DEVELOPMENT AND EVALUATION OF PASSIVE INTEGRATED TRANSPONDER TAG TECHNOLOGY

ANNUAL REPORT: 1999 TO 2000

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EXECUTIVE SUMMARY

This report covers research conducted during 1999 and 2000 (FY00) for an ongoing project to expand and improve technology for passive-integrated-transponder tags (PIT tags) throughout the Columbia River Basin (CRB). Since 1984, the National Marine Fisheries Service (NMFS) has conducted this work in cooperation with the Bonneville Power Administration (BPA).

Timely and accurate information derived from PIT-tag technology is increasingly critical to resource stakeholders in developing recovery programs and in assessing the effectiveness of efforts to enhance survival of juvenile and adult salmonids. Continued development of PIT-tag technology will enable researchers to address issues expressed in the NMFS biological opinions for operation of the Federal Columbia River Power System (FCRPS) and the proposed Snake River recovery plan. The FY00 work was divided into six individual projects summarized below.

1. Transition to the 134.2-kHz ISO-Based PIT-Tag System for Juvenile Salmonids

In 1997, BPA established a multi-agency Transition Planning Team to oversee the entire transition from the 400-kHz PIT-tag system for juvenile salmonids to a new ISO-based 134.2-kHz system. The Transition Planning Team then established multi-agency technical teams to address individual system components. In August 1999, the planning team concluded that all of the components were or would be available in time to complete the transition for the year 2000 smolt migration. Therefore, the focus in FY00 was on installing and then assessing the performance of the ISO-based PIT-Tag system for juvenile salmonids.

Pacific States Marine Fisheries Commission (PSMFC) headed these efforts, and we assisted in the inspection and evaluation of installed PIT-tag equipment. Acceptance tests included evaluations with tagged wooden sticks and with fish at all dams to obtain accurate measurements of reading efficiencies (i.e., the number of tags read in comparison to the number released) for individual coil/transceiver combinations. We led the effort to design the tests that used fish. Results of these tests indicated that the ISO-based system was performing satisfactorily, as it yielded reading efficiencies of over 95% for most single-coil transceiver combinations and all multiple-coil transceiver combinations.

During 2000, performance of the ISO-based interrogation system was exceptional, although some transceivers experienced extended periods when the temperatures inside of their enclosures were near the maximum operational temperature. Such prolonged exposure to heat can severely shorten the life span of electronic components, and so alternative solutions for reducing the temperatures for these transceiver locations should

be investigated. We discussed potential solutions with PSMFC and Destron Fearing (the equipment manufacturer).

Successful completion of the first smolt migration season using the ISO-based interrogation system marked the end of the transition efforts. The exceptional performance of the system reflects the efforts expended by personnel from multiple agencies over the past 4-5 years.

2. Development of 134.2-kHz ISO-Based Systems for Fish Ladders

During development of the ISO-based interrogation system for juvenile salmonids, we recognized that the longer read ranges possible with the 134.2-kHz ISO tags would allow detection of adult salmon in fish ladders. Because there were no commercially available transceiver systems that could read tags in fish ladders, we initiated a project in FY98 to develop interrogation systems for adult salmonids using the ISO tag. This work has concentrated on tag detection in fish ladder orifices.

The goal of this project is to develop an interrogation system that can be installed into any FCRPS fish ladder. The plan is to install full-scale interrogation systems in one ladder at Bonneville Dam in 2001 and in all of the ladders at Bonneville Dam in 2002, when fish tagged with ISO tags will start to return in statistically significant numbers. Installation of interrogation systems at additional dams will be considered for 2003.

Interrogation systems consist of antenna systems (antenna housings and the internal coil windings) and transceiver systems that decode the return signals and transmit tag codes to the computer. The NMFS research and development team has been responsible for developing these components. The work to develop an interrogation system will progress through three phases: development phase, evaluation phase, and an implementation phase.

2.1. Adult PIT-Tag Oversight Committee--BPA, NMFS, and the U.S. Army Corps of Engineers (COE) established an Adult PIT-Tag Oversight Committee (APTOC) in early 2000 to address technical issues and provide collective insight on policy and implementation matters.

During FY00, APTOC established the following technical teams:

1) Information Gathering on Fish Passage Team,
2) Evaluation of Prototype Transceivers and Antenna Systems Team,
3) Dam Installation and Infrastructure Team, and
4) Application-Based Performance Requirements Evaluation Team.

These teams will provide APTOC with guidance during the development, evaluation, and installation of an interrogation system for fish ladders. They will also help APTOC review technical issues and draft technical documents. NMFS leads the Evaluation of Prototype Transceivers and Antenna Systems Team, and has members on the other three technical teams.

2.2. Transceiver/Antenna Systems Testing Sites--We conducted field tests to determine behavioral responses of fish to antenna systems, to determine reading efficiency with fish, to determine the effects of ambient radio-frequency (RF) noise on tag detection, and to verify suitability of equipment for installation and long-term operation. All of these factors were evaluated in the field in FY00.

One of the field sites used was the Adult Fish Facility (AFF) exit ladder at Bonneville Dam. Unfortunately, it normally contains the smallest orifice size (18 x 18 in) of all FCRPS projects and thus presents the least challenge for reading tags. Since future interrogation systems will need to work in larger orifices (24-26 in and possibly larger), we proposed that a two-section antenna housing be designed for the AFF exit ladder so that both 18- and 26-inch square orifices could be evaluated. Approval of the design was given after our testing indicated that the larger orifice inserts did not impact fish passage.

NMFS and its contract engineers observed significant interference from electromagnetic noise in the RF range during the fish tests conducted in spring 2000. Thus, an alternative testing site was needed where contract engineers could investigate whether adding aluminum shielding to the fish ladder weir walls and floor might help reduce electromagnetic interference (EMI). We measured ambient RF noise conditions at several sites before settling on NMFS Pasco Field Station. We built a test facility that was completed in June that the contractors and NMFS could use to develop an RF shield. The Pasco facility was also used to test other aspects of the interrogation system.

Large antennas are significantly more susceptible to noise interference than smaller ones; therefore, to make accurate comparative measurements among transceiver systems in the laboratory, we constructed an EMI-shielded room at NMFS Sand Point facility. EMI-shielded rooms allow read-range and reading-efficiency measurements to be made under minimal ambient RF-noise conditions. This EMI-shielded room was used for the development of the open-architecture system and for most of the laboratory tests conducted during the thorough evaluation of both transceiver systems at the end of FY00.

2.3. Antenna System Development and Standardization--The overall goal for the antenna system is to develop a standardized design that can be used throughout the CRB. By the end of FY99, NMFS had made a preliminary recommendation to use a housing design that does not significantly change the original orifice geometry (the insert-only design). To standardize a design for orifice antenna housings, NMFS consulted with

the COE and NMFS regional personnel to determine whether chamfers of the antenna housings could be standardized to 1 inch on both the upstream and downstream sides. The 1-inch chamfers would permit the maximum antenna-coil width to be used. This would improve detection capability and would reduce the cost of manufacturing the antenna housings because one fabrication mold could be used for any orifice size.

The COE and the NMFS Regional office agreed in July 2000 that all of the antenna housings installed throughout the FCRPS could have 1-inch chamfers on both the upstream and downstream sides. However, when the first antenna housings were fabricated to incorporate the 1-inch chamfers for the 26-inch orifices, the antennas performed poorly. Subsequent tests determined that for optimal performance antenna windings needed to be isolated from the surrounding water by 2 inches and a new 1-inch chamfer antenna housing was designed that incorporated the 2-inch separation.

Using this housing design, a common antenna configuration that could be used by all transceiver systems was established and will be installed in the Washington Shore Ladder and other locations in FY01.

Another important step was to design an appropriate RF shield. Using known sources of EMI, NMFS and its contractors developed two prototype shield designs. Prior to fish tests in September 2000, NMFS personnel fabricated and installed prototype shields of each design into the AFF exit ladder at Bonneville Dam. Screen cleaners at this site were the only identified source of noise and so one set of fish tests was run with the 3-sweeper cycle left on continuously. For both transceiver systems, approximately two-thirds of the fish were missed with the gapped shield while none was missed transiting the orifice with the continuous shield. In addition, although no fish were missed, the number of reads per fish was basically cut in half with the continuous shield. Based on these tests, we recommend that continuous shields be installed into the Washington Shore Ladder for the full-ladder evaluation scheduled for FY01.

2.4. Transceiver System Development--To meet the 2002 goal of installing PIT-tag interrogation systems for adult salmon in all fish ladders at Bonneville Dam, the NMFS research and development team and BPA have taken a "spread the risk" approach by supporting the simultaneous production of two transceiver systems. One system denoted as the "open architecture" system separated the analog board module from the module responsible for processing codes and interfacing with data processing systems (the interface module). The second system was developed by Destron Fearing (DF), who modified their ISO-based transceiver system used for interrogating juvenile fish (model FS1001). The new DF system is referred to as the DF-Adult System.

During December and January, preliminary tests were performed to determine the feasibility of combining the strengths of both systems. In January 2000, Patten Engineering and DF agreed to work together to help improve the DF-Adult System by

combining the technological strengths of the open-architecture analog board, and the manufacturing and firmware strengths of the DF-Adult System.

NMFS prepared a document for the contractors that described the requirements for configuration, packaging, performance, communications, memory, power, environment, operations and maintenance, and documentation for the transceiver systems.

Other efforts to help the contractors with their development were to run fish tests during the springtime at Bonneville Dam in the AFF exit ladder with both orifice sizes. The reading efficiencies for spring chinook salmon transiting both 18- and 26-inch orifices in the upstream direction were above what we had expected, ranging from 88.6 to 100%. The video cameras used during these tests helped us realize that interpreting PIT-tagged adult fish passage is going to be more complicated than for juvenile salmon passage at the fish facilities because without the video cameras, it is impossible to know the direction the fish are traveling. In addition the video cameras demonstrated that when fish fall back, they are often at extreme angles that make interrogating them impossible and that fish will also occasionally nudge their noses or tails into an orifice without going through, yet their tags were read.

These springtime fish tests also gave us some general information on how adult salmon use fish ladders. Fish passage time through the ladder varied widely. Many passed through the four weirs in less than a minute; others stayed in the ladder for longer than a day. We did tape one fish that used the overflows on all four weirs. We had another fish that left the ladder on the first day we tagged it and then was recorded again a month later.

The critical step in the evaluation phase was to select a transceiver system for the full-ladder test scheduled for FY01 in the Washington Shore Ladder. The plan was to conduct a thorough evaluation of the two transceiver systems during the fall fish run so that the fisheries community would be knowledgeable about how both were performing and what if anything was necessary to make both systems into production models. This was done by performing a series of fish and electronic laboratory tests. Both systems read 100% of the fish going upstream through the 18- and 26-inch orifices when the screen cleaners were not active. The laboratory tests determined that the DF-Adult System had only a few firmware modifications that needed to be made while the open-architecture system was 6-12 months away from being a production unit (most of the needed changes were also firmware based). Based on these tests, the team recommended that APTOC select the DF-Adult Transceiver System for the full-ladder tests scheduled for 2001.

2.5. Future development of adult detection systems--At this point, the components of the interrogation system appear ready for the final full-ladder evaluation step that is planned for the Washington Shore Ladder at Bonneville Dam. Therefore, the

COE is proceeding with planning for the installation of an interrogation system for 24 orifices. We expect that the installation and evaluation of the prototype extended-range interrogation system in the Washington Shore Fish Ladder will provide: 1) estimates of tag-reading efficiencies for 18-inch orifices, individual weirs, and a complete fish ladder; 2) guidelines for future installations (e.g., number of weirs to cover, cost estimates, time needed, grounding specifications); and 3) information on whether there is a need for weir overflow detection. The evaluation will also provide new information on how adult salmon use fish ladders.

The experience at the AFF made it apparent that it would be prudent to monitor future installation sites for minimally 1 year in advance of a scheduled installation in order to identify and remedy any sources of EMI. Thus, we will monitor the three Bonneville Dam ladders scheduled for installation in 2002. Since McNary Dam fish ladders may be installed in 2002, we will also monitor there.

3. Installation, Evaluation, and Maintenance of the ISO-Based Flat-Plate System for Juvenile Fish at Bonneville Dam

NMFS installed a 400-kHz flat-plate (pass-by) PIT-tag interrogation system for juvenile salmon in the downstream migrant channel of the Bonneville Dam Powerhouse I in 1996. The continued reliable operation of a PIT-tag system at this site is essential to meet informational needs of fisheries investigators and managers in the CRB. Therefore, like the rest of the PIT-tag equipment at the juvenile fish facilities, the 400-kHz flat-plate system needed to be replaced with an ISO-based system in time for the 2000 smolt outmigration.

In November, the 400-kHz flat-plate interrogation system was removed and the ISO-based production units were temporarily installed in order to evaluate several antenna designs to determine the best configuration for the permanent installation. These tests determined that four coils would be sufficient. NMFS permanently installed the ISO-based system in February 2000. The entire 400-kHz system was replaced except for the antenna housings and the computer used to collect data. To prevent electromagnetic interference, all four of the transceivers were synchronized. The final equipment combination yielded consistent reading ranges of 18-19 cm compared to the 10-cm reading range for the 400-kHz system.

In March 2000, NMFS conducted fish tests to determine tag-reading efficiencies using hatchery chinook salmon and hatchery steelhead. The overall tag-reading efficiency for all four coils combined was 99 and 94% for the chinook salmon and steelhead, respectively. Since the facility was still operating on an 8-hour-per-day schedule, PIT-tag interrogation had to be terminated at the end of the day. NMFS speculated that some PIT-tagged steelhead may have remained within the downstream migrant channel and exited after the PIT-tag interrogation system was turned off.

Therefore, a second test with steelhead was conducted in April; this yielded a tag-reading efficiency of 95%. However, 9 minutes of data are missing from this test and therefore it is possible that one or more fish may have passed by the interrogation system during that time. Based on 2000 test results, we recommend that similar tag reading tests be conducted in 2001.

To ensure reliable system operation, we conducted routine inspections and maintenance on the flat-plate system during the 2000 field season. During the season, approximately 11.5 hours of data were lost when the synchronizing controller failed. Less time would have been lost had the failure not occurred during the July 4th holiday. Data were also lost from one detector when a tuning inductor failed. Like the DF equipment used at the other CRB sites, the ISO-based flat-plate system performed exceptionally well during the 2000 season.

The COE has still not set a final schedule for the construction of the juvenile fish collection and sampling facility for Bonneville Dam Powerhouse I. A flat-plate system will continue to be needed until this facility is completed.

4. Fabrication and Installation of a Three-Way Side-to-Side PIT-Tag Diversion Gate at Little Goose Dam

The COE released 60% drawings on their facility-modification project for Little Goose Dam in June 2000. The COE decided in August that the revamp project would use 10-inch pipe in the section where the side-to-side diversion gate would be installed. Personnel from the NMFS Pasco Field Station fabricated the 10-inch side-to-side gate in September. In October 2000, the bids the COE received for the project were more than double what they had budgeted for and so they decided in November to delay the Little Goose Dam project for at least another year. Although NMFS will participate in this facility-modification project when it occurs, this effort will be supported through the COE. BPA support for this project ended with the fabrication of the diversion gate.

5. Separation-by-Code System: Computer Program (MULTIMON)

During 1992-1994, NMFS developed and evaluated a separation-by-code system (computer program and fish diversion gates) at their Manchester Research Station. The computer program controls the separation of targeted PIT-tagged fish from untargeted tagged and untagged fish based on their individual tag codes. The development of MULTIMON is a joint project with Pacific Northwest National Laboratory, whose personnel write the computer code. NMFS personnel oversee the development; test the program after modification; and collaborate with PSMFC personnel on technology transfer, maintenance issues, and assisting fisheries researchers.

The separation-by-code system was first tested at Lower Granite Dam in 1995; however, the computer program has changed a great deal since then. Because research needs change each year and new equipment (i.e., hardware, software, and electronic components) is installed or upgraded, we recognize that MULTIMON is unlikely to ever be totally static. Nonetheless, the program reached the stage that at the conclusion of the 1999 field season, PSMFC took over the primary responsibility of maintaining MULTIMON at the dams. There were a few items left to complete for the program in FY00; otherwise, the primary role for NMFS during the 2000 season was to support PSMFC as needed.

Most of the computer program modifications for the 2000 migration season were to make the program more secure in case of failures and thus help PSMFC with its operations and maintenance of the program. For example, the program was modified so data files were now automatically saved every 5 minutes instead of every 15 minutes. This significantly reduced the amount of data that could be lost when power failures occur. In addition, backup copies of the different setup files were created daily; this would permit PSMFC to quickly replace a file if it became corrupted. To keep the Windows-98 platform more stable, we made it possible to define how much RAM was reserved for the tag database file. Thus, for most sites, Windows 98 retained use of most of the RAM. Based on the needs for several separation-by-code research projects in the past 3 years, we added the ability to define the start and stop times for a collection period that could last between 1 second and 24 hours.

The most significant modification during FY00 was to write a Windows-based interface program (called REMOTE) that made the process for sending remote commands (e.g., loading new data base and map files) straightforward and kept MULTIMON actively collecting data while it performed the tasks. In the past, these tasks were performed locally which required that MULTIMON be taken out of its active data-collecting mode.

PSMFC has started the process of writing a Windows-based application (MINIMON) to replace the DOS-based MULTIMON application. So far, it is still primarily a monitoring program as it is unable to control separation-by-code functions. They will continue to add functionality to this program. NMFS is supporting this effort. At this time, NMFS does not plan any significant modifications for MULTIMON for the 2001 season.

6. Information Transfer, Technical Reviews, and Technical Support

As in previous years, NMFS actively advised other agencies on PIT-tag related matters, such as facility designs to accommodate PIT-tag systems, PIT-tag system maintenance, assistance in using prototype equipment and the MULTIMON computer program, and information transfer. They also provided assistance in adapting PIT-tag

technology for investigations into new areas such as the feasibility of an in-stream interrogation system based on the flat-plate system developed by this team. Because NMFS personnel designed or co-developed many of the present PIT-tag systems and their components, and because they provide technical support and training to ensure the reliable operation of these systems, these personnel are an important resource for users of PIT-tag technology throughout the CRB. Specific technology transfer activities of NMFS personnel during the reporting period are itemized in this report.

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INTRODUCTION

Since 1984, the National Marine Fisheries Service (NMFS) in cooperation with the Bonneville Power Administration (BPA) has conducted an ongoing research and development project to expand and improve technology for Passive-Integrated-Transponder tags (PIT tags) throughout the Columbia River Basin (CRB). Work conducted as part of this project during 1999-2000 was divided into six individual projects, which are covered separately in this report.

The efforts by personnel associated with this project have produced and will continue to produce products that aid resource stakeholders in assessing the effectiveness of actions taken to enhance the survival of juvenile and adult salmonids. These products and their uses include

- Survival and migration timing information on stocks to evaluate water management strategies and fish passage/collection facilities
- Data needed for the management and restoration of salmonids and other fish stocks
- Information required for the management of multiple species in a variety of habitats
- Tools that enable fisheries researchers and managers to address previously unanswerable questions

These products are also used in genetic, physiology, behavior, and captive broodstock research on endangered species. The continued development of PIT-tag technology will enable researchers and fisheries managers to address issues expressed in both of NMFS biological opinions for operation of the Federal Columbia River Power System (FCRPS)(NMFS 1995a, 2000) and the proposed Snake River Recovery Plan (NMFS 1995b; tasks 2.1.d, 2.3.b.4, 2.4.a, 2.6.c.2, and 2.9.d).

TRANSITION TO THE 134.2-kHz ISO-BASED PIT-TAG SYSTEM FOR JUVENILE SALMONIDS

In 1997, BPA established a multi-agency Transition Planning Team to oversee the entire transition from the 400-kHz PIT-tag system for juvenile salmonids to a new 134.2-kHz system based on documents published by the International Organization for Standardization (ISO). The Transition Planning Team then established the following multi-agency technical teams to address individual system components:

Team	Area of Oversight
Transceiver Technical Team	Development of stationary transceivers
Portable Transceiver Evaluation Team	Development of portable readers
Tag Development Team	Development of suitable PIT tags
Infrastructure Team	Plan and oversee construction necessary at the dams for the transition, installation of stationary transceivers, and necessary changes to tagging software and PTAGIS database for implementing the 134.2-kHz ISO-based system.

We participated on all of these technical teams as well as on the Transition Planning Team. The Transition Planning Team met in September 1998 to review progress on all components (stationary and portable transceivers, tags, infrastructure needs, installation schedules, and systems management tools). The team concluded that all of the components were or would be available in time to complete the transition for the year 2000 smolt migration, and the final decision to proceed was made in August 1999.

Installation at the juvenile fish facilities of the FCRPS projects began in September 1999. Scheduling and planning for this event was a major effort headed by Pacific States Marine Fisheries Commission (PSMFC). During FY00, the Infrastructure Team oversaw the installation of electromagnetic field (EMF) shields, catwalks, and conduit and junction boxes for electrical power and fiber-optic cables, as well as the new stationary transceivers. Installation of all necessary equipment was completed by mid-March 2000. We assisted in the inspection and evaluation of installed PIT-tag equipment.

The Infrastructure Team was also in charge of acceptance tests to evaluate the performance of the installed equipment. In March, these tests revealed a synchronization problem with the transceivers. Destron Fearing (DF), the manufacturer, corrected the problem in a timely manner in all of the transceivers.

The acceptance tests also included evaluations using tagged wooden sticks and fish at all of the dams to get accurate measurements of reading efficiencies (i.e., the number of tags read in comparison to the number released) for each individual coil/transceiver combination. We led the effort to design the fish tests and also assisted in getting the necessary fish permits. Due to limited resources and time constraints, only the pathway that the majority of PIT-tagged fish follow was evaluated at each dam. Fish tests were contracted to Biomark by PSMFC, and all acceptance tests were finished by the middle of April. Results indicated that the ISO-based system was performing satisfactorily as it yielded reading efficiencies over 95% for most single coil-transceiver combinations and all multiple coil-transceiver combinations.

NMFS was available during the first smolt migration season after these installations to assist BPA and PSMFC in solving problems that were identified with the new PIT-tag equipment. Fortunately the performance of the ISO-based interrogation system was exceptional, and no immediate problems were found. However, during the summer, some transceivers experienced extended periods when the temperatures inside their enclosures were near the maximum operational temperature. Such prolonged exposure to heat can severely shorten the life span of electronic components; therefore, alternative solutions for reducing the temperatures for these transceiver locations should be investigated. NMFS personnel discussed potential solutions with PSMFC and Destron Fearing in August 2000.

This interrogation equipment, which is designed for juvenile salmon, will be used during the 2001 migration to monitor adult salmon passage through 31-cm pipes at Lower Granite Dam and through the Adult Fish Facility at Bonneville Dam. For 2001 and 2002, these sites will include both 400-kHz and 134.2-kHz equipment.

The successful completion of the first smolt migration season marks the end of the transition efforts. The exceptional performance of the ISO-based interrogation system reflects the efforts expended by personnel from multiple agencies over the past 4-5 years. This was a project in which the entire fisheries community can take pride.

DEVELOPMENT OF A 134.2-kHz ISO-BASED SYSTEM FOR FISH LADDERS

The ability to detect returning PIT-tagged adult salmon has long been a critical need for the fisheries community; its need was included in the 1995 NMFS biological opinion. In that document, the U.S. Army Corps of Engineers (COE), BPA, and NMFS were directed to "complete the design and development of adult fish PIT-tag detector systems in adult fish passage facilities at mainstem dams immediately, followed by installation with no adverse effect to adult passage" (NMFS 1995a; Incidental Take Statement para. 14). NMFS 1998 supplemental biological opinion and 2000 biological opinion also emphasize the need for adult detection systems at FCRPS projects (NMFS 1998, 2001).

In addition, the Northwest Power Planning Council recognized this need and called for a PIT-tag system for adults in its 1994 Fish and Wildlife Program. Specifically, data collected from adult interrogation will support investigations addressing transport benefits, adult passage rates between dams, travel time, fallback rates, and smolt-to-adult return rates (SARs) of listed salmonids (NMFS 2001, Section 10.5.1.7).

The first interrogation system for adult salmon using 400-kHz technology was installed at Lower Granite Dam in 1986, and the second was installed in the Adult Fish Facility (AFF) at Bonneville Dam in 1998. These 400-kHz systems, using electronics developed for juvenile fish, can interrogate adult salmon transiting 31-cm diameter pipes but do not have the reading range to interrogate fish transiting fish ladders. At Lower Granite Dam, all adults pass through the 400-kHz detectors. At Bonneville Dam, only a small fraction of adults passing the dam is interrogated since the interrogation takes place only in the AFF.

During development of the ISO-based interrogation system for juvenile salmonids, NMFS recognized that the longer reading ranges possible with the 134.2-kHz ISO tags would allow detection of adult salmon in fish ladders. Because there were no commercially available transceiver systems available with the necessary sensitivity to read tags in fish ladders, NMFS initiated a project in FY98 to develop suitable interrogation systems. This work has concentrated on detection in fish ladder orifices. Some development work on detecting fish using the weir overflows was conducted, but the decision was made to postpone further development until the fisheries community identifies a significant need for this type of system.

The implementation goal of this development project is to install, at a minimum, interrogation systems that will cover all of the ladders at Bonneville Dam for 2002, when fish tagged with ISO tags will start to return in statistically significant numbers. The NMFS 2001 biological opinion requires that detectors be installed at appropriate FCRPS

projects prior to the expected return of any adult salmon from the 2001 juvenile outmigration (Section 10.5.1.6). Installation of interrogation systems at additional dams will be considered for 2003.

To reach this implementation goal, we need to satisfy the goal of developing an interrogation system that can be installed into any FCRPS fish ladder. Interrogation systems consist of antenna systems (antenna housings and the internal coil windings) and transceiver systems that decode the return signals and transmit tag codes to the data-collecting computer. The NMFS research and development team has been responsible for developing these components. The work to develop an interrogation system will progress through three phases: development phase, evaluation phase, and an implementation phase. During the initial development phase knowledge about fish behavior is gained and technology is developed. During the evaluation phase a production system will be identified, and during the implementation phase the system will be deployed in a staged manner. The progress made during FY00 is described below.

Adult PIT-Tag Oversight Committee

Regional coordination and participation in critical planning and decisions are essential to the success of this project. To this end, the BPA, COE, and NMFS established an Adult PIT-Tag Oversight Committee (APTOC) in early 2000 to address technical issues and provide collective insight on policy and implementation matters. The APTOC replaced the Adult PIT-Tag Development Team (APTDT), a management team established in 1998, because of sporadic participation on the APTDT from the fisheries community. Since the development of these interrogation systems is critical to the entire fisheries community, the APTDT was recast during FY00 as APTOC to elicit wider participation.

Presently, the APTOC includes members from BPA, COE, NMFS, the U.S. Fish and Wildlife Service, the separate state agencies, the Columbia River Inter-Tribal Fish Commission (CRITFC), the Columbia Basin Fish and Wildlife Authority, and PSMFC. The BPA and COE will maintain ultimate responsibility for implementation and policy decisions with their separate responsibilities outlined in their June 1996 memorandum of understanding (BPA/COE 1996).

The APTOC is responsible for such tasks as drafting the requirements document for a transceiver system that will work in orifices and drafting a management plan that includes project objectives, goals, and schedule. These documents are then sent out for regional review and comment and returned to BPA. This approach is set up to obtain fisheries management input and thus ensure that the system will satisfy regional research needs. The first version of the management plan was released by APTOC in March. The plan is updated periodically to keep it current with the progress of the project.

During FY00, APTOC established the following technical teams:

1) Information Gathering on Fish Passage,
2) Evaluation of Prototype Transceivers and Antenna Systems,
3) Dam Installation and Infrastructure, and
4) Application-Based Performance Requirements Evaluation.

These new technical teams will provide APTOC with guidance during the development, evaluation, and installation of an interrogation system for fish ladders. They will also help APTOC review technical issues and draft technical documents. NMFS chairs the Transceiver-Antenna Technical Team and has members on the other teams. The work of the Transceiver-Antenna Technical Team will be covered in the following sections of this report. In June, this team formed a multi-agency evaluation team that was responsible for conducting the thorough evaluation of the transceiver systems during the fall of 2000. Based on the results, APTOC recommended proceeding with the full ladder evaluation planned for the Washington Shore Ladder at Bonneville Dam in 2001.

APTOC is also responsible for planning these installations throughout the FCRPS. During its August meeting, APTOC decided to proceed with planning for installations into the remaining three fish ladders at Bonneville Dam in 2002. There was discussion about including installation at McNary Dam ladders in 2002, but this was not scheduled. This decision will be revisited in May 2001 after there are some results from the full ladder evaluation. A final decision on what will be installed in 2002 will be made in July 2001. Installation of adult interrogation systems at additional dams will be evaluated for 2003.

In May, the COE presented to the APTOC results from its project that modeled potential designs for an antenna housing to detect fish using weir overflows. The results were positive, as hydraulic changes were minimal for the two most favorable antenna-housing designs: one that split the extended weir wall width between the upstream and downstream sides and the other that only extended the width upstream (Northwest Hydraulic Consultants 2000). These designs would permit an 18-in-wide flat-plate PIT-tag detector to be installed at the top of a weir, and the NMFS research and development team believed this would be sufficient for detecting most of the tagged fish using a weir overflow. However, no field confirmation tests of the model results were conducted or are planned at this time.

Since the interrogation systems for orifices appear to be sufficiently effective with individual reading efficiencies exceeding 90%, NMFS regional personnel continue to recommend that no further development on the interrogation system for weir overflows be done. If the results from the Washington Shore Ladder test suggest that it is necessary to detect fish using weir overflows in addition to detecting fish using orifices, then

APTOC would direct the NMFS research and development team and the COE to resume development work on an interrogation system for weir overflows.

Transceiver and Antenna System Testing Sites

Extended-range PIT-tag interrogation systems can only be tested to a limited extent in a laboratory setting, thus field tests are required to verify laboratory findings. They are essential to determine the effects of antenna housings on ladder hydraulics, to determine behavioral responses of fish to antenna systems, to determine reading efficiencies with fish, to determine the effects of ambient radio-frequency (RF) noise on tag detection, and to verify suitability of equipment for installation and long-term operation. All of these factors were evaluated in the field during FY00.

The AFF exit ladder at Bonneville Dam is a good test site because it provides access to power and equipment (unlike the main fish ladders, it can be periodically dewatered throughout the year). More antenna housings were installed in this ladder during FY00 so that fish tests could be run simultaneously on multiple transceiver systems. Unfortunately, the AFF ladder normally contains the smallest orifices (18 x 18-inches) found at any FCRPS project, and thus presents the most limited opportunity for evaluations of tag reading. Since future interrogation systems will need to work in larger orifices (24- to 26-inch and possibly larger), the NMFS research and development team proposed to APTOC, NMFS regional office, and the COE that a two-section antenna housing for the AFF exit ladder be designed so that both 18- and 26-inch square orifices could be evaluated. The 26-inch orifice is the largest orifice located at a FCRPS project (McNary Dam). The fisheries community can be confident that any transceiver system that passes evaluation tests with the largest orifices will work in all FCRPS fish ladders. The tests were scheduled for the end of FY00.

Approval was given to install the larger orifice inserts provided that fish passage was not affected by the change in ladder hydraulics. The 26-inch orifice insert sections were installed during March 2000. After observing their effects on ladder hydraulics, NMFS regional and COE hydraulic engineers and biologists approved the inserts, indicating that they did not think the 26-inch orifices would impede fish passage through the ladder. Video documentation during the spring fish tests confirmed this conclusion. Although the 26-inch inserts were approved, the 18-inch orifice inserts were installed during most of the year. The two-section design for this antenna housing permitted us to easily exchange antenna sections during the spring and fall series of fish tests. Thus, we were able to test two orifice sizes (18 and 26 inches) in the AFF exit ladder at Bonneville Dam during 2000.

The NMFS research and development team and its contractors observed significant interference from electromagnetic noise in the RF range during fish tests

conducted in spring 2000 (for overall results of the fish tests, see the section below on Transceiver System Development). In fact, testing was aborted on one day because of high electromagnetic interference (EMI) that essentially eliminated tag detectability. Thus, finding solutions for reducing the impact of ambient RF noise on the equipment became a high priority. Motors for the screen cleaners on the downstream migrant channel in Bonneville Dam Powerhouse II were identified as one source of EMI; however, no sources have been identified for the other observed random EMI. COE project personnel tried to eliminate the screen-cleaner motor noise but they have been unsuccessful. Additional corrective action by COE is scheduled for 2001.

Another solution was to find an alternative testing site where NMFS and its contractors could investigate whether adding aluminum shielding to the fish ladder weir walls and floor might help reduce EMI. NMFS measured ambient RF noise conditions at several sites before settling on its Pasco Field Station. In June, NMFS completed a test facility to help with developing an RF shield that could be installed into fish ladders as well as to provide a facility that could be used to test other aspects of the interrogation system. For example, tests were conducted to determine the best RF grounding approach for the shields. Although these tests did not finalize the grounding scheme, they did result in several designs that will be tested at Bonneville Dam fish ladders in 2001.

Large antennas are significantly more susceptible to noise interference than smaller ones; therefore, to make accurate comparative measurements among transceiver systems in the laboratory, NMFS constructed an EMI-shielded room at their Sand Point facility. EMI-shielded rooms allow reading-range and reading-efficiency measurements to be made under minimal ambient RF-noise conditions. This EMI-shielded room was used for development of the transceiver systems discussed below and for most laboratory tests conducted during the thorough evaluation of transceiver systems at the end of FY00.

Antenna System Development and Standardization

The overall goal for the development of the antenna system is to develop a standardized design that can be used throughout the CRB. We believe that the progress made in FY00 has moved us significantly closer to accomplishing this goal. By the end of FY99, NMFS had made a preliminary recommendation to use the insert-only housing design. This design does not significantly change the original orifice geometry, and there was no significant difference in tag detectability between the three housing designs (Downing et al. 2000). Furthermore, the fiberglass material used to fabricate the housings has held up well. When the antenna housings installed in January 1999 in the Cascades Island Ladder were inspected in December 1999, only a single nick (~ 0.5 cm) in the fiberglass gel-coat was apparent on one of the housings. The fiberglass housings will be examined again in February 2001 when the ladder is dewatered.

To help finalize the recommendation on the antenna housing design, in January 2000 NMFS replaced two antenna housings in the Cascades Island Ladder with insert-only designs. Replacing two antenna housings made it possible to test both prototype transceiver systems (DF Adult and PE/NMFS) in this ladder. The COE could then concentrate its video work in 2000 on comparing fish movement through insert-only modified and unmodified orifices.

As in FY99, NMFS periodically monitored the antenna systems installed in the Cascades Island Ladder for electronic stability (tuning, resonance frequency, and AC impedance were measured). The stability of these parameters is assumed to indicate that the antennas have not developed any leaks and that the design is reliable (Table 1). Videotape evidence collected by the COE during FY00 continued to document that fish species (e.g., salmonids and lamprey) do not hesitate to use the modified orifice (Robert J. Stansell, U.S. Army Corps of Engineers, Bonneville Lock and Dam, Cascade Locks, OR 97014, Pers. commun., September 2000).

To reach the goal of a standardized design for orifice antenna housings, NMFS consulted with the COE and NMFS regional personnel to determine whether it would be hydraulically acceptable for the chamfers of the antenna housings to be standardized on both the upstream and the downstream sides to 1 inch. The modified orifices would maintain the same inside dimension as the original orifice; the only difference would be in the chamfer detail. Currently, the chamfers in the different fish ladders throughout the FCRPS range from 0 to 5 inches; in some cases, there are differences in chamfer width within the same ladder. However, most upstream chamfers are 1 inch.

Standardization to a 1-inch chamfer would permit the maximum antenna-coil width to be wrapped. Antenna coils within the housings are wrapped on the flat surface of the orifice internal face; therefore, in the most extreme case, reducing the downstream chamfer from 5 to 1 inches would increase the area where a coil could be wrapped from 2 to 5-6 inches (Fig. 1) The wider coil would improve the ability of the extended-range PIT-tag detection system to detect tagged fish transiting the orifice. Using similar widths for similar orifice sizes would also mean that the performance of the PIT-tag system would be more consistent among orifices of the same size. Standardization would also reduce the cost of manufacturing antenna housings because each orifice size would require only one fabrication mold instead of multiple molds for the multiple chamfer sizes. This would also help speed up fabrication of the antenna housings, which would make it easier to meet future installation schedules.

Table 1. The tuning frequency values (kHz) taken periodically since the four antennas were installed in Cascades Island Fish Ladder at Bonneville Dam. Differences between the values for the different antennas are not important, as the only concern is whether an individual antenna's values change over time. The measurements have an accuracy of ± 0.5 kHz. Only measurements taken while the fish ladder was full of water are presented because the tuning frequency does change slightly when measurements are taken in a dry fish ladder.

Antenna housing design	Coil width (cm)	Weir number	Date installed	Dates when measurements taken					
				Feb 99	May 99	Jul 99	Apr 00	May 00	Sep 00
Insert only	11.5	56	Jan 99	131.7	131.9	132.0	131.7	131.6	131.8
Extension only	6	55	Jan 99	131.1	131.2	131.3	131.2	131.4	131.2
Insert only	12.7	54	Jan 00				138.0	137.9	137.9
Insert only	12.7	53	Jan 00				110.2	110.2	110.2

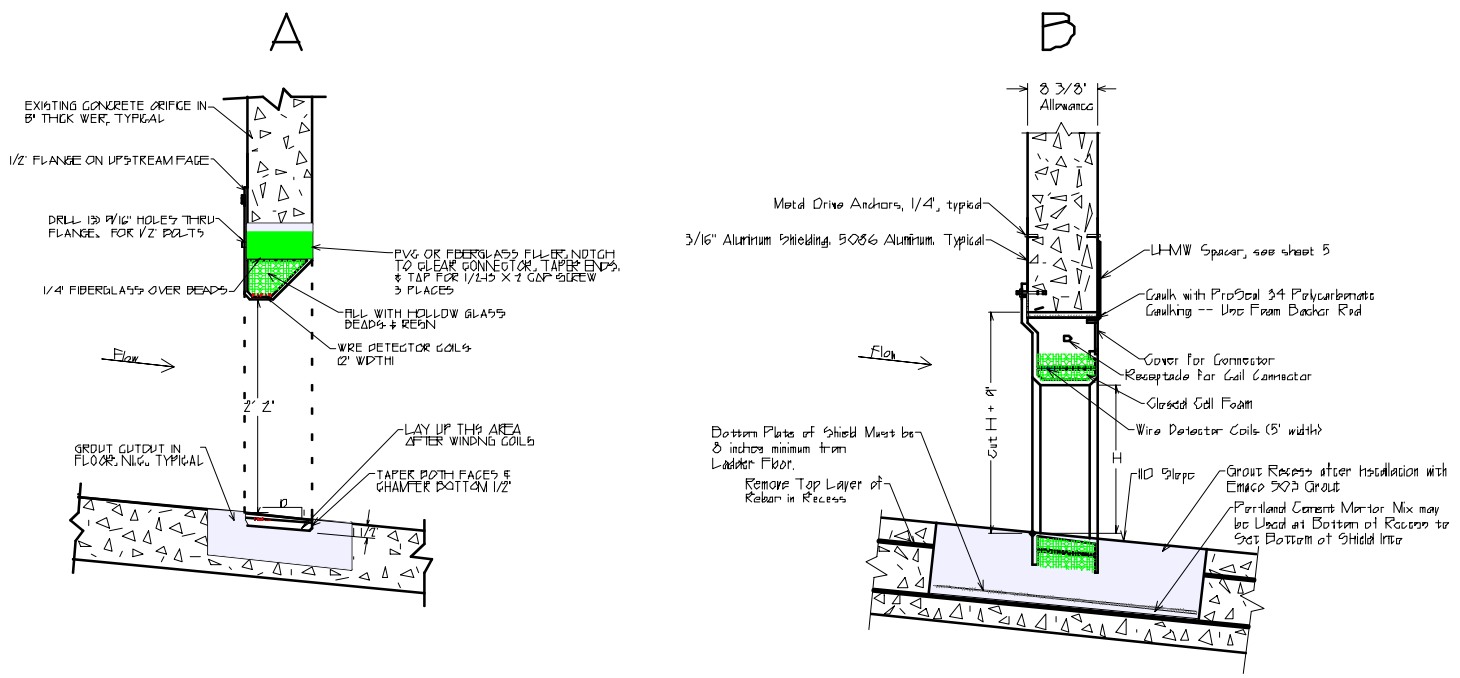

Figure 1. Cross-section drawings of the original 5-inch chamfer antenna-housing design (A) used in the AFF during 2000 and the final 1-inch chamfer antenna-housing design (B) that will be produced for the 2001 installations. Note the increased coil width and the increased separation between the coil windings and the water in B.

The COE and the NMFS regional office agreed in July 2000 that all antenna housings installed throughout the FCRPS could have 1-inch chamfers on both the upstream and downstream sides. However, when the first antenna housings were fabricated to incorporate 1-inch chamfers for the 26-inch orifices, the antennas performed so poorly at the Pasco test facility that we concluded they should not be installed into the AFF.

Tests determined that coils were closer to the water than they had been in the original antenna housings fabricated in February. Subsequent tests at the Pasco facility and in the laboratory at Sand Point determined that, for optimal performance, the antenna windings needed to be isolated from the surrounding water by 2 inches (the original design only had a 0.5-inch separation). This led to a new 1-inch chamfer antenna housing design that incorporated the 2-inch separation (see drawing B in Fig. 1). This design will be used for the Washington Shore Ladder and other installations in FY01.

Another important step in reaching the goal of standardizing the antenna system was to determine a common antenna configuration that could be used by all transceiver systems. At the end of FY99, the different prototype transceiver systems required different antenna configurations within the housings. Development work during February and March on the prototype transceiver systems was successful in determining an acceptable common antenna configuration. Tests conducted using the antenna-housing design with 2-inch separation yielded a final configuration (e.g., inductance and series tuning capacitance) that resulted in the greatest antenna efficiency. These tests finalized the design for the housings that will be fabricated for the Washington Shore Ladder and other installations for 2001. Antenna housing fabrication will begin in November 2000.

Another important step was to design an appropriate RF shield. Using known sources of EMI, tests at the NMFS Pasco test facility resulted in two promising shield designs: a continuous shield that worked best against magnetic-field interference, and a gapped shield that worked best against electric-field interference. The difference between the two designs is that when the 3-inch gap at the top is left open, the shield is electrically open; when it is welded shut, the shield is electrically shorted (Fig. 2). This way, the shield can be relatively easily switched between the two different designs.

Since both components of electromagnetic fields are present when RF noise is present, it was unknown which shield would do better in the “real world” at the dams (although, because a PIT-tag antenna is more sensitive to magnetic fields than electric fields, we thought that the continuous shield would perform better). Therefore for the fish tests conducted in September and October, NMFS personnel fabricated and installed prototype shields of each design and installed them into the AFF exit ladder.

Figure 2. Photo of the alternate continuous RF shield (note welded strip at the top of the shield) that will be installed into the fish ladders during FY01. When shields are installed at the dams, the floor sections will be 8 inches beneath the fish ladder floor (not flush with the floor as shown in the photo).

At Bonneville Dam Powerhouse II, the screen-cleaner motors in the downstream collector channel were the only positively identified source of EMI, thus one set of fish tests was run with the three-cycle sweeper left on continuously. The screen cleaner cycle takes 10 minutes to complete. There are three sets of brushes that are activated during that time; hence the RF noise generated during the cycle is not uniform. The noise level appeared to be highest when the screen cleaner motors were under load (i.e., the brushes were actively working). Furthermore, there are times during the cycle when little RF noise was generated (e.g., when the system was changing to the next sweeper brush).

Unfortunately, we could not control when fish passed through the orifices during these tests, and the difficulty in communicating with anyone standing near the screen cleaners made it impossible to pinpoint what screen-cleaner motors were doing when a fish went through. Although it was not a perfect test, we did learn some important information. For both transceiver systems, approximately two-thirds of the fish were not detected while transiting the orifice with the gapped shield, while all were detected while transiting the orifice with the continuous shield. In addition, although all fish were detected, the number of repeat detections per fish was basically cut in half with the continuous shield. Based on these tests, we recommend that continuous shields be installed into the Washington Shore Ladder for the FY01 full-ladder evaluation.

Transceiver System Development

To meet the 2002 goal of installing PIT-tag interrogation systems for adult salmon in all fish ladders at Bonneville Dam, the NMFS research and development team and BPA have taken a "spread the risk" approach by supporting several transceiver development efforts simultaneously. NMFS initiated contracts in FY99 to three companies for transceiver development work. The objective was to support the simultaneous production of two systems.

The first of these systems is denoted as the Open-Architecture System. In this system, the analog board module is separated from the interface module (the module responsible for processing codes and interfacing with data processing systems). NMFS contracted two companies, Patten Engineering (PE) and RF Engineering, to design and build analog boards for this system, while NMFS developed the interface module. The open-architecture concept was employed to allow the contracted engineers to focus on developing the most difficult part of a transceiver system (the analog board) and to permit flexibility in the selection of various analog boards so that the final product could be applied to a wide range of applications.

The second system was developed by Destron Fearing (DF), who modified their model FS1001, ISO-based transceiver system (previously used for interrogating juvenile fish). The new system is referred to as the DF-AdultSystem.

Field development tests were then performed during 1999 at Bonneville Dam in the AFF exit ladder with the two prototype transceiver systems (Open-Architecture system with the PE analog board and DF Adult) to verify the laboratory results in the field and thus help the contractors with their development efforts (Destron Fearing 1999, Downing et al. 2000). Reading ranges were less than what had been obtained in the laboratory, but were fully adequate for detection of adult salmon under dry and static watered-up ladder conditions. Reading ranges were measured with tags positioned at 0 and 45 degrees throughout all areas of the orifice openings. NMFS also received an analog board from RF Engineering. Laboratory testing revealed that their analog board did not reach the standard set by the DF and PE electronics. The result was that at the end of FY99, we had two promising transceiver systems: the DF-Adult and the PE/NMFS Open-Architecture Systems.

The two promising prototype systems, DF Adult and the PE/NMFS Open-Architecture systems, were further developed during the fall and winter of FY00 to improve the stability and reliability of their electronics. In addition, during December and January, preliminary tests were performed to determine the feasibility of combining the strengths of the two systems. Since the preliminary results were favorable, NMFS and the two contractors worked on the technical and legal hurdles that had to be overcome for this combined system to be developed. In January 2000, PE and DF agreed to work together to help improve the DF-Adult System by combining the technological strengths of the PE analog board and the manufacturing and firmware strengths of the DF system.

To help the contractors with their development efforts, the "Requirements Document for PIT-Tag Transceiver Systems for Orifices Located in Fish Ladders throughout the Columbia River Basin" was drafted by NMFS and released by APTOC in February. This document described the requirements for configuration, packaging, performance, communications, memory, power, environment, operations and maintenance, and documentation for these transceiver systems.

More field development tests to help the contractors with their development efforts were performed in the springtime at Bonneville Dam in the AFF exit ladder. A study plan describing these tests was submitted by NMFS to APTOC (BPA 2000). Fish tests were scheduled in the AFF exit ladder using antennas for 18- and 26-inch orifices between 19 April and 5 May 2000. Since the synchronizing circuits for the PE and DF systems were not compatible, the two systems could not run concurrently; therefore, the systems were tested on alternate days. Fish were tagged on 2 days during each week.

The reading efficiencies for spring chinook salmon transiting both 18- and 26-inch orifices in the upstream direction were above what we had expected, ranging from 88.6-100% (Table 2). If the fish transiting the orifices while the screen cleaner motors were active are eliminated from the calculations, then the reading efficiencies were 95% or better for each of the individual orifices. Only fish that were positively recorded by the

video cameras were used in the calculations (the COE Fisheries Field Unit did an excellent job in taking and analyzing all of the videotapes). Furthermore, only fish transiting upstream were counted because fish going downstream tend to fall back at all angles, which makes it difficult both to record them with the video cameras and to read their PIT tags. Some fish were counted multiple times because they fell back through the ladder and then re-entered the orifices. We counted each upstream pass through an orifice independently, so anytime a fish was not read on one of its passes, it was counted as a miss.

The video cameras helped us realize that interpreting PIT-tagged adult fish passage is going to be more complicated than for juvenile salmon passage at the fish facilities because without the video cameras, it is impossible to know the direction the fish are traveling at each orifice.

In addition, the video cameras demonstrated that when adult fish fall back, they are often at extreme angles that make interrogation impossible and also that fish will occasionally nudge their noses into an orifice without going through, yet their tags will be read (implying that they have gone through). Similar behavior can cause detection on the upstream end of the orifice when the fish has not actually fallen back through, or re-entered, the orifice.

These springtime fish tests also gave us some general fish behavior information. The time it took fish to pass through the fish ladder was variable. Many fish passed through the four weirs in less than a minute; others stayed in the ladder for longer than a day. We did tape one fish that used the overflows on all four weirs. We had another fish that left the ladder on the first day we tagged it and then was recorded again a month later.

During the spring tests, some problems occurred with transceiver components failing, with turbulence (bubbles) making it impossible to use the video cameras in one of the weirs, and with marginal turbidity one day (A Secchi disk reading of 3 ft seems to be the lower limit for viewing fish in the 26-inch orifices within the AFF fish ladder). Furthermore, there were the unexpected high ambient RF conditions that stopped the testing during the third week.

NMFS research and development team and its contractors then spent 2 weeks in May investigating the electromagnetic interference (EMI) problem directly and setting up EMI-monitoring systems on several weirs. After months of monitoring weirs in the AFF ladder, we have still not identified all of the intermittent source(s) of RF noise. The levels are different in the four weirs, but all of the weirs have been affected. It was thought to be weather dependent, but that correlation was eliminated in June. Although the unexplained noise was overwhelming only a few days, many days have short periods (10-90 minutes) when interrogation of tags would be affected.

Table 2. Results from 4 days of fish tests conducted in the AFF exit ladder at Bonneville Dam. Numbers of fish and reading efficiencies (RE) are included for the two transceiver systems and two sizes of orifices. Note that sample sizes are different for each data column.

	DF-Adult System		PE/NMFS Open-Architecture System	
	18-inch orifice	26-inch orifice	18-inch orifice	26-inch orifice
Number of upstream fish read	72	53	62	38
Total number of upstream fish	74	53	62	43
Reading efficiency (%)	97.3	100	100	88.4
RE adjusted for active screen cleaner motors	98.6	--	--	95
Average number of reads/fish	10.2 ± 3.2	10.8 ± 5.2	6.3 ± 2.7	4.1 ± 1.6

It is difficult to locate EMI sources because an ambient RF situation is rarely static. Further complicating the issue, noise from different sources that alone would not interfere with the transceivers can combine to create frequencies or intensities that do cause problems. We will continue to take ambient RF measurements in different fish ladders, but the fisheries community needs to recognize that these are just snapshots in time and that there will be times when ambient noise will affect the performance of the installed interrogation systems.

More field development tests were performed at NMFS Pasco Field Station during the summer with the two prototype transceiver systems. After each series of tests, marked improvements were made to the interrogation system as a whole (i.e., improvements were also made to the antenna systems such as adding the RF shields). By the end of these development tests, the multi-agency Transceiver-Antenna Technical Team (a technical team sponsored by APTOC) had become confident that it was time to move forward with installing an interrogation system into a full ladder (Washington Shore Ladder at Bonneville Dam) for the 2001 season.

A critical step for this full-ladder test was to select a transceiver system. The plan was to conduct a thorough evaluation of the two transceiver systems so that the fisheries community would be knowledgeable about how both were performing and what, if anything, was necessary to make both systems into production models. To prepare for this evaluation, the multi-agency evaluation team finalized the requirements document and then determined how to evaluate each requirement to ensure a fair assessment of the status of the two systems (TATT 2000a,b).

To select the transceiver system, the evaluation team performed fish tests and a series of electronic laboratory tests and then wrote a report on the results (TATT 2000c). Both systems read 100% of the fish going upstream through the 18- and 26-inch orifices when the screen cleaners were not active. Furthermore, they read each fish approximately 10 times as it transited an orifice. The laboratory tests determined that the DF-Adult System had only a few firmware modifications that needed to be made while the PE/NMFS Open-Architecture System was 6-12 months away from being a production unit (most of the needed changes were also firmware based). Based on these tests, the team recommended that APTOC select the DF-Adult Transceiver System for testing at the Washington Shore Fish Ladder. The identified firmware changes will be made for the units that will be used in the full-ladder test.

Components of the interrogation system now appear ready for the final full-ladder evaluation step that is planned for the Washington Shore Ladder at Bonneville Dam. Therefore, the COE is proceeding with planning for the installation of an interrogation system for 24 orifices. We expect that the installation and evaluation of the prototype extended-range interrogation system in the Washington Shore Fish Ladder will provide

1) estimates of tag-reading efficiencies for 18-inch orifices, individual weirs, and a complete fish ladder;
2) guidelines for future installations (e.g., number of weirs to cover, cost estimates, time needed, grounding specifications); and
3) information on whether there is a need for weir overflow detection.

The evaluation will also provide new information on how adult salmonids use fish ladders.

The experience at the AFF made it apparent that it would be prudent to monitor future installation sites for minimally 1 year in advance of a scheduled installation in order to identify and remedy any sources of EMI. Thus, we will monitor the three Bonneville Dam ladders scheduled for installation in 2002. Since McNary Dam fish ladders may be installed in 2002, we will also monitor there. At one location in the Oregon ladder at McNary Dam, we will monitor orifices installed with both continuous and gapped shields.

We will also monitor the RF noise levels for each of the transceivers in the Washington Shore Ladder. In addition, if deemed necessary, we plan on contracting EMI consultants to help NMFS and the COE solve the screen-cleaner noise problem at Bonneville Dam. If high noise levels are recorded, the EMI consultants would also periodically perform an overall profile of the ambient RF noise (e.g., a frequency spectrum and amplitudes of pertinent frequencies) at this ladder to help us learn more about the types of RF noise at Bonneville Dam.

The prototype interrogation system for orifices that will be installed in the Washington Shore Ladder will be different from what was tested in the AFF during 2000 as we get closer to a production system. The system to be evaluated in 2001 will differ from that tested in the AFF in the following ways:

1) the DF-Adult transceiver will include the firmware changes identified during the 2000 evaluation process;
2) the antenna-housing design will have 1-inch chamfers and a 2-inch separation gap between the antenna windings and the water;
3) the RF shield will have multiple grounding options;
4) a fixed-reference or test tag will be included; and
5) a new custom-made antenna cable will be utilized.

Therefore, before installation begins at Bonneville Dam, we plan to conduct a system checkout at the NMFS Pasco test facility in early January 2001 using the new system components. However, conditions vary compared to Bonneville Dam (e.g., grounding and number of adjacent units is very different); thus, the final checkout cannot be completed until everything is installed in the Washington Shore Ladder.

INSTALLATION, EVALUATION, AND MAINTENANCE OF THE ISO-BASED FLAT-PLATE SYSTEM FOR JUVENILE FISH

The NMFS research and development team installed a 400-kHz flat-plate (pass-by) PIT-tag interrogation system for juvenile salmon in the downstream migrant (DSM) channel of Bonneville Dam Powerhouse I in 1996 (Nunnallee et al. 1998). This site is designated BVX in the PTAGIS database. The continued reliable operation of this system is essential to meet informational needs of fisheries investigators and managers in the CRB. Therefore, like the rest of the PIT-tag equipment at the juvenile fish facilities, the 400-kHz flat-plate system needed to be replaced with an ISO-based system in time for the 2000 smolt outmigration.

Since 1997, NMFS and their contractor PE have been working together to develop the replacement 134.2-kHz ISO-based flat-plate system for juvenile fish. NMFS has also been responsible for evaluating the replacement system to ensure that it would meet the same performance criteria as the 400-kHz system. The objective is to meet or surpass the results for the 400-kHz system (10-cm reading range for both angles and reading efficiencies of 85-90% for individual coils and 95% for the entire system). NMFS was also in charge of installing and maintaining the system during the 2000 migration season (these efforts were coordinated with the COE and PSMFC).

PE delivered the final production boards in September 1999. In November, the 400-kHz flat-plate interrogation system was removed and the ISO-based production units were temporarily installed in order to evaluate several antenna designs to determine the best configuration for the permanent installation. These tests determined that four coils would be sufficient. The 400-kHz system had utilized two coils; however, previous tests with prototype ISO-based equipment had suggested eight coils might be necessary. As before, the system consists of upstream and downstream antenna arrays. The two antenna housings now contain two overlapping antennas (coils) that have been positioned for minimum cross coupling and interference.

NMFS permanently installed the ISO-based system in February 2000. The entire 400-kHz system was replaced except for the antenna housings and the computer used to collect data. To prevent electromagnetic interference, all four of the transceivers were synchronized. After installation, the system was evaluated for reading range and reading efficiency. The final equipment combination yielded consistent reading ranges of 18-19 cm compared to the 10-cm reading range for the 400-kHz system.

On 13 March 2000, NMFS conducted fish tests to determine tag-reading efficiencies using the same procedure that was used to evaluate the 400-kHz flat-plate system (Prentice et al. 1998, 1999). Tests were conducted using 201 hatchery chinook salmon (*Oncorhynchus tshawytscha*; mean fork length 69.6 mm) and 213 hatchery

steelhead (*O. mykiss*; mean fork length 187.5 mm). The juvenile salmonids were released one at a time into the DSM channel about 20 m upstream from the flat-plate system. The chinook salmon passed over the interrogation system within about two minutes from the time of release while the steelhead took minutes to many hours before exiting the DSM channel. The overall tag-reading efficiency for all four coils combined was 99 and 94% for the chinook salmon and steelhead, respectively. Since the facility was still operating on an 8-hour-per-day schedule, PIT-tag interrogation had to be terminated at the end of the day.

The NMFS research and development team speculated that some PIT-tagged steelhead may have remained within the DSM channel and exited after the PIT-tag interrogation system was turned off. Therefore, a second test using 116 juvenile steelhead (mean fork length 187.0 mm) was conducted on 5 April when the facility was operating on a 24-hour-per-day schedule. The fish were released one at a time over a 2-hour period. The first fish was detected at 09:37 on 5 April and the last fish at 13:04 on 6 April. The test was stopped after 48 hours. A total of 110 tags were read; this yielded a tag-reading efficiency of 95%.

Although the April data supported the speculation about the results from the March test, that some steelhead may have remained in the system after 8 hours, it also yielded a similar reading efficiency. Thus, it appeared that there may be a difference in fish behavior between the two species that affects their reading efficiencies. For example, some steelhead may have passed over the flat-plate in an orientation that did not allow the tag to be read; some fish may have remained in the current of the channel for many days beyond the date the test was completed.

This was the first time that steelhead were used for evaluating this site, so we do not have comparative results; previous tests had been done with chinook and coho salmon (*O. kisutch*). In addition, 9 minutes of data are missing from this test and therefore it is possible that one or more fish may have passed by the interrogation system during that time. Based on 2000 test results, we recommend that similar tag-reading tests be conducted in 2001.

To ensure reliable system operation, we conducted routine inspections and maintenance on the flat-plate system during the 2000 field season. This effort included the tag-reading tests using tagged drones conducted by NMFS and facility personnel. Results of the daily tagged-drone tests were near 100%. Results varied slightly depending on who was conducting the test. In spite of the variability in results, the tagged-drone tests remain a valuable indicator of the systems overall operation status. These tests indicate when a major component fails as well as when overall performance decreases. During the 2000 out-migration season, approximately 11.5 hours of data were lost when the synchronizing controller failed. Less time would have been lost had the failure not occurred during the July 4th holiday.

Data were also lost from one detector when a tuning inductor failed. The failure affected only the one detector and did not adversely affect the three other units. Otherwise, adjustments to the pneumatic rams that operate the antenna housing lift mechanism were made on two occasions. No data were lost due to the partially malfunctioning pneumatic ram. Like the DF equipment used at the other CRB sites, the ISO-based flat-plate system performed exceptionally well during the 2000 season.

This equipment will continue to be used in 2001. The COE has still not set a final schedule for the construction of the juvenile fish collection and sampling facility for Bonneville Dam Powerhouse I. A flat-plate system will continue to be needed until this facility is completed.

FABRICATION AND INSTALLATION OF A THREE-WAY SIDE-TO-SIDE DIVERSION GATE

The COE released 60% drawings on their facility-modification project for Little Goose Dam in June 2000. NMFS reviewed them and returned comments. The COE decided in August that the revamp project would use 10-inch pipe in the section where the side-to-side diversion gate would be installed. The COE also decided in August to combine a minor revamp project for the facility at Lower Granite Dam with this one for issuing a contract. Personnel from the NMFS Pasco Field Station fabricated the 10-in side-to-side gate in September. In October, the bids the COE received for the project were more than double what they had budgeted for and so they decided in November to delay the Little Goose Dam project for at least another year. Although NMFS will participate in this facility-modification project when it occurs, this effort will be supported through the COE. BPA support for this project ended with the fabrication of the diversion gate.

SEPARATION BY CODE SYSTEM: THE MULTIMON COMPUTER PROGRAM

During 1992-1994, NMFS developed and evaluated a separation-by-code system (computer program and fish diversion gates) at their Manchester Research Station. The computer program controls the separation of targeted PIT-tagged fish from untargeted tagged and untagged fish based on their individual tag codes. The development of the computer program, MULTIMON, is a joint project with Pacific Northwest National Laboratory (PNNL), whose personnel write the computer code. NMFS personnel oversee the development; test the program after modification; and collaborate with PSMFC personnel on technology transfer, maintenance, and assisting fisheries researchers. PNNL and NMFS personnel have worked together on the MULTIMON user guide and online help file (accessible while the program is running).

The separation-by-code system was first tested at Lower Granite Dam in 1995; however, the computer program has changed a great deal since then. For example, in 1996, modifications were made to MULTIMON to facilitate the evaluation of 134.2-kHz ISO-based stationary transceiver systems. Thus, the program can now simultaneously function with both 400-kHz and 134.2-kHz transceivers. In addition, each year has seen modifications to make the program more user friendly and new features added to assist researchers in completing their studies. Furthermore, technological advances have changed computers dramatically since 1995, and we have taken advantage of these advances to improve MULTIMON.

Because research needs change each year, and new equipment (i.e., hardware, software, and electronic components) is installed or upgraded, we recognize that MULTIMON is unlikely to ever be totally static. Nonetheless, the program reached the stage that at the conclusion of the 1999 field season, PSMFC took over the primary responsibility of maintaining MULTIMON at the dams. There were a few items left to complete for the program in FY00; otherwise, the primary role for NMFS during the 2000 season was to support PSMFC as needed.

Most of the computer program modifications for the 2000 migration season were to make the program more secure in case of failures and thus help PSMFC with its operations and maintenance of the program. For example, the program was modified so data files were now automatically saved every 5 minutes instead of every 15 minutes. This significantly reduced the amount of data that could be lost when power failures occur. In addition, backup copies of the different setup files were created daily; this would permit PSMFC to quickly replace a file if the active one became corrupted. To keep the Windows-98 platform more stable, we made it possible to define how much RAM was reserved for the tag database file. Thus, for most sites, Windows 98 retained use of most of the RAM. Based on the needs for several separation-by-code research

projects in the past 3 years, we added the ability to define the start and stop times for a separation-by-code collection period that could last between 1 second and 24 hours.

The most significant modification during FY00 was to write a Windows-based interface program (called REMOTE) that made the process for sending remote commands (e.g., loading new data base and map files) straightforward and kept MULTIMON actively collecting data while it performed the tasks. When these tasks are performed locally, MULTIMON must be taken out of its active data-collecting mode. The ability for MULTIMON to recognize remote commands that would enable PSMFC to manage its data files more effectively from its Gladstone, Oregon office had been added in 1997, but the process had been awkward until this REMOTE program was designed. This modification made it much easier to administer MULTIMON remotely.

PSMFC has started the process of writing a Windows-based application (MINIMON) to replace the DOS-based MULTIMON application. So far, it is still primarily a monitoring program as it is unable to control separation-by-code functions. They successfully ran a parallel setup with both MULTIMON and MINIMON operating at two sites between July and September 2000.

They will continue to add functionality to this program. At this time, NMFS does not plan any significant modifications for MULTIMON for the 2001 season. For example, the only planned change is to add the ability to connect a global-positioning system to the data-collection computer so that for the towed-tunnel array used in the Columbia River estuary, they can have a geographic location attached to the tag-data information. In addition, we would also correct any bugs that were found by PSMFC during their use of the program.

INFORMATION TRANSFER, TECHNICAL REVIEWS, AND TECHNICAL SUPPORT

NMFS actively collaborates with other agencies on PIT-tag related matters such as facility designs to accommodate PIT-tag systems, PIT-tag system maintenance, assistance in using prototype equipment and the MULTIMON computer program, and information transfer. Because NMFS personnel designed or co-developed many of the present PIT-tag system components, they are an important resource for providing technical support and training to ensure the reliable operation of PIT-tag technology throughout the CRB. They also provide assistance in adapting PIT-tag technology for investigations into new areas. Activities that NMFS was involved in during the 1999-2000 reporting period are outlined below.

- Provided assistance to PSMFC regarding the repair of PIT-tag interrogation systems, use and repair of ancillary equipment such as fish diversion gates, and setting up MULTIMON at CRB dams.

- Assisted investigators from several fisheries agencies in setting up the MULTIMON program to accommodate their separation-by-code requirements.

- Designed and installed a control system that activated a set of lights, which distinguished fish that could be collected and those that could not be collected, in the Adult Fish Facility at Bonneville Dam. We also administered the separation-by–code at this site for the University of Idaho at the request of the Fish Passage Advisory Committee.

- Provided information on the CRB PIT-tag system to numerous national and international investigators. For example, we consulted with investigators from the Institute of Marine Research in Norway regarding the technical feasibility of developing deep-water towed-array interrogation systems for ocean sampling. We also reviewed the Ballard Lock installation for the COE.

- Designed ISO-based equipment. Due to the basin-wide transition to the ISO-based PIT-tag system, new interrogation equipment had to be designed for both the towed-tunnel array used in the Columbia River estuary (Ledgerwood et al. 2000) and for the system used to detect tags deposited by birds in locations not accessible by jeep (Ryan et al. in press).

- Helped plan and participated in the PIT-Tag 2000 Workshop held at Skamania Lodge near Stevenson, Washington in January 2000. Activities included assisting in the demonstration of PIT-tag tagging techniques, presenting papers, and acting as session moderators.

- Assisted the PIT-tag Steering Committee in its production of an instructional video for PIT tagging fish. The video will aid researchers in learning how to properly handle and tag juvenile salmon.

- Participated in the 1999 Manchester Street Festival held in Kitsap County by providing demonstrations of PIT-tag equipment used in CRB. This was a community outreach effort to help highlight NMFS activities.

- Provided the COE with information on the three-way rotational diversion gate at Lower Granite Dam to help decide whether to add that modification to the planned revamp at this site.

- Assisted investigators from several fisheries agencies regarding the feasibility of an in-stream interrogation system based on the flat-plate system developed by this team.

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