Pre-Proposal

Development of unified codeset for radio-telemetry applications

Principal Investigator:

Theodore Castro-Santos, PhD
Research Ecologist
US Geological Survey
S.O. Conte Anadromous Fish Research Laboratory
P.O. Box 796, One Migratory Way
Turners Falls, MA 01376
413-863-3838
tcastrosantos@usgs.gov

Co-Principal Investigators:

John W. Beeman
Research Fishery Biologist
US Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
5501A Cook-Underwood Road
Cook, Washington 98605 USA
509-538-2299 x257
john_beeman@usgs.gov

Introduction

Radio telemetry is used in a wide variety of fisheries and wildlife applications. It is a vital tool for fish passage research, where it is used to identify and develop safe and effective routes around dams and other barriers to fish migrations. Significant advances in radio telemetry techniques have occurred in recent years; perhaps most notably, it has become possible to configure tags and receivers such that hundreds of unique codes can be carried on a single radio frequency. This has been achieved by developing codesets, a kind of 'barcode' system whereby a series of pulses of variable length are transmitted. A receiver then decodes these pulses and records the associated identification number. This technology has made it possible to simultaneously observe large numbers of migrating fish, leading to dramatic improvements in our understanding of fish passage problems and the effectiveness of solutions.

An important limitation to this new technology is that the codesets and the hardware and software used to decode them may be considered proprietary. In many cases tags produced by a given developer can only be read by that company's receiver—because receivers constitute a significant capital outlay on the part of the user, this means that users, having once purchased a given receiver are restricted to using only that company's tags, and future receivers must also come from the same company to retain compatibility. This has led to a situation in which developers of radio-telemetry technology have difficulty accessing the market, and users have little choice as to which technology they can use, both because of the codeset restrictions and the limited pool of providers. All of this leads to higher prices of both tags and receivers, driving up the cost of studies and limiting their scope.

In response to this situation, the Bioengineering Section of the American Fisheries Society has convened a subcommittee to explore the possibility of developing an open-source codeset that can be used by any developer of telemetry equipment. This subcommittee, represented by the authors of this proposal, has developed a codeset framework that should meet this need. Both developers and users have expressed a desire to see this codeset refined and tested. The purpose of this proposal is to seek funding to make this final step possible. If successful, the results will be published in a widely-read trade journal such as Fisheries, which will accomplish two goals: a) the information will be made available to the intended user groups and developers; and b) the structure of the codeset will be public information, ensuring universal access to developers of both tags and receivers.

Methods and Products

The proposed work will proceed in five phases. The first phase (already complete) is to develop a codeset framework. This defines the intended radio frequency range, duration of pulses and inter-pulse intervals, and checksum format. Two potential structures have been identified: One structure ('native codeset') will have a uniform timebase for both pulse durations and inter-pulse intervals. This approach could allow for development of receiver software that can decode signals based solely on the structure of the code itself. The code is 'native' because it follows a binary structure and so the value of each code is intrinsic, i.e. it can be decoded mathematically. The second structure ('lookup codeset') is not restricted to a uniform timebase, and code values are not necessarily intrinsic to the structure. In this case, a 'lookup table' is required, in which the receiver matches the recorded code with a pre-defined set of possible codes.

Each of these approaches has intrinsic strengths and weaknesses: because no matching is required, the native approach could have shorter logging times and require less computing power and memory than the lookup approach. Structure of the codes is limited by the base-2 intervals, however, and this may preclude optimization of tag life and detection efficiency. The greater flexibility in interval widths allowed for by the lookup approach may allow for shorter transmitter on-times and improved resolution, but requiring greater memory and computing power and thus slower determination of code.

The second phase of this proposed work will assess the relative strengths and weaknesses of these two codeset structures. Both the 'native' and 'lookup' approaches will be compared by simulating codesets with a range of pulse durations and inter-pulse intervals. The simulation will include realistic assumptions of component stability and accuracy, producing a representative range of outputs for a given codeset structure. This exercise will also simulate receiver tolerances. In this way it will be possible to quantify the tradeoffs associated with longer or shorter pulse and interval durations, and will resolve which of the two approaches is optimal, given existing technology. The costs and benefits of including a checksum pulse (a technique for reducing false reads) will also be quantified in this phase. In addition to identifying optimal criteria given current technologies, this phase will also help guide development of future codesets.

Having identified theoretical performance in Phase 2, the next task (Phase 3) is to test the full codeset with receivers produced by several manufacturers. Manufacturers will program their receivers with one or more candidate codesets. The entire codeset(s) will then be input into each receiver using an arbitrary waveform generator and a pulse modulation signal generator. This will serve to verify the results of Phase 2 and will also identify if codeset detection is robust across platforms.

The final test (Phase 4) is to simultaneously test receivers and tags from multiple manufacturers. This will be a simulated field experiment, with receivers deployed in a realistic array, and tags passed through the array exhibiting known movements that mimic behaviors of migrating fish. In addition to the new codeset, existing codesets will also be tested. This will provide direct comparison of the codeset with existing technology and complete the proof-of-concept.

Having established a codeset and demonstrated its functionality, the results of these experiments will be published in an international peer-reviewed journal and presented at one or more scientific meetings (Phase 5). The publication will include the structure of the codeset as well as information gleaned during each of the phases. Tradeoffs between on-time and tag life will be quantified and reported, as will likelihood of collisions and other factors that may prevent detection. Although the final report will include a recommended codeset structure, flexibility will be maintained within this structure, allowing for further development, either by the Bioengineering Section or by the public or private sector.