Evaluation of a Full-Flow PIT-Tag Interrogation System at McNary Dam, 2002

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EXECUTIVE SUMMARY

In 2001, the National Marine Fisheries Service evaluated the technical feasibility of interrogating PIT-tagged fish in large-diameter juvenile fish bypass pipes (full-flow bypass system) at McNary Dam. Objectives of this evaluation were:

1) to develop a PIT-tag interrogation system that could function year-round rather than only seasonally,

2) to provide greater flexibility in the operation of the juvenile fish facility without disrupting operation of the present juvenile interrogation systems, and

3) to develop a PIT-tag interrogation system that can be used with the existing juvenile fish bypass pipe that leads from the powerhouse to the juvenile fish collection and monitoring facility.

Based on information from the evaluation conducted in 2001, the new interrogation system was installed in 2002 and its performance evaluated. The system far exceeded the goal of 95% tag-reading efficiency for four antennas.

Two methods of determining tag-reading efficiency were used: direct and indirect. The direct method uses a known number of tagged fish that are released at a specific location upstream from the detectors. That number is then compared to the number of unique tag codes read. Using this method, over 98% reading efficiency was obtained under all test conditions. The second method relies upon a statistical comparison of tags read between antennas. This method showed tag-reading efficiency of the system ranged between 99.5 and 100% during the season.

Comparisons of tag-reading efficiency were also made between the new full-flow detection system (MCX) and the existing PIT-tag interrogation system (MCJ). The MCX consistently showed higher tag-reading efficiencies than the MCJ system. The differences between the systems can be explained in part by the possible sudden passage of large numbers of tagged fish from the wet separator causing tag collision on the MCJ system or by fish being bypassed to the river without being interrogated.

A contributing factor to the success of the MCX system was the use of radio frequency (RF) clamps to shape the electromagnetic field generated by the antenna. This concept was developed in 2001 and deployed for the first time on this project. The shaping of the electromagnetic field enabled a narrow tag-reading “window” to be

formed, thus reducing the likelihood of more than one tag being read at any one time. This reduced the loss of information from “tag code collision.”

Radio frequency interference and electromagnetic field exposure measurements were made at various MCX locations by consulting electrical engineers. The PIT-tag interrogation equipment was found to be in conformance with FCC requirement § 15.209(a), *Radiated emission limits, general requirements* and within the electromagnetic maximum permissible exposure standards of the IEEE.

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INTRODUCTION

The National Marine Fisheries Service (NMFS) Biological Opinion for Operation of the Federal Columbia River Power System addresses the issue of increasing passage survival of juvenile Pacific salmonids *Oncorhynchus* spp. at hydroelectric dams in the Columbia River Basin. One proposed approach includes bypassing fish under full-flow conditions and routing them directly back to the river rather than through the juvenile fish collection and monitoring facilities (NMFS 2000, Sections 9.6.1.4.2 and 9.6.1.4.6).

Currently, when fish are bypassed and routed to the juvenile fish facilities at Columbia and Snake River hydroelectric dams, PIT-tagged fish are automatically detected and information regarding migrational behavior, timing, and survival is obtained (Prentice et al. 1990, Nunnallee et al. 1998, Downing et al. 2001). However, when juvenile fish are bypassed and routed directly back to the river rather than through the juvenile fish facilities, PIT-tag detection does not occur, and the opportunity to obtain this information is lost. The collection of this information greatly benefits many studies associated with salmonid recovery efforts in the Columbia River Basin.

In 2001, NMFS evaluated the technical feasibility of developing a PIT-tag interrogation system for large-diameter juvenile fish bypass pipes (i.e., full-flow bypass system). The objectives were to develop a PIT-tag interrogation system that would:

1) enable PIT-tag interrogation year-round rather than only seasonally as is presently the case,

2) provide greater flexibility in the operation of the juvenile fish facility without precluding operation of the present juvenile interrogation systems, and

3) use the existing 91.4-cm-diameter juvenile fish bypass pipe that leads from the McNary Dam powerhouse to the juvenile fish collection and monitoring facility.

Based upon information obtained from a battery of tests conducted at the NMFS Pasco Research Station, the project was determined to be technically feasible (Nunnallee and Prentice 2002). This report focuses on the installation of the PIT-tag system electronics (i.e., antenna system and transceiver) and the evaluation of the system once it became functional. The new system is designated MCX (McNary experimental) in the Columbia River Basin PIT-tag Information System (PTAGIS), a regional database system. The existing juvenile collection and monitoring PIT-tag system at the dam is designated MCJ in PTAGIS, and the data collected at this location is publicly available (PSMFC 1996).

ANTENNA AND TRANSCEIVER INSTALLATION AND OPERATION

Methods

Antenna Location

The experimental PIT-tag interrogation system was installed on the main juvenile fish transport pipe in the area located 77.7-98.7 m downstream from the powerhouse. At this point, the 91.4-cm-diameter steel transport pipe is located 10.8 m above the ground (mid-pipe to ground level). A total of four antennas were planned for the project with an option for additional units if required. In early 2002, U.S. Army Corps of Engineers (COE) contractors initiated work installing structural components (radio frequency (RF) shields, walkways, pipe access hatch, transceiver housing boxes, etc.), AC electrical power, and communications lines for the new full-flow PIT-tag interrogation system.

The transport pipe was cut, and the first RF shield containing a fiberglass pipe section was installed at 77.7 m from the powerhouse. Fiberglass pipe was required because only low-conductance material can be used in antenna construction. The second, third, and fourth shield/pipe units were located at 85.9, 90.5, and 98.7 m downstream from the powerhouse, respectively. The shield boxes were constructed of aluminum and measured 2.4 m high by 2.4 m wide by 1.8 m long. A section of 91.4-cm-diameter fiberglass pipe, to which the antenna was attached, passed through the center of each box (Figure 1). A hatch was placed in the top of the steel pipe about 2.4 m from the first antenna for system inspection and for conducting preliminary tag-reading tests with PIT-tagged drones.

Installation

On 20 March 2002, structural components were sufficient to install the antennas in the RF shield boxes and the transceivers in NEMA 4[1] housing boxes (Figures 1-2). The electronic installation work was performed by NMFS and its contractor, Digital Angel Corporation[2] (parent company of Destron Fearing, the PIT-tag

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1 Rated by the National Electric Manufacturers Association for indoor or outdoor use to provide a degree of protection against rain, sleet, snow, windblown dust, falling dirt, splashing or hose-directed water, and external ice formation.

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

Figure 1. Overview of the 91-cm diameter PIT-tag interrogation system installed on the main juvenile fish bypass pipe at McNary Dam.

Figure 2. PIT-tag transceiver mounted in a NEMA 4 box under a sun shield.

equipment manufacturer). One antenna was installed in each of the four shield boxes. The antenna configuration installed was a double/parallel coil design. This antenna was constructed using 16-gauge, 600-V, PVC-coated wire.

The wire was wrapped in two sets or coils, each coil consisting of a single layer of closely spaced wire wraps around the pipe. The two coils of wire were separated by 3.8 cm. Each set of wire wraps was wound to attain an inductance of approximately twice that which has previously been found to work efficiently with an antenna series tuning capacitance of 4,700 pF. The two coils were then connected in parallel, in phase, and in series with the tuning capacitors. After being adjusted to come to resonance at about the midpoint of the internal tuning range of the transceivers, the final number of wire wraps on each coil of the antenna was 13. The resultant total inductance was 325 μH for each antenna.

Each coil of the double coil antenna was wrapped on anti-vibration pads that were attached to a coil adjuster band. Each adjuster consisted of a 10-cm-wide piece of polyethylene sheeting that extended around the pipe. The ends of each polyethylene strip were connected with wire ties to form a band around the pipe. Attached evenly around each band were eleven 10-cm by 10-cm by 1-cm thick closed-cell foam blocks. The wire for each coil was wound over the foam block/band system. This arrangement allowed the coils of the antenna to be adjusted individually after wrapping for antenna tuning purposes.

The purpose of the foam was to reduce mechanical coupling of vibration from the transport pipe to the antenna and to eliminate the effects of shrinkage and expansion of the pipe with temperature changes. Once an antenna was wrapped, RF clamps were installed on either side of the antenna. The clamps consisted of 31-cm wide by 5-mm thick sheets of aluminum cut to form a collar around the pipe. The clamps were not connected directly to the main shield box and made direct contact with the pipe only at four attachment points. The RF clamps were spaced 25.4 cm on either side of antennas 01 and 03 and 30.5 cm on either side of antennas 02 and 04 (Figure 3).

Destron Fearing model FS1001-A transceivers were installed in the NEMA 4 electrical boxes located at ground level (Figure 2). Conditioned AC 120-V electrical power was routed from a known clean source, the juvenile collection and monitoring facility PIT-tag instrument room. Electrical grounding from a second source was used to eliminate a grounding problem that initially resulted in electromagnetic interference (EMI).

Figure 3. Antenna with RF clamps.

Preliminary Evaluation and Testing

Prior to antenna tuning and conducting PIT-tag reading efficiency tests, water velocity in the 91.4-cm pipe was determined. A velocity meter was extended into the water column through a hatch in the pipe, which was located about 2.4 m upstream from the first antenna. The meter showed a velocity of 3 m/sec near the sides of the pipe and 3.4 m/sec near the center of the water column. Flow volume in the pipe was about 0.85 m^3/sec at a depth of 45 cm.

Antenna tuning was verified on 2 April using PIT-tagged drones which were attached to a line and passed through the pipe hatch. The drones were allowed to drift downstream and then were retrieved via the attached line. Additional tests were conducted with free-floating drones which were retrieved in the secondary dewatering system located downstream from the newly installed interrogation system. These tests were performed repeatedly until satisfactory conditions existed for the antenna, transceiver, and RF clamp positions. The interrogation system was evaluated throughout the season with PIT-tagged fish in order to determine the best configuration for spacing of the RF clamps.

Radio Frequency Emissions and Electromagnetic Exposure

Consulting electrical engineers Hatfield and Dawson were contracted by NMFS to make radio frequency interference (RFI) and electromagnetic field (EMF) exposure measurements at various MCX locations. On 26 June 2002 a series of measurements were taken to determine if the PIT-tag interrogation equipment was in conformance with the requirements of §15.209 (a) *Radiated emission limits, general requirements* of the Rules & Regulations of the Federal Communications Commission. In addition, measurements were taken to determine compliance with the electromagnetic maximum permissible exposure (MPE) limits of IEEE Std C95.1, 1999 Edition, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" (C95.1). A report from Hatfield and Dawson describing the methods and results is included in the Appendix.

Results and Discussion

The double parallel coil antenna configuration evaluated in 2001 proved to be an effective antenna for the MCX facility (Nunnallee and Prentice 2002). The advantage of this antenna configuration over a single coil antenna is that for a similar inductance, the total number of turns is about twice what it would be for a single coil. This means that the amp turns (exciter current (A) × number of turns) are about double that of a single coil antenna. The amp turns equate to the electromagnetic field intensity needed to interrogate PIT tags. Previous testing showed this type of antenna to have very good tag excitation and detection properties when the tag was at less than ideal orientation.

The RF field clamps are used to load or reduce the longitudinal portion of the electromagnetic field produced by the antenna in order to limit the distance along the axis of the pipe where PIT tags can be excited and detected. When the excitation field is too large, signals from multiple tags within the field may interfere with one another and detections will be lost. Similarly, if high volumes of fish pass through such a field, some tagged individuals can be missed due to collisions between tag transmissions (i.e., "tag code collision"). The RF field clamps proved to be very effective in reducing the loss of data from this factor as indicated by the high tag-reading efficiency obtained even under conditions where large numbers of fish were introduced at one time (i.e., direct tag-reading efficiency Tests 3 and 4).

The spacing of the RF clamps had an effect on tag detection during the season for run-of-the-river fish (Figure 4). Clamp spacing was 25.4 cm on antennas 01 and 03 and 30.5 cm on antennas 02 and 04. Antennas 01 and 03 had higher respective mean tag detection rates (93.6 and 88.4%), over a 31-day period in July than antennas 02 and 04 (87.4 and 83.8%). To improve overall tag-reading performance, all the clamp settings at MCX will be changed to 25.4 cm in time for the 2003 field season.

A fiber based insulation material was sprayed on the walls and ceiling of the shield boxes to reduce vibration. The material had a very high water content at the time of installation and was difficult to dry. Water from this material, in addition to that which condensed from the air, ultimately made contact with the antenna coils and caused a reduction in antenna current during the first 2 months of operation.

To reduce the condensation problem, two air vents were installed in the walls of each shield box: one near the floor and one near the ceiling. These vents enabled air to circulate in the shielded box and thus provided a means for the moisture to escape. The

modification appears to have reduced the condensation problem but has not totally solved it. We recommend that insulation be sprayed on the pipes with the shield boxes to further reduce the condensation problem.

Overheating of the transceivers occurred on several occasions during the summer months. The transceivers are set to send an alarm when internal temperatures reach 60°C. High temperature within the transceiver can cause premature component failure. Several temporary measures were taken with mixed results. The door to the transceivers were opened to enable better air circulation. This reduced the temperature to normal operating parameters. However, with the door of the transceiver left open, dirt and debris can contaminate the electronic components and cause problems. At the time of this report, no permanent solution to the high-temperature problem has been determined, but several solutions are being evaluated, and a permanent solution will be implemented prior to the 2003 field season.

The transceivers were found to change tune with changes in operating temperature and other unknown causes. Capacitors in the antennas and transceivers were changed several times during the field season in an attempt to stabilize the tune of the system, and results from these tests showed promise. Based on laboratory and field test results, new capacitors were installed in all antennas and transceivers in early November 2002.

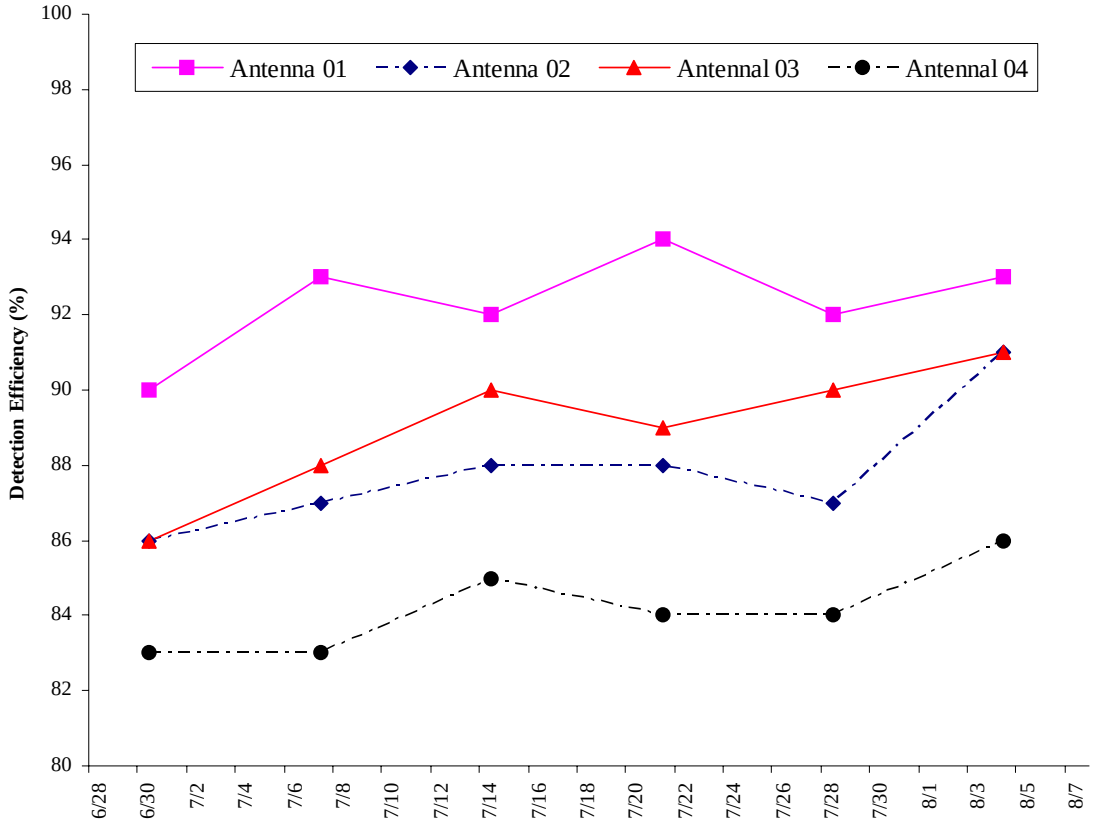

Figure 4. Detection efficiencies for two different RF clamp spacings: antenna coils 01 and 03 had RF clamps set 25.4 cm from either side, and antenna coils 02 and 04 had clamps spaced at 30.5 cm.

Conclusions and Recommendations

Antenna Construction

The use of adjustable bands on which the antenna coils were wrapped expedited tuning of the antenna and is recommended for future installations. Furthermore, the closed-cell foam pads on which the antenna coils were directly wrapped have assured uniform antenna configuration during pipe expansion and contraction cycles due to temperature changes within the shield boxes. These same foam blocks also have aided in reducing antenna vibration, which was a concern at the onset of the project.

Radio Frequency Field Clamps

RF field clamps, used in conjunction with coil spacing, provide the means to adjust and shape the effective electromagnetic field pattern of the antenna. These clamps allow the electromagnetic field to be shaped such that the upstream and downstream reading range of the antenna can be adjusted to reduce the effect of tag-code transmission collisions and loss of detection when tag density is high. At the same time, a strong RF field intensity can be maintained within the central part of the antenna to ensure a high tag-reading probability. An RF clamp spacing of 25.4 cm on either side of the antenna coil provided a better tag detection rate than a 30.5-cm spacing for the MCX system.

Radio Frequency Shield Box

The RF shield box construction was adequate, but future shield boxes of this size should incorporate air vents with dust filters to reduce the possibility of water condensation on antenna coils.

Radio Frequency Emissions and Electromagnetic Exposure

In summary, the report of Hatfield and Dawson (Appendix) states that the MCX PIT-tag system is in conformance with the requirements of §15.209 (a) *Radiated emission limits, general requirements* of the Rules & Regulations of the Federal Communications Commission and with the electromagnetic maximum permissible exposure (MPE) limits of IEEE Std C95.1, 1999 Edition, “IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz” (C95.1).

SYSTEM TAG-READING EFFICIENCY USING A DIRECT STATISTICAL METHOD

Methods

Preliminary tests using PIT-tagged fish in conjunction with the drone test data were used to verify system tuning, aid in the design of large-scale PIT-tag reading efficiency tests (described below), and to verify fish handling and release techniques to be used in subsequent system reading tests.

On 2 April two preliminary tests using PIT-tagged juvenile hatchery steelhead *O. mykiss* were conducted. In the first test, a total of 25 fish were introduced one at a time into the transport pipe via the hatch located upstream from the first antenna. In a second test, fish were released into the entrance of the 91.4-cm transport pipe at the powerhouse. For these releases, a fish transport truck was parked on the deck of the powerhouse. Fish were transferred from the truck to a portable fish-hauling container by net. The container was then hand carried to a position near the entrance to the fish transport pipe within the powerhouse. At this point the fish were placed in a holding tank supplied with a continuous supply of water and oxygen.

Prior to release, each previously PIT-tagged fish was scanned and its tag code automatically recorded in a release file. The scanned fish was then placed in a release container (Figure 5) and released into a hopper to which a 9.1-m long by 7.6-cm-diameter flexible hose was attached (Figure 6). The discharge end of the hose was located in the 91.4-cm-diameter fish transport pipe. Flush water was continuously introduced into the hopper to ensure fish escapement from the hopper and hose. For this test, fish were released one at a time, with the release time varying from 5 sec to 15 sec. A total of 41 fish were released.

Based upon the results of the preliminary tests on 2 April, two series of four tests each were conducted to determine the tag-reading efficiency of the MCX system using a direct evaluation method, which compares the number of individual fish interrogated to a known number of fish released. It should be noted that this method is only accurate for the time and conditions of the test and does not necessarily represent reading efficiency over a prolonged period. Fish used in these tests were previously PIT-tagged hatchery juvenile summer steelhead (mean fork length (FL) = 234 mm).

Figure 5. Previously PIT-tagged and scanned juvenile salmon being placed in release containers.

Figure 6. PIT-tagged juvenile salmon being released into a hopper to which a flexible hose was attached that lead to the entrance of the 91-cm diameter bypass pipe.

All fish were released into the entrance of the main 91.4-cm-diameter transport pipe that leads from the powerhouse to the juvenile fish collection and monitoring facility using the procedures described for the second of the two preliminary tests (2 April).

Test 1 of the first test series began on 9 April 2002 with the release of 175 fish, one at a time, at about 15-sec intervals. For Test 2, 176 fish were released, one at a time, at about 5-sec intervals. For Test 3, 200 fish were released in groups of five at about 15-sec intervals, and for Test 4, 184 fish were released in groups of 10 at about 15-sec intervals. Overall, 735 fish were released into the main transport pipe. A summary of the conditions for each test is shown in Table 1.

On 16 April 2002, NMFS conducted a second series of tests that were similar in design to those conducted on 9 April using previously PIT-tagged hatchery juvenile subyearling chinook salmon *O. tshawytscha* (mean FL = 72 mm). Four tests were conducted using the same testing protocol used in the 9 April tests with juvenile steelhead. For Test 1, 175 fish were released, one at a time, at about 15-sec intervals. For Test 2, 175 fish were released, one at a time, at about 5-sec intervals. For Test 3, 200 fish were released in groups of five at about 15-sec intervals, and for Test 4, 190 fish were released in groups of 10 at about 15-sec intervals. Overall, a total of 740 fish were released. A summary of the test conditions for each test is shown in Table 2.

Results and Discussion

During the two preliminary tests on 2 April, we observed high detection efficiencies. All but one fish was detected during the first preliminary test (96% reading efficiency for all four antennas combined) and all fish were detected (100% reading efficiency) during the second preliminary test. The results of the 9 and 16 April tag-reading efficiency tests are shown in Tables 1 and 2 and are presented for the four antennas combined. As previously stated, the method used in this test series is referred to as the direct evaluation method of determining system reading efficiency. When using this approach, the number of individual fish interrogated is directly compared to a known number of fish released.

Results show that reading efficiency was high for both juvenile steelhead and chinook salmon (99.5 and 99.9%, respectively, for tests combined), regardless of the rate or density at which fish were introduced into the pipe.

Table 1. Tag-reading efficiency test conditions and results on 9 April using PIT-tagged juvenile hatchery summer steelhead.

Test	Release time interval	No. fish released	No. fish detected	% reading efficiency (4 antennas combined)
1	1 fish per 15 sec	175	174	99.4
2	1 fish per 5 sec	176	174	98.9
3	5 fish per 15 sec	200	199	99.5
4	10 fish per 15 sec	184	184	100.0
			mean	99.5%

Table 2. Tag-reading efficiency test conditions and results on 16 April using PIT-tagged juvenile hatchery fall chinook salmon.

Test	Release time interval	No. fish released	No. fish detected	% reading efficiency (4 antennas combined)
1	1 fish per 15 sec	175	175	100.0
2	1 fish per 5 sec	175	174	99.4
3	5 fish per 15 sec	200	200	100.0
4	10 fish per 15 sec	190	190	100.0
			mean	99.9%

The tests were conducted as planned with no difficulties encountered. One concern prior to testing was that the fish release rate and/or density could result in several fish being in the detection field of an antenna at the same time. In most cases if this situation occurs, no tag code will be read (tag code collision). The data suggest that this condition did not occur at a significant level during either the 9 or 16 April test series, since for both series,100% of the fish were read during the last releases, which had the highest fish densities (10 fish every 15 sec). We attribute these results in part to the effectiveness of the RF field clamps in restricting the width of the detection field, thus restricting the number of tags that could be in the "read window" at any one time.

The interrogation data obtained from PTAGIS showed the maximum number of tags per minute successfully read during the 9 and 16 April test periods as 75 tags per minute. This rate was only exceeded on six occasions during the 2002 season. The highs for the season were 96 and 95 tags per minute for MCX and MCJ, respectively. These data suggest that the MCX system, as presently configured, should be able to handle the tag volume now and in the near future.

Conclusions

The MCX PIT-tag interrogation system worked as designed, providing tag-reading efficiencies near 100% (four antennas combined) when tested with juvenile steelhead and chinook salmon released at a variety of rates and densities.

SYSTEM TAG-READING EFFICIENCY USING AN INDIRECT STATISTICAL METHOD

Methods

Periodically during the field season an indirect statistical method was used to determine system tag-reading efficiency. This method relies upon a comparison of PIT-tagged fish read on one antenna to those read on other antennas in a system (e.g., tags read on antenna 1 to 2, 3, and 4 and all combinations and permutations therein for a single group of antennas) or a comparison of one system to another (e.g., MCX to MCJ and vice versa).

On two occasions during the field season, two-way comparisons were made between the tag-reading efficiency of the four antennas of MCX to those of the entire MCJ system. The first comparison period covered interrogations from 15 April to 9 May, during the peak period of migration for yearling chinook salmon and steelhead. The second comparison period was from 1 to 31 July, during the peak migration of subyearling chinook salmon.

The comparisons used all previously PIT-tagged fish passing through the McNary bypass system. All comparisons were made of combined tag-reading efficiency data from all four MCX antennas and data from the combined MCJ system. MCJ PIT-tag event logs were consulted and adjustments made to MCJ data for periods when fish were bypassed to the river (normally every other day or during debris cleaning periods) or transceivers were not operating.

Results and Discussion

PIT-tag reading comparisons were made between MCX and MCJ during the periods of 15 April-9 May and 1-31 July 2002. Results during these comparison periods are presented in Tables 5-8. For each comparison, the total number of PIT-tagged fish observed in each fish category (i.e., chinook salmon or steelhead, hatchery or wild) is presented by day in addition to the percent detected for a particular system (MCX or MCJ) for that day. The overall tag-reading efficiency for all days combined per fish category is also presented.

Table 5. PIT-tag reading efficiency of the McNary Experimental (MCX) system based on daily detections of the MCX compared to those of the existing detection system (MCJ) for PIT-tagged hatchery and wild chinook salmon and hatchery and wild steelhead during their peak migration period, 15 April to 9 May 2002.

	Hatchery chinook			Wild chinook		
Day	MCX total	MCJ total	MCX efficiency (%)	MCX total	MCJ total	MCX efficiency (%)
4/15	8	8	100	7	7	100
4/16	27	27	100	20	20	100
4/17	56	57	98	32	32	100
4/18	118	119	99	34	34	100
4/19	284	289	98	65	65	100
4/20	307	311	98	59	59	100
4/21	363	370	98	59	59	100
4/22	365	371	98	68	69	98
4/23	373	379	98	77	77	100
4/24	466	470	99	106	106	100
4/25	609	618	98	163	163	100
4/26	525	530	99	130	130	100
4/27	553	565	97	123	123	100
4/28	519	523	99	101	101	100
4/29	591	596	99	132	132	100
4/30	716	726	98	133	133	100
5/01	880	894	98	172	172	100
5/02	1,960	1,978	99	417	417	100
5/03	2,275	2,295	99	465	465	100
5/04	4,112	4,137	99	674	676	99
5/05	3,906	3,922	99	565	565	100
5/06	4,173	4,202	99	640	641	99
5/07	4,867	4,907	99	610	613	99
5/08	5,478	5,510	99	529	529	100
5/09	3,361	3,378	99	405	406	99
Totals	36,892	37,182	99	5,786	5,794	100

Table 5. Continued.

	Hatchery steelhead			Wild steelhead		
Day	MCX total	MCJ total	MCX efficiency (%)	MCX total	MCJ total	MCX efficiency (%)
4/15	----	----	----	2	2	100
4/16	5	5	100	2	2	100
4/17	6	6	100	13	13	100
4/18	7	7	100	17	17	100
4/19	8	8	100	36	36	100
4/20	16	16	100	42	42	100
4/21	17	17	100	35	35	100
4/22	19	19	100	45	46	97
4/23	26	26	100	128	128	100
4/24	31	31	100	119	119	100
4/25	26	26	100	125	126	99
4/26	24	24	100	127	129	98
4/27	24	24	100	122	122	100
4/28	16	16	100	136	137	99
4/29	24	26	92	205	208	98
4/30	26	26	100	196	198	98
5/01	31	31	100	132	132	100
5/02	38	38	100	147	147	100
5/03	67	68	98	235	236	99
5/04	100	100	100	247	249	99
5/05	101	101	100	191	192	99
5/06	87	88	98	137	137	100
5/07	90	90	100	100	100	100
5/08	103	103	100	118	118	100
5/09	40	41	97	42	42	100
Totals	932	937	99	2,699	2,713	99

Table 6. PIT-tag reading efficiency of the existing detection system at McNary Dam (MCJ) based on daily detections of the MCJ compared to detections of the McNary Experimental system (MCX). Detections are PIT-tagged hatchery and wild chinook salmon and hatchery and wild steelhead during their peak migration period, 15 April to 9 May 2002.

	Hatchery chinook			Wild chinook		
Day	MCJ total	MCX total	MCJ efficiency (%)	MCJ total	MCX total	MCJ efficiency (%)
4/15	10	10	100	6	6	100
4/16	32	33	96	22	23	95
4/17	62	63	98	33	34	97
4/18	134	135	99	37	38	97
4/19	281	283	99	63	64	98
4/20	314	319	98	62	62	100
4/21	360	366	98	57	57	100
4/22	369	373	98	66	67	98
4/23	376	391	96	76	78	97
4/24	480	488	98	108	109	99
4/25	612	625	97	163	164	99
4/26	511	525	97	129	129	100
4/27	549	562	97	124	126	98
4/28	528	535	98	99	100	99
4/29	617	628	98	134	135	99
4/30	719	731	98	133	137	97
5/01	922	931	99	172	173	99
5/02	2,006	2,030	98	422	426	99
5/03	2,333	2,367	98	463	466	99
5/04	4,162	4,226	98	676	682	99
5/05	3,897	3,957	98	558	561	99
5/06	4,179	4,257	98	650	655	99
5/07	4,872	4,932	98	600	600	100
5/08	5,412	5,559	97	531	540	98
5/09	3,362	3,410	98	406	411	98
Totals	37,099	37,736	98	5,790	5,843	99

Table 6. Continued.

	Hatchery steelhead			Wild steelhead		
Day	MCJ total	MCX total	MCJ efficiency (%)	MCJ total	MCX total	MCJ efficiency (%)
4/15	----	----	----	2	2	100
4/16	5	5	100	3	3	100
4/17	8	9	88	17	18	94
4/18	7	7	100	24	25	96
4/19	7	7	100	30	30	100
4/20	14	14	100	44	47	93
4/21	18	18	100	33	33	100
4/22	18	18	100	61	63	96
4/23	32	34	94	136	141	96
4/24	30	31	96	105	107	98
4/25	24	24	100	140	148	94
4/26	25	25	100	129	136	94
4/27	22	22	100	112	113	99
4/28	15	16	93	142	145	97
4/29	27	27	100	215	216	99
4/30	27	28	96	179	182	98
5/01	28	28	100	130	132	98
5/02	41	41	100	141	143	98
5/03	64	72	88	245	250	98
5/04	101	105	96	242	247	97
5/05	109	119	91	193	195	98
5/06	82	84	97	131	134	97
5/07	90	93	96	99	104	95
5/08	105	110	95	107	112	95
5/09	34	34	100	46	48	95
Totals	933	971	97	2,706	2,774	97

Table 7. PIT-tag reading efficiency of the McNary Experimental system (MCX) based on daily detections of the MCX compared to those of the existing detection system at McNary Dam (MCJ). Detections are of PIT-tagged subyearling chinook salmon during their peak migration period, 1 to 31 July 2002.

Day	MCX total	MCJ total	MCX efficiency (%)
7/01	886	887	99
7/02	962	965	99
7/03	967	971	99
7/04	1,160	1,160	100
7/05	1,258	1,259	99
7/06	2,161	2,166	99
7/07	2,089	2,092	99
7/08	2,239	2,244	99
7/09	3,037	3,044	99
7/10	2,557	2,562	99
7/11	2,570	2,574	99
7/12	1,726	1,732	99
7/13	1,095	1,095	100
7/14	646	647	99
7/15	685	687	99
7/16	763	765	99
7/17	552	553	99
7/18	431	433	99
7/19	262	265	98
7/20	312	312	100
7/21	318	319	99
7/22	230	232	99
7/23	145	145	100
7/24	125	125	100
7/25	138	139	99
7/26	125	125	100
7/27	198	198	100
7/28	131	132	99
7/29	152	152	100
7/30	138	138	100
7/31	111	111	100
Totals	28,169	28,229	99

Table 8. PIT-tag reading efficiency of the existing detection system at McNary Dam (MCJ) based on daily detections of MCJ compared to those of the McNary Experimental system (MCX). Detections are of PIT-tagged subyearling chinook salmon during their peak migration period, 1 to 31 July 2002.

Day	MCJ Total	MCX Total	MCJ Efficiency (%)
7/01	876	881	99
7/02	972	975	99
7/03	945	949	99
7/04	1,181	1,189	99
7/05	1,279	1,303	98
7/06	2,144	2,164	99
7/07	2,093	2,106	99
7/08	2,258	2,280	99
7/09	3,046	3,086	98
7/10	2,563	2,592	98
7/11	2,551	2,587	98
7/12	1,714	1,741	98
7/13	1,083	1,109	97
7/14	631	650	97
7/15	699	723	96
7/16	758	796	95
7/17	552	581	95
7/18	419	438	95
7/19	268	285	94
7/20	310	340	91
7/21	322	342	94
7/22	219	235	93
7/23	144	157	91
7/24	128	136	94
7/25	145	154	94
7/26	124	129	96
7/27	190	194	97
7/28	138	144	95
7/29	141	153	92
7/30	138	144	95
7/31	110	119	92
Totals	28,141	28,682	96

The comparison between MCX and MCJ during the period of 15 April-9 May showed high daily and overall tag-reading efficiency regardless of species or fish origin (hatchery or wild). Overall tag-reading efficiencies per species and fish origin ranged from 99 to 100% for the MCX system (Table 5) and 97 to 99% for the MCJ system (Table 6). The slightly lower overall tag-reading efficiency of the MCJ system can, in part, be explained by the fact that every other day (odd numbered days) fish were bypassed to the river for a period of 20 to 30 minutes during fish transport barge loading. During this period, fish were detected on the MCX system only.

To the extent possible, adjustments to the data were made for loss of detections during periods of fish bypass by examining PTAGIS records for those time periods. However, this process could not exactly determine all the fish which were bypassed resulting in some "apparent" lack of detection efficiency for MCJ.

A second source of data loss occurred during the release of large fish back to the river that may have entered the wet separator (e.g., kelts, fall backs). For these releases, the barrier screen at the end of the wet separator is raised, and the large fish are directed into a sump that leads to a 36-cm-diameter pipe (without PIT-tag detectors) that in turn leads to the river. During these operations, smolts can also exit the wet separator via the pipe and thus are not subject to interrogation by the MCJ PIT-tag interrogation system. The release of large fish from the wet separator is done only as needed, and these events are not systematically recorded. It is suggested that some thought be given to installing a PIT-tag interrogation system on this exit pipe.

The comparison between MCX and MCJ during the period of 1 to 31 July also showed high daily and overall tag-reading efficiency for subyearling chinook salmon. Overall tag-reading efficiency was 99% for the MCX system (Table 7) and 96% for the MCJ system (Table 8).

Conclusions

The MCX and MCJ PIT-tag interrogation systems are in close agreement regarding fish detection. The slightly lower tag-reading efficiency observed on the MCJ system in comparison to MCX was likely due to fish bypass operations during transport loading, when detections occurred only on the MCX system. The systems are being observed and data collected to track changes in system performance.

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APPENDIX

Electromagnetic Field and Radio Frequency Harmonic Measurements on the FS 1001 Transceiver System

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ELECTROMAGNETIC FIELD AND RF HARMONIC MEASUREMENTS

ON

DESTRON-FEARING FS 1001 TRANSCEIVER SYSTEM

AT

JUVENILE FISH BYPASS PIPE

MCNARY DAM, UMATILLA OREGON

FOR

NATIONAL MARINE FISHERIES

JUNE 26, 2002

INTRODUCTION

On 26 June, 2002 electromagnetic and radio frequency harmonic field measurements were made on the Destron-Fearing FS1001 passive integrated transponder (PIT) tag systems at the juvenile fish bypass pipe at McNary Dam located on the Columbia River near Umatilla, Oregon. The PIT-tag system operates at 134.2 kHz. Electric and magnetic field measurements were made to determine compliance with the maximum permissible exposure (MPE) limits of **IEEE Std C95.1, 1999 Edition**, ***"IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz"*** (C95.1)

RF harmonic measurements were made to verify conformance with the requirements of §15.209 (a) *Radiated emission limits, general requirements* of the Rules & Regulations of the Federal Communications Commission.

ELECTROMAGNETIC FIELD EXPOSURE MEASUREMENTS

A NARDA model 8718D survey meter (serial number [sn] 001194, cal. 12/01), with a model 8764D electric field probe, sn 1004, (100 kilohertz to 300 megahertz, +/-0.75 decibel (dB) frequency sensitivity, +/-0.5dB isotropic response) were used to make the measurements. The probe factor for 134 KHz was automatically added to the readings by the meter. The overall accuracy of the electric field measurements was +/- 0.75 dB.

The magnetic field measurements were made using a Holaday Instruments HI-3637 VLF 3-axis magnetic field meter, (SN 83853). The response of this meter extends from 2 to 400 KHz, respectively.

RADIATED HARMONIC EMISSION MEASUREMENTS

Radiated emissions were measured at a distance of 3 or 5 meters from the PIT tag antennas. Potomac Instruments meters were used for the measurements. The FIM 22, SN 191, measures from 200 to 550 kilohertz (KHz) while the FIM 21, SN 558, measures from 540 to 1600 KHz. Both meters have 10 KHz bandwidths. The meters were compared to sources of known accuracy for calibration.

The FCC §15.209 emission limits at three meters vary from 896 microvolts per meter (uV/m) at 268 KHz to 179 uV/m at 1340 KHz (the tenth harmonic of 134 KHz). These limits were not exceeded where the measured fields, identifiable as originating at the PIT tag antennas were greater than the ambient RF noise level.

MAIN 36 IN DIAMETER JUVENILE FISH BYPASS PIPE PIT-TAG INTERROGATION SYSTEM

The PIT tag system installed on the 36 inch-diameter juvenile fish bypass pipe that leads from the McNary Dam powerhouse to the juvenile fish collection and monitoring facility Fig. 1. The first antenna, of the four antenna PIT-tag interrogation system, is located on the pipe 253 ft down stream from the powerhouse. At this point the 36 inch- diameter steel pipe in this located 35 ft off the ground (mid pipe to ground level). Each antenna is housed in a shield box constructed of aluminum and measuring 8-ft high by 8-ft wide by 6-ft long. A section of 36-inch diameter fiberglass pipe, to which each antenna is attached, passes through the center of each box. The second, third, and forth shield/pipe antenna units are located 27 ft, 15 ft, and 27 ft downstream from the first, second, and third shield/pipe antenna units respectively. The transceivers for each of the four antennas were located at ground level Fig. 2. The electronics of each transceiver were housed in a Nema four box which was in turn placed in a second Nema four box.

MEASURED ELECTROMAGNETIC FIELD EXPOSURE

None of the measured electric or magnetic fields measured at the juvenile fish bypass pipe PIT tag antennas exceeded the C95.1 MPE limits of 614 volts per meter (V/m) or 121.64 amperes per meter (A/m), respectively. Readings a few inches from the fish pipe antennas showed a magnetic field of 24 A/m which decreased to 4 A/m at the edge of the shield and to 1.6 A/m (the FCC MPE) 21 inches from the antennas.

At the metal door of the shield box enclosure the field was 0.3 A/m. The corresponding electric field close to the antenna was 190 V/m. All four units had essentially the same readings

The measured magnetic field at the #4 transceiver was 0.35 A/m with both the inner and outer shield doors open.

RF HARMONIC MEASUREMENTS ON JUVENILE FISH BYPASS PIPE ANTENNAS #1 & #3 MEASURED AT A DISTANCE OF 3 METERS

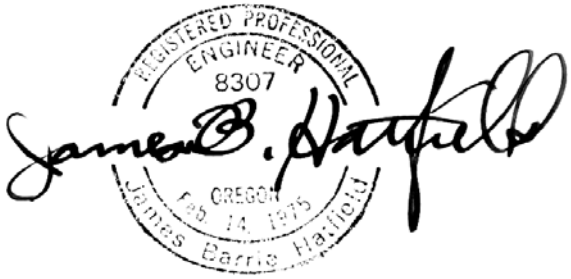
FREQUENCY, KHz	MEAS. FIELD, uV/m	FCC §15.209 LIMIT, uV/m
268	35 to 50 *noise level	896
402	140 - 200*	597
536	140 - 200*	447
670	200 - 300	358
804	200 #radio station	298
938	80	256
1072	25	224
1206	<100	199
1340	#	179

CONCLUSION

The measured electromagnetic exposure from the juvenile fish bypass pipe FS 1001 (PIT) tag antennas at McNary dam does not exceed the C95.1 MPE limits or the FCC electromagnetic field MPE limits outside of the shield enclosures. The measured harmonics emitted from the juvenile fish bypass pipe FS 1001 (PIT) tag antennas also did not exceed FCC §15.209 limits.

STATEMENT OF ENGINEER

James B. Hatfield, P.E. states that all information shown in this report is true and accurate to the best of his knowledge.

July 17, 2002

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