14. Dimensions of the fish ladders at Bonneville and McNary Dams.

Fish ladder	Orifice size (in)	Overflow type	Overflow (ft)	Ladder slope	Ladder width (ft)
Bonneville Dam					
Washington Shore	18 × 18	partial	6	1:10	24
Bradford A&B Branches	24 × 24	partial	6	1:16	40
Cascades Island	24 × 24	full	35	1:16	35
McNary Dam					
Washington Ladder	23 × 21	full	30	1:20	30
Oregon Ladder	26 × 26	full	30	1:20	30

River-Run Adult Migrants

To evaluate the impact of ladder design on rates of orifice use by fish, we analyzed detections of river-run adult salmonids that had been PIT-tagged previously (mostly as juveniles). For example, we examined the proportions of four salmonid populations that primarily used the orifices (the percentage of fish that were detected in at least seven of the eight weirs) as they ascended the different fish ladders (Table 15). Again, there were too few PIT-tagged coho salmon to obtain solid estimates for the different ladders.

Results for the different ladders suggested that fall chinook salmon may use weir overflows more frequently in ladders that have partial overflows than in ladders with full overflows (Table 15). At Bonneville Dam, much lower proportions of fall chinook primarily used the orifices in the three ladders with partial overflows than in the ladder with a full overflow (Cascades Island). Rates of orifice use were 40% in the Washington Shore Ladder, 65% in both Bradford Island Ladders, and 80% in the Cascades Island Ladder. The two full overflow ladders at McNary Dam also had high proportions of fall chinook primarily using the orifices (~90%). The proportions at McNary Dam might be higher because fewer fish use its ladders; although at the peak of the fall run, approximately the same numbers of fish use both the Bradford Island Ladders and MOL.

For other runs of chinook salmon and steelhead, 90% or more primarily used the orifices in all of the ladders except for BWSL, where proportions of orifice use ranged from 70 to 80% (Table 15). Thus, it appears that the one ladder where we can tag fish for a direct evaluation of the performance of the orifice-based system is the ladder where fish are least likely to use the orifices. However, this mainly impacted fall chinook, as the previous section showed that 60% of a population needs to primarily use the orifices in order to attain a minimum reading efficiency of 90%.

In addition to the partial overflows of the BWSL, this ladder also has the shortest distance between weirs and is the narrowest (Table 14). Since higher proportions of fish from all salmonid populations evaluated used overflow weirs in this ladder, we concluded that there must be something about the BWSL design that encourages this behavior. Another factor that undoubtedly affects fish behavior in the BWSL is that this ladder attracts the highest densities of all fish populations, including shad.

The orifice-based system in MOL detected all salmonid populations at higher rates than the orifice-based system in BWSL because a higher proportion of each salmonid population primarily used the orifices in that ladder (Tables 9, 13, and 15). At least 90% of each salmonid population primarily used the orifices in the MOL, while the proportion of orifice use in the BWSL ranged from 40 to 80%.

Table 15. Proportions by species of river-run populations that primarily used the orifices while ascending fish ladders at Bonneville and McNary Dams, 2002. Population values were derived from analyzing 75 to 150 river-run adults of each species. Fish were a mixture of wild and hatchery origin; most were PIT-tagged as juveniles. Shading highlights heavy use of overflow weirs by fall chinook salmon in partial vs. full overflow ladders and bold type highlights the consistently lower proportions observed in the BWSL.

		Proportion of fish that primarily used the orifices(%)			
Fish ladder	Overflow type	Spring chinook	Fall chinook	Steelhead (A-run)	Steelhead (B-run)
		Bonneville Dam			
Washington Shore	Partial	**75**	**40**	**80**	**70**
Bradford Island (A and B Branch)	Partial	95	65	90	95
Cascades Island	Full	90	80	90	90
		McNary Dam			
Washington Ladder	Full	97	88	98	90
Oregon Ladder	Full	95	90	95	90

When such high proportions of salmonids primarily use orifices, fewer weirs need to be active to achieve high reading efficiencies. During the peak of the spring migration, NMFS found that the orifice-based system in the MOL would have read 98% (1,019) of the 1,038 spring chinook salmon detected by all eight weirs if the only PIT-tag antennas operating had been those in the bottom two or upper two weirs (Downing 2002). These results were similar to findings at BWSL in 2001, where the orifice-based interrogation system performed well during the spring migration, and efficiency rates showed that four weirs would have been sufficient to detect 95% of adult spring chinook (Downing et al. 2004). Results at MOL during spring 2002 also indirectly supported the conclusion that antennas containing moisture were performing satisfactorily: three of the four antennas in the bottom two weirs in MOL were identified as containing moisture, while no antennas in the upper two weirs were, yet both sets of weirs performed equally well.

Fish Detected at Lower Granite Dam

Similar to the evaluation performed above for McNary Dam, we investigated whether there was a difference in detection rates between jacks and adult salmon at Bonneville Dam because of orifice use vs. weir overflow use in the ladders. At Bonneville Dam there is a flume-based interrogation system for adult salmonids in the AFF (this system is designated B2A in PTAGIS) in addition to the orifice-based systems in all of the ladders. The flume-based system is only active when the AFF is used to sample fish; to actively collect fish, a picketed lead is dropped into the BWSL to force fish into the AFF. The fish that go through the B2A antennas should also have passed the four weirs with orifice-based detectors that are located below the entrance into the AFF. Researchers remove some fish, but others (including all jacks since jacks are not radio tagged) continue up the BWSL and thus have another chance to be detected by the orifice-based antennas in the upper section.

For the analysis, we used 127 spring/summer chinook jacks and a subsample of 692 adult spring/summer chinook that had been detected at Lower Granite Dam (Table 16). Despite being active only about half of the day, the flume-based system detected an additional 7% (9 of 127) of jacks that were not detected by the orifice-based system, while all adults detected by the flume-based system (n = 665) were also detected by the orifice-based system.

Overall reading efficiencies of both systems for both jacks and adults were below 100% because some fish detected at Lower Granite Dam, which had definitely passed Bonneville Dam, went undetected by either system. Similar to the results for McNary Dam, the results for Bonneville Dam showed jacks using the weir overflows more than adult spring/summer chinook salmon.

Table 16. Reading efficiencies by the different PIT-tag systems at Bonneville Dam for spring/summer chinook salmon that were later detected at Lower Granite Dam in 2002. Fish were 2-year-old jacks (n = 127) and 3-year-old adults (n = 692).

PIT-tag system	Jacks	Adults
All systems at Bonneville Dam*	85.8	96.1
Orifice-based systems in all ladders	78.7	96.1

* This includes all orifice-based systems plus the antennas surrounding the flumes in the Adult Fish Facility (B2A).

Summary and Conclusions

Ladder design appeared to affect fish behavior in terms of orifice and overflow usage. Results for ladders at both Bonneville and McNary Dams strongly suggested that fall chinook salmon might use the weir overflows more in ladders that have partial overflows than ladders with full overflows. At Bonneville Dam, much lower proportions of fall chinook salmon primarily used the orifices in the three ladders with partial overflows (BWSL, 40%; Bradford Island 65% both ladders) than in the Cascade Island Ladder, which has a full overflow (80%). For the other runs of chinook salmon analyzed and for steelhead, proportions of fish primarily using the orifices were 90% or higher in all ladders except for BWSL.

The orifice-based interrogation system in the MOL detected salmonid populations at a higher rate than the orifice-based system in the BWSL because a higher proportion of every salmonid population primarily used the orifices in that ladder. At least 90% of each salmonid population primarily used the orifices in the MOL, while this proportion ranged from 40 to 80% in the BWSL. In fact the BWSL had the lowest proportion of fish primarily using the orifices for all salmonid populations.

Thus, it appears that the one ladder where we can tag fish for a direct evaluation of the performance of the orifice-based system is the ladder where the fish use the orifices the least. As was observed at McNary Dam, the PIT-tag systems at Bonneville Dam missed more jacks than adults. This trend is important because jack counts are used to estimate future adult returns.

READING EFFICIENCIES OF RADIO- AND PIT-TAGGED SALMONIDS

Introduction

In March 2004, the University of Idaho and NMFS finished processing the radiotelemetry data to determine migration routes through Bonneville and McNary Dams for salmonids tagged with both radio and PIT tags in 2002. They separated the salmonids into three groups: spring/summer chinook salmon, fall chinook salmon, and steelhead. Normally, the radiotelemetry data show whether a fish passed on the Washington or Oregon side of Bonneville Dam but do not distinguish which of the four ladders was used for final passage. For these analyses, NMFS radiotelemetry database manager developed a computer script to provide individual ladder migration information.

Since salmonids often swim up and down multiple ladders at dams (especially Bonneville Dam), we limited our comparison between PIT- and radio-tag detections to the data from ladders that were used during the *final* ascent at each dam. If the final record had a fish heading down a ladder, that fish was excluded from the analysis. Furthermore, we analyzed data only from double-tagged fish with 134.2-kHz PIT-tags because interrogation systems in the fish ladders are 134.2-kHz systems (they are not designed to and will not read 400-kHz tags). We also excluded from analysis any double-tagged fish that migrated up Bradford Island and Cascades Island Ladders at Bonneville Dam before noon on 26 April because these PIT-tag interrogation systems were not connected to the data-collection computers before that time.

When the final radiotelemetry data became available (after we had submitted the 2003 draft of this document), we analyzed all double-tagged fish tagged in 2002. We noticed that like the PIT-tag systems, the radiotelemetry systems did not perform equally in all of the ladders. Therefore, we changed our analyses to use final ascent records recorded by either the PIT-tag interrogation systems or the radiotelemetry antennas.

We also analyzed spring and summer chinook separately because most double-tagged summer chinook salmon were from the Upper Columbia River (86% of the known source fish and 76% of the summer chinook tagged at Bonneville were detected at Wells Dam compared to Lower Granite Dam). Status reviews of chinook salmon have emphasized that summer chinook salmon returning to the Snake River have life histories similar to spring chinook returning to both the Snake and Upper Columbia Rivers: all are stream-type salmonids (Matthews and Waples 1991; Myers et al. 1998). Stream-type salmonids tend to spawn in smaller tributaries, remain in freshwater throughout their first year and typically undertake extensive offshore ocean migrations. Summer chinook salmon returning to the Upper Columbia River are ocean-type fish that have life histories more like fall chinook salmon. Ocean-type salmonids tend to spawn in the mainstem, emigrate as subyearlings, and undertake coastal ocean migrations. Stream-type and ocean-type salmonids behave differently in fish ladders and consequently are detected at different rates by orifice-based PIT-tag interrogation systems. Below, we present reading efficiencies for the different subgroups to demonstrate this observation.

Tag-Reading Efficiencies

Spring/Summer Chinook

Based on final ascent as determined by both PIT-tag and radiotelemetry data, 408 double-tagged spring/summer chinook salmon were categorized as having passed via the Washington side at Bonneville Dam. Of these fish, 133 ascended the Cascades Island Ladder and 275 ascended the BWSL (Table 17). The PIT-tag system in Cascades Island Ladder detected 129 of the 133 fish (97.0%), and the entire 12-weir PIT-tag system in BWSL detected 249 of 275 (90.5%) with 243 (88.4%) detected in the upper eight weirs.

The PIT-tag system in the Bradford Island A Branch detected 121 of the 130 (93.1%) double-tagged salmon that ascended this ladder, while the system in the B Branch detected 152 of the 154 (98.7%) double-tagged salmon that ascended this ladder. At McNary Dam, the PIT-tag systems in the Oregon and Washington Ladders detected 99.1% (332/335) and 93.5% (287/307) of the double-tagged spring/summer chinook categorized as having passed, respectively.

Table 17. Numbers of double-tagged (PIT-tagged and radio-tagged) spring/summer chinook salmon that passed the different ladders at Bonneville and McNary Dams in 2002 and then the numbers and detection rates for the PIT-tag systems.

Fish ladder	Total PIT or radio-tag (RT) detections	PIT-tag detections	Percentage PIT/total
Bonneville Dam			
Bradford A branch	130	121	93.1
Bradford B branch	154	152	98.7
Cascades Island Ladder	133	129	97.0
Washington Shore Ladder (all 12 weirs)	275	249	90.5
Washington Shore Ladder (upper 8 weirs)	275	243	88.4
McNary Dam			
Washington side	307	287	93.5
Oregon side	335	332	99.1

The above reading efficiencies for spring/summer salmon populations combined revealed several fish ladders with detection rates below 95%. When we separated results for the two populations, we observed that the PIT-tag interrogation systems detected spring chinook salmon at rates above 97% in all ladders, but detected summer chinook salmon at rates above 95% in only two ladders (Tables 18 and 19). Furthermore, when we omitted the eight summer chinook detected only by the counting-window PIT-tag system in the MOL, then the orifice-based system only detected 89.8% of the summer chinook. The radio-tag detection rates are presented to show the variation between ladders and to show that variation among radiotelemetry systems does not appear to be related to fish behavior.

When we separated the salmon into stream-type and ocean-type groups (by using only double-tagged summer chinook salmon PIT tagged at Bonneville Dam, and subsequently detected at Wells or Lower Granite Dam), we observed a strong behavioral difference in ladder use between the two groups. Although numbers of ocean-type salmon were low, the detection trends were evident. Stream-type salmon definitely used the orifices more than ocean-type salmon, as all of their ladder reading efficiencies by the orifice-based systems were more than 97% (Table 20).

Further proof that the ocean-type salmon used the weir overflows more is demonstrated by looking at the reading efficiencies for MOL with and without data collected at the counting-window antennas (Table 20). Detection rates for ocean-type summer chinook salmon were lowest in BWSL; they were below 60% for the whole ladder and only 53.8% in the upper section.

Table 18. Numbers of double-tagged (PIT-tagged and radio-tagged) spring chinook salmon that passed the different ladders at Bonneville and McNary Dams in 2002 and detection rates for the PIT-tag and radio-tag systems.

Fish ladder	Total PIT or radio-tag (RT) detections	PIT-tag detection rates	RT detection rates
Bonneville Dam			
Bradford A branch	78	97.4	88.5
Bradford B branch	118	99.2	87.3
Cascades Island Ladder	107	99.1	95.3
Washington Shore Ladder (all 12 weirs)	200	98.5	94.0
Washington Shore Ladder (upper 8 weirs)	200	98.0	
McNary Dam			
Washington Ladder	177	97.2	97.7
Oregon Ladder	247	99.2	94.3
Oregon Ladder (orifice-based only)	247	98.8	

Table 19. Numbers of double-tagged (PIT-tagged and radio-tagged) summer chinook salmon that passed the different ladders at Bonneville and McNary Dams in 2002 and detection rates for the PIT-tag and radio-tag systems.

Fish ladder	Total PIT or radio-tag (RT) detections	PIT-tag detection rates	RT detection rates
Bonneville Dam			
Bradford A branch	52	86.5	96.2
Bradford B branch	36	97.2	88.9
Cascades Island Ladder	26	88.5	92.3
Washington Shore Ladder (all 12 weirs)	75	69.3	96.0
Washington Shore Ladder (upper 8 weirs)	75	62.7	
McNary Dam			
Washington Ladder	130	88.5	98.5
Oregon Ladder	88	98.9	93.2
Oregon Ladder (orifice-based only)	88	89.8	

Table 20. Numbers and reading efficiencies (%) for the different ladders at Bonneville and McNary Dams in 2002 of double-tagged (PIT-tagged and radio-tagged) spring/summer chinook salmon that were separated into stream-type and ocean-type categories.

	Stream type		Ocean type	
Fish ladder	N	%	N	%
Bonneville Dam				
Bradford A branch	86	97.7	32	78.1
Bradford B branch	124	99.2	23	95.7
Cascades Island Ladder	108	98.1	20	85.0
Washington Shore Ladder (all 12 weirs)	213	98.6	39	59.0
Washington Shore Ladder (upper 8 weirs)	213	97.7	39	53.8
McNary Dam				
Washington Ladder	194	97.4	83	86.7
Oregon Ladder	263	99.2	51	94.1
Oregon Ladder (orifice-based only)	263	98.9	51	82.4

Fall Chinook Salmon

The detection of the double-tagged fall chinook salmon (also ocean-type salmon) by the BWSL PIT-tag system was also much lower than in the other ladders: the entire 12-weir system detected 72.4% while the upper section of eight weirs detected only 62.2% of the 315 fall chinook salmon that ascended BWSL (Table 21). Unlike the ocean-type summer chinook salmon, reading efficiencies of systems in all other ladders at Bonneville and McNary Dam were over 95% for double-tagged fall chinook salmon, with the exception of the Cascades Island Ladder.

Only 61 fall chinook salmon ascended Cascades Island Ladder, which increased the proportional representation of each undetected fish (each fish represented approximately 1.6%). In fact, had only one more fish been detected, reading efficiency would have been 95%. The PIT-tag system in the Bradford Island A Branch detected 98.3% of 175 double-tagged salmon that ascended this ladder. The system in the Bradford Island B Branch detected 95.6% of 113 double-tagged salmon that ascended this ladder. At McNary Dam, the PIT-tag systems in the Oregon and Washington Ladders detected 99.6% (230/232) and 98.7% (221/224), respectively.

Based on testing done in Minnesota by Destron Technologies, PSMFC retuned the transceivers in the McNary Washington Ladder differently in early August, and it certainly appeared to improve detection as the reading efficiency for fall chinook salmon (98.7%) was higher than that recorded for spring chinook salmon (97.2%), a population that is much more orifice oriented (see Table 15).

Table 21. Numbers of double-tagged (PIT-tagged and radio-tagged) fall chinook salmon that passed the different ladders at Bonneville and McNary Dams in 2002 and then the numbers and detection rates for the PIT-tag systems.

Fish ladder	Total PIT or radio-tag (RT) detections	PIT-tag detections	Percentage PIT/total
Bonneville Dam			
Bradford A branch	175	172	98.3
Bradford B branch	113	108	95.6
Cascades Island Ladder	61	57	93.4
Washington Shore Ladder (all 12 weirs)	315	228	72.4
Washington Shore Ladder (upper 8 weirs)	315	196	62.2
McNary Dam			
Washington Ladder	225	221	98.2
Oregon Ladder	231	230	99.6
Oregon Ladder (orifice-based only)	231	230	99.6

Another interesting difference between fall chinook and other salmon populations was its much higher percentage (9.5% or 70/734) of double-tagged fish released below Bonneville Dam that never ascend any ladders at the dam (Table 22). This was almost four times the rate of missing passage data for steelhead, which had the second highest rate of missing data (2.5% or 23/924).

Table 22. Percentage for each double-tagged salmonid population of fish that were released below Bonneville Dam and then had no passage record at Bonneville Dam.

Salmonid Population	No passage data (%)
Spring chinook salmon	0.6
Summer chinook salmon	0.0
Fall chinook salmon	9.5
Steelhead	2.5

Steelhead

Based on final ascent as determined by both PIT-tag and radiotelemetry data, 382 double-tagged steelhead were categorized as having passed BWSL. Of these, the entire 12-weir system detected 93.5% while the upper section of eight weirs detected 90.3% (Table 23). The PIT-tag system in the Cascades Island Ladder detected 120 of the 128 (93.8%) double-tagged fish that ascended this ladder. PIT-tag systems in the Bradford Island A and B Branches detected 88.5% and 96.5% respectively of the double-tagged salmon that ascended each ladder. At McNary Dam, the PIT-tag systems in the Oregon and Washington Ladders detected 96.7% (654/676) and 94.9% (168/177), respectively.

Since many of the overall steelhead reading efficiencies were below 95% for the individual ladders at Bonneville Dam, we separated the steelhead tagged at Bonneville Dam into A-run (n = 409) and B-run (n = 295) groups based on the Corps cutoff date of 26 August to determine if there was a difference in detection between the two groups. We found that the PIT-tag systems detected the B-run steelhead better than the A-run steelhead (Table 24). Tag-reading efficiencies were above 95% for B-run steelhead in all ladders, but were above 95% for A-run steelhead in only one ladder at Bonneville Dam. Although we had tagged low numbers of A-run steelhead, we had observed a similar difference in detection between the two run types in the fish we PIT tagged in 2001 for evaluation of the prototype production PIT-tag interrogation system in BWSL (Downing et al. 2004).

Table 23. Numbers of double-tagged (PIT-tagged and radio-tagged) steelhead that passed the different ladders at Bonneville and McNary Dams in 2002 and numbers and detection rates for the PIT-tag systems.

Fish ladder	Total PIT or Radio-tag (RT) detections	PIT-tag detections	Percentage PIT/Total
Bonneville Dam			
Bradford A branch	191	169	88.5
Bradford B branch	200	193	96.5
Cascades Island Ladder	128	120	93.8
Washington Shore Ladder (all 12 weirs)	382	357	93.5
Washington Shore Ladder (upper 8 weirs)	382	345	90.3
McNary Dam			
Washington Ladder	177	168	94.9
Oregon Ladder	676	654	96.7
Oregon Ladder (orifice-based only)	676	650	96.2

Table 24. Numbers and reading efficiencies (%) for the different ladders at Bonneville and McNary Dams in 2002 of double-tagged (PIT-tagged and radio-tagged) steelhead that were separated into A- and B-run groups.

	A-run Steelhead		B-run Steelhead	
Fish ladder	N	%	N	%
Bonneville Dam				
Bradford A branch	79	79.7	39	100.0
Bradford B branch	64	96.9	25	96.0
Cascades Island Ladder	38	86.8	24	95.8
Washington Shore Ladder (all 12 weirs)	99	91.9	103	99.0
Washington Shore Ladder (upper 8 weirs)	99	89.9	103	93.2
McNary Dam				
Washington Ladder	46	97.8	21	100.0
Oregon Ladder	180	98.3	163	98.2
Oregon Ladder (orifice-based only)	180	96.6	163	97.5

Summary and Conclusions

Radiotelemetry data for all salmonids tagged with both radio and PIT tags in 2002 have been processed by the University of Idaho and NMFS to determine migration routes through Bonneville and McNary Dams. Once this was completed, we established how many double-tagged salmonids on their final ascents had passed each ladder based on both radiotelemetry and PIT-tag data. We then determined reading efficiencies for the different salmonid populations.

There were large differences in the reading efficiencies for the different salmonid populations. These differences appeared to reflect behavior trends that differed among individual salmonid populations, with detections highest in populations that ascended fish ladders primarily through the orifices. All orifice-based interrogation systems in the fish ladders at Bonneville and McNary Dam detected spring chinook salmon (>97%) and B-run steelhead (>93%) well. The upper orifice-based PIT-tag interrogation system in the BWSL detected stream-type salmon and steelhead at rates of at least 90%, but detected ocean-type salmon (Upper Columbia River summer chinook and fall chinook salmon) at rates closer to 60%. These results support conclusions from concomitant analyses reported here, which demonstrated that fall chinook salmon used weir overflows in BWSL more than they did in other fish ladders.

We were surprised to see a difference in reading performance between the Bradford A and B branches since they have the same ladder design; however, there are two differences between the PIT-tag systems that are important. The A branch has some antenna cables that are long (>80 ft) while all of the antenna cables for the B branch are shorter than 70 feet and most are <50 ft. The other difference is that the sun shines directly on some of the metal enclosure boxes that house the transceivers in the A branch (this led to some problems with high temperatures). In 2003, we will see whether this trend continues or whether the lower rates might be more caused by technical problems during the first year of operation.

VISUAL FISH COUNTS VS. PIT-TAG DETECTIONS

Over the years, the accuracy of visual fish counts at the counting windows has been questioned. Concerns have been raised because the count numbers are estimated for the periods during which counters take breaks, no fish counts occur at night, and there are some human-counting errors. Now that adult PIT-tag detection systems are installed at both Bonneville and McNary Dams, we have been asked how well the PIT-tag detections and visual fish counts matched. To address this question, we compared proportions of spring chinook salmon counted or detected at McNary Dam that were previously counted or detected at Bonneville Dam.

Visual fish counts for adult spring chinook salmon (tagged and non-tagged) during 2002 were 268,813 at Bonneville Dam and 129,357 at McNary Dam (Fig. 5). Thus, 48.1% of the Bonneville Dam total was counted at McNary Dam. The PIT-tag systems at McNary Dam detected 414 (52.5%) of the 789 Snake River adult spring chinook salmon detected at Bonneville Dam (these are fish with ISO tags only). Therefore, the two approaches yielded similar proportions (48.1 and 52.5%) for adult spring chinook salmon.

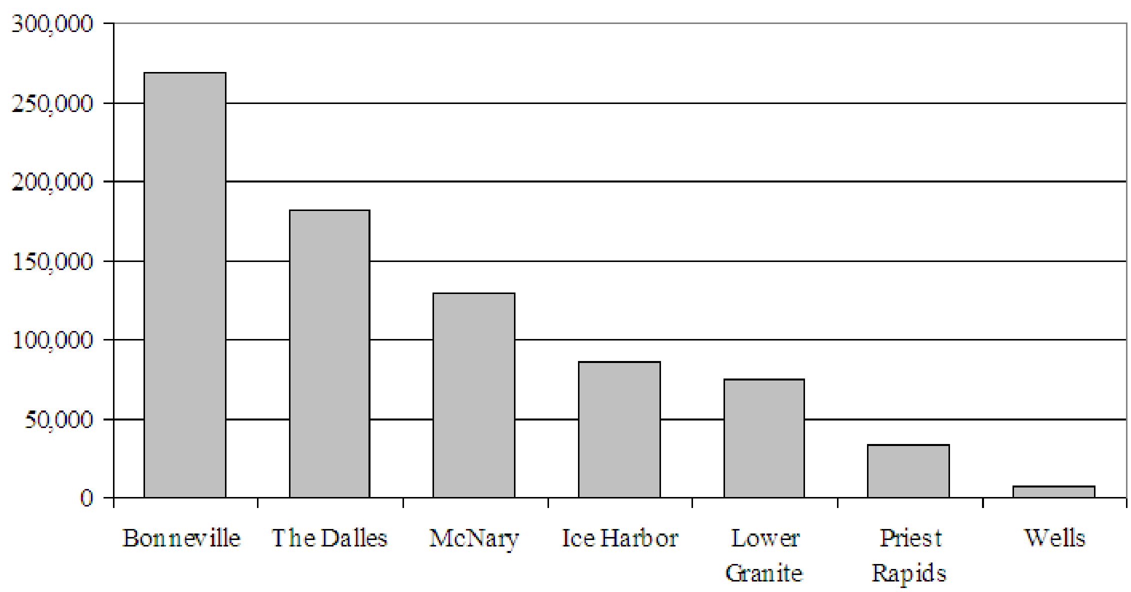

Figure 5. Visual fish counts for adult spring chinook salmon reported for the different dams throughout the Columbia River Basin, 2002.

PERFORMANCE OF ORIFICE ANTENNAS CONTAINING MOISTURE

Introduction

During October 2001, NMFS, Destron Technologies, and PSMFC determined that performance in three orifice-based antennas in the BWSL had significantly degraded, and they suspected the cause was moisture in the antennas. Tests on other antennas suggested there might be moisture in the cable connectors. Both these suspicions were confirmed by tests conducted in December 2001 when the Corps dewatered the ladder. It is important to note that **all** of the antennas were **still** reading tagged fish, but because fish numbers were minimal, it was difficult to distinguish how effectively.

The two most degraded antennas were replaced and dissected to evaluate how the manufacturing process for the fiberglass antennas could be improved. Further investigation revealed that an incompatibility of materials in relation to the manufacturing method caused pinholes to form that could eventually allow water to seep in. In December and January, the manufacturing process for the antenna housings was improved by significantly reducing the amount of foam used in the antenna and by covering the back of the connector plug and surrounding the capacitors with resin. However, around 25% of the fiberglass orifice antenna housings that were installed in 2002 were identified in April as probably containing some moisture (Table 25).

There was insufficient time to modify these antenna housings before the fish ladders had to be watered up. For the antenna housings in the BWSL that had been installed in 2001, the connectors were cleaned and reconnected in 2002 using a new procedure designed to reduce the likelihood of water leakage. No other work was done on the existing antenna housings to make them more watertight.

To investigate the long-term impact of antennas containing moisture, NMFS requested that some antennas in each ladder be set up so that their transceivers reported all reads for each individual fish (i.e., the unique read feature was turned off). Only one read is required to record a fish being present at an antenna, but the variable of the number of reads/fish is a useful tool for demonstrating degradation in performance over time. In addition, all transceivers in BWSL were left set up with unique read feature off for the entire year to permit comparisons to 2001. In September 2002, all transceivers at all ladders were set with the unique read feature turned off so that we could collect baseline information on each antenna. They will be left set up this way for 2003.

In addition, each transceiver sends out a status report every 60 to 360 minutes that includes parameter information which can be used to track both short- and long-term problems. For example, the status report can indicate when high temperatures cause internal electromagnetic noise levels to rise significantly (and detune the transceiver). Destron Technologies and PSMFC are still trying to determine which parameter will be the most diagnostic for predicting when an antenna needs to be replaced. They already use certain parameters to determine when an interrogation unit needs maintenance.

Table 25. List of antennas in each ladder that were measured as probably containing moisture between January and April 2002. Information provided by PSMFC.

Fish ladder	Antenna IDs for antennas containing moisture
Bonneville Dam	
Bradford A branch	02, 0A, 0F
Bradford B branch	14, 16, 18, 20
Cascades Island	0F, 10
Washington Shore Ladder (upper section)	4B, 5B, 7A, 8A, 8B, 9A
McNary Dam	
Oregon Ladder	07, 08, 0D, 0E, 0F, 10, 11
Washington Ladder	01, 03, 07, 0E, 0F, 10

Three times during the season, PSMFC tested all antennas in the fish ladders with a megohmmeter to determine whether the resistance measurement had changed significantly for any antenna (when resistance between two antenna cables measures less than infinity, the conclusion is that the antenna probably contains moisture). These tests showed that most antennas remained consistent over all sets of measurements, but others did change their status. Furthermore, since only a small amount of condensation is needed to cause a false positive reading for moisture, PSMFC is re-evaluating this test. Antennas for which measurements consistently indicated moisture over the entire 2002 season are listed in Table 26. In Tables 27-29, cells containing data from these antennas are shaded.

Table 26. List of antennas in each ladder for which all sets of measurements made in 2002 indicated that the antenna probably contained moisture. Information provided by PSMFC.

Fish ladder	Antenna IDs for antennas containing moisture
Bonneville Dam	
Bradford A branch	02, 0A, 0F
Bradford B branch	14, 18, 20
Cascades Island	0F, 10
Washington Shore Ladder (upper section)	4B, 5B, 8A, 8B, 9A
McNary Dam	
Oregon Ladder	08, 0D, 0E, 0F, 10, 11
Washington Ladder	07, 0E, 0F, 10

Tag-Reading Performance

During 2001 and 2002, NMFS compared the median number of reads/fish in the BWSL (Table 27). April dates were chosen for the analysis in 2002 because the 2001 data were already analyzed, and to have comparable data sets, we needed data that was representative of the results for a similar time period. This comparison showed that performance of antennas containing moisture in April 2002 was equal to or better than in April 2001. Therefore, it appeared that the antennas containing moisture had not degraded over time.

Table 27. Median values for reads/fish for each antenna in the Washington Shore Ladder at Bonneville Dam on two dates in April 2001 and 2002. The table also indicates how many adult salmonids transited a particular orifice or antenna on these dates. Shaded cells indicate antennas that consistently measured as containing moisture during 2002.

Antenna IDs	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B*	8A	8B	9A	9B
28 April 2002																
Medians	19.0	16.5	14.5	22.0	18.0	19.0	16.0	16.0	14.0	13.0	17.0	21.0	18.0	17.5	17.0	6.0
Count	11	14	12	13	11	13	8	17	10	16	13	15	17	10	17	10
24 April 2001																
Medians	14.0	16.0	16.0	14.5	20.0	16.5	17.0	16.0	15.5	15.0	15.5	11.0	17.0	15.5	15.5	4.0
Count	24	5	23	6	23	6	21	8	20	9	20	9	21	8	18	10

* Antenna 7B was replaced in December 2001

Furthermore, results of a nonparametric Mann-Whitney statistical test showed that the difference between median numbers of reads/fish for antennas containing moisture and those without moisture in 2002 was not significant ($P > 0.05$). Excluded from this analysis was Antenna 9B, because its reads/fish are affected by a high-voltage line running underneath the orifice. A *t*-test was used in the status report in May (Downing 2002), but a statistician recommended using medians instead of averages because the data were not normally distributed. These results indicate that there was no real difference in tag-reading ability between antennas that contained moisture and those that did not.

Analyses conducted on all ladders from May to September 2002 demonstrated that whenever a median value for the reads-per-fish went below five, then that antenna was missing fish occasionally. This was clearly demonstrated with data collected in September after PSMFC set up all transceivers to report repeat detections of individual fish: weir counts were 10-30% less in weirs having one antenna that detected less than 5 reads/fish (bold face numbers in Table 28).

Table 28. The median values for reads/fish for each antenna, fish counts, and weir totals collected 30 August-4 September 2002 for the orifice-based interrogation systems in the different ladders at Bonneville and McNary Dams. Antennas for which all measurements indicated moisture are shaded dark; those for which most measurements indicated moisture are shaded light.

Bradford A branch (BO1)

Antenna IDs	10	0F	0E	0D	0C	0B	0A	09	08	7	06	05	04	03	02	01
Medians	8.0	6.0	**1.5**	8.0	10.0	9.0	6.0	8.0	10.0	9.0	8.0	10.0	9.0	11.5	9.0	6.5
Fish counts	23	25	4	27	26	27	22	25	23	29	26	27	25	26	25	22
Weir totals	48		**31**		53		47		52		53		51		47	

Bradford B branch (BO1)

Antenna IDs	20	1F	1E	1D	1C	1B	1A	19	18	17	16	15	14	13	12	11
Medians	7.0	10.0	10.0	11.0	9.0	11.0	9.5	9.5	9.0	6.0	**4.0**	11.0	11.0	9.0	11.0	8.0
Fish counts	39	32	47	29	41	31	44	32	41	31	32	30	39	33	43	35
Weir totals	71		76		72		76		72		**62**		72		78	

Cascades Island (BO2)

Antenna IDs	10	0F	0E	0D	0C	0B	0A	09	08	07	06	05	04	03	02	01
Medians	9.0	8.0	8.0	9.5	12.0	12.0	11.0	13.0	11.0	11.0	11.5	11.0	12.0	16.0	9.0	9.0
Fish counts	26	21	34	18	32	19	33	16	30	20	28	19	30	21	29	17
Weir totals	47		52		51		49		50		47		51		46	

Washington Shore Ladder (BWL)

Antenna IDs	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B
Medians	12.0	14.0	13.0	13.0	12.0	11.0	11.0	12.0	11.0	10.0	12.0	13.0	13.0	12.0	9.0	**3.0**
Fish counts	44	51	39	56	42	54	46	55	44	51	41	51	45	49	35	43
Weir totals	95		95		96		101		95		92		94		**78**	

McNary Oregon Ladder (MC1)

Antenna IDs	12	11	10	0F	0E	0D	0C	0B	0A	09	08	07	06	05	04	03
Medians	**4.0**	9.0	8.0	8.0	11.0	10.0	10.0	6.5	11.0	10.0	9.0	7.0	10.0	10.0	**5.0**	**3.0**
Fish counts	50	52	55	54	65	49	62	48	62	49	51	55	51	55	50	43
Weir totals	**102**		109		114		110		111		106		106		**93**	

McNary Washington Ladder (MC2)

Antenna IDs	10	0F	0E	0D	0C	0B	0A	09	08	07	06	05	04	03	02	01
Medians	10.5	8.0	12.0	10.0	10.0	**2.0**	**4.5**	13.0	13.0	9.0	15.0	8.0	10.0	**3.0**	10.0	11.0
Fish counts	38	39	40	39	39	19	36	39	43	34	41	35	40	23	41	38
Weir totals	77		79		**58**		75		77		76		**63**		79	

However, in some ladders, fish tend to use one side of the ladder more than the other, and in those cases, the impact of antennas with lower median reads/fish values was either increased or reduced. That and other fish behavior (i.e., fish do not have to use the orifices, and some fish go up and down within a ladder) make it impossible to conclude at this time whether median values of 5-9 reads/fish may also mean that some fish are missed. This question needs to be determined over the next few years.

Of the nine orifice antennas that had median values of less than 5 reads/fish (their median values are bolded in Table 27), only two were from antennas wherein most measurements indicated moisture; none was from the group of antennas wherein all measurements indicated moisture. Thus there must be other reasons besides having some moisture in the antennas for these systems to miss detecting some fish. For example, antenna 9B in the BWSL (whose median value was 3.0 reads/fish in Table 28), has a high voltage line installed under it that definitely impacts its reading ability.

In addition, some antennas that had median values less than 5 reads/fish have long antenna cables, others appeared to have poor grounding, and others were in locations that may be impacted by intermittent local electromagnetic interference. Low median values were also seen in antennas where we frankly do not know the reason for the poor performance. Again, these are new systems and we are still learning how to improve their performance.

Antennas with the unique-read turned off were tracked over the entire season. They generally showed that the median values for reads/fish remained fairly consistent over the season; although as in 2001, it appeared that for some there was a decrease over time (Table 29). Some of the decline over time may be attributed to the higher summer temperatures affecting the tuning and causing RF noise in the transceivers that masked the tag signal. And some might be due to fish behavior of different salmonid populations (e.g., how quickly or at what angle a fish transits an orifice).

Table 29. The median values for reads/fish for six antennas in the Washington Shore Ladder at Bonneville Dam over several dates in 2001 (the days we tagged fish) (top) and for nine antennas in the McNary Oregon Ladder during 2002 (bottom). Shaded cells indicate antennas that consistently measured as containing moisture. The consistent, but notably lower read numbers from Antenna 03 are shown in boldfaced.

Bonneville Washington Shore Ladder

2001 dates	Antenna ID					
	2B	3A	3B	8A	8B	9A
16-18 Apr	17.5	15.0	17.5	17.0	16.0	15.0
24-25 Apr	15.5	17.0	18.0	18.0	16.0	15.0
13-Jun	16.0	14.0	16.0	15.0	13.0	14.0
18-19 Sep	13.0	13.0	14.0	13.0	12.0	13.0
25-26 Sep	13.0	12.0	13.0	12.0	14.0	13.0

McNary Oregon Ladder

2002 dates	Antenna ID								
	0E	0D	0B	08	07	06	05	04	03
24-26 May	12.0	12.0	8.0	11.0	11.0	13.0	13.5	7.0	**3.5**
9-14 Jun	13.0	11.0	8.0	11.0	10.5	12.0	12.0	7.0	**4.0**
5-8 Jul	14.0	12.0	7.0	11.0	10.5	10.0	12.0	7.0	**4.0**
19-21 Jul	11.5	9.0	7.0	10.0	9.0	10.5	9.0	6.5	**3.0**
30 Aug-3 Sep	11.0	10.0	6.5	9.0	7.0	10.0	10.0	5.0	**3.0**

Summary and Conclusions

Around 20% of the antennas installed into the fish ladders at Bonneville and McNary Dams consistently measured as containing moisture over the entire 2002 season. Our comparison of the number of reads/fish at BWSL for April 2001 and 2002 showed that the performance of all antennas in April 2002 was equal to or better than in April 2001. Therefore, it appeared that the antennas containing moisture had not degraded over time. Furthermore, a nonparametric statistical test comparing the number of reads/fish in 2002 between BWSL antennas with and those without moisture showed the difference was not significant. Similar comparisons between antennas with and without moisture in the other ladders also showed no significant differences. Thus, there did not appear to be any difference in the ability of the antennas to read tags based on whether or not they contained moisture.

Analyses conducted on all ladders from May to September 2002 demonstrated that whenever a median value for the reads-per-fish went below five, then that antenna was missing fish occasionally. Weir counts were 10 to 30% less in weirs having one antenna whose median value was less than 5 reads/fish. Of the nine orifice antennas that had median values less than 5 reads/fish, only two were from antennas that mostly measured as containing moisture; none was from the definite group of antennas containing moisture. Therefore, other reasons must exist for the poor performance of these systems (e.g., long antenna cables, poor grounding, or electronic noise) besides having some moisture in the antennas. It bears repeating that these are new systems, and we are still learning how to improve their performance.

It is important to note that no antennas failed during 2002. Analyses of all antennas in mid September using number of reads/fish, weir counts, and transceiver antenna current levels did not consistently identify any single antenna that was weak. Thus, PSMFC, NMFS, and Destron Technologies concluded that none of the antennas needed to be replaced during the 2002-2003 dewatering period.

All of the antennas will continue to be monitored in the future since moisture could eventually seep into areas that contain high voltage; when moisture reaches these areas, reading performance will be impacted.

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