# 14.

# Sonic Fish Tracking

By

PARKER S. TREFETHEN*

The need for knowledge by fishery agencies of fish movements has long been recognized and many techniques, such as disc tags, streamer tags, dyes, and tattoos, have been devised to obtain this important information. Valuable data have been accumulated by these methods for population studies, catch evaluation, timing of migrations, and delays during migration, but none of these tags are able to produce minute-by-minute information on fish movements in specific areas or on the behavior and orientation of fish in response to specific stimuli in their natural environment. Detailed information on behavior of fish is necessary for understanding migrations and predicting changes in migratory routes, for providing adequate fish passage facilities for certain species of fish, and in the management of a fishery.

In the absence of a suitable tag for observing detailed movement patterns of fish, the Bureau of Commercial Fisheries undertook a programme to develop special equipment that could be employed to observe adult salmon as they migrated upstream. Dr. Gerald Collins initiated this research and investigated the possibility of utilizing mechanical noise-makers or radio transmitters attached to a fish, but these techniques were unsatisfactory and it became apparent that underwater sound was the only feasible method that could be employed.

The Seattle Development Laboratory of Minneapolis-Honeywell Regulator Company under contract to the Bureau designed a sonic tag and produced receiving equipment that would "home" automatically on the tag's signal and track the fish to which the tag was attached. The first usable tag was an aluminum capsule 0.86 inches in diameter and 2.37 inches long, and weighed from 0 to 2 grams in water. This was a self-contained battery-operated unit that produced a pulsed 132 kc signal detectable for eight hours, and had a tracking range of 250 feet.

This tag was employed for three years to observe fish behavior, but after its initial use it became obvious that the life and tracking range of this tag was too short and its operation too unreliable for prolonged experiments. During this three-year period, however, the advances in sonic and electronic engineering and in subminiaturization of electronic parts made it possible to design and produce a tag with more desirable characteristics.

* Bureau of Com. Fish., Seattle, Wash., U.S.A.

The basic tag now in use was designed for us by Automated Controls Company, Alderwood Manor, Washington. It is capable of producing a tracking signal for 24 to 60 hours in fresh water at a range of 500 to 1200 feet; in salt water the range is reduced to about one-third. The dimensions have been decreased to 1.8 inches long and 0.6 inches in diameter, while the weight has been increased by only 6 grams. The frequency of the signal, 132 kc, and the pattern of the signal from the tag are similar to those of the tag previously employed.

The new tag is constructed in two units: (1) the transducer-oscillator unit which contains the resonating zirconium-titanate crystal, printed circuits and necessary electronic components to stabilize the signal in varying temperatures; and (2) the battery unit which contains the power supply. By using different types of miniature batteries and by varying the number of cells in a battery unit the duration of signal can be controlled without altering the dimensions. By increasing the length of the battery unit and utilizing a longer battery, the duration can be increased to over 5 days and the range to over 1500 feet.

The components of each unit are assembled to fit within buterate-plastic shells that, when joined, form a completed tag. This tag is waterproof and capable of withstanding water pressures at depths of more than 100 feet. Attachment to a fish is made with a hog-ring device that is cemented to the tag and clamped into the fish behind its dorsal fin.

This tag has been successfully employed to track fish in salt and fresh water, in shallow water and deep forebays of dams and in rapidly flowing water that is not extremely turbulent. We have found that adult migrant salmon appear to prefer water less than 30 feet deep, that they tend to follow a shoreline and that there is a difference in their behavior between daylight and darkness. Fish have been tracked up to 15 hours, but the duration was usually limited by personnel endurance rather than by the equipment.

We have demonstrated that individual fish can be kept under constant observation in their natural environment with specialized sonic equipment. To accomplish this, it was necessary to employ a tag that is larger than tags used in the usual tagging programmes. Because of its size, and the method of application, its effect on natural behavior patterns is an important consideration in the analysis of the results. We have attempted to minimize the effect of handling while attaching the tag, by keeping the fish under water at all times. About one out of four fish tagged in this manner reacted to the procedure by swimming rapidly around a tagging box for several seconds; the others showed no visible reaction. The fish was then held up to four hours to eliminate the effect of the tagging.

The sonic properties apparently do not affect the behavior of adult migrant fish. Tagged and untagged chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Salmo gairdneri*), tagged with a sonic tag and placed in fast flowing and in quiet water, exhibited no visible differences in their behavior patterns. Several investigators have concluded that fish, when subjected to frequencies between 0.005 and 70 kc, became quickly adjusted to the new sound after an initial "start" and accepted it as part of the large volume of noise normally encountered in their environment.

Another factor that might have affected the validity of the information being collected was the weight of the tag and its drag as it was carried through the water. In so far as possible we streamlined the tag to reduce the drag, but it remained relatively large and the weight was foreign to a fish. A series of tests, designed to compare the movement of tagged and untagged fish through different water conditions in a fisheries behavior laboratory, were conducted to examine the effect of the tag being employed and, also, the effect of a smaller tag that weighed 12 to 15 grams. No effect was observed between tagged and untagged fall-run chinook salmon and blueback salmon of the Columbia River. An apparent effect was observed on spring-run chinook salmon, but we are not certain that the observed behavior is the result of the sonic tag and handling, for in other types of experiments the behavior of spring chinook salmon appears very erratic. More experiments are necessary before we can assume that the tag does not affect behavior of spring chinooks.

Throughout our behavior experiments we have utilized receiving equipment that has been only slightly modified from the original design. This automatic tracking system is servo-powered, utilizing four receiving or detecting barium titanate transducers and four receiver channels for tracking a tagged fish. Two of the transducers are used for tracking in azimuth and two are for tracking in elevation. A 132 kc sound source (sonic tag) in the common axis of a pair of transducers produces a signal in each transducer. As it is moved from the common axis toward the axis of either transducer the output from one rapidly increases toward a maximum, while the output of the opposite transducer decreases. The two signals are used to balance each other in a difference amplifier and the sharply defined null provides sensitivity to vertical and horizontal angular displacement from the common axis. These detecting transducers are clustered around the echo-ranging transducer and when the tag is in the null, or common axis, the ranging system is aimed at the tagged fish. The exact position of the fish is determined by echoes from sound impulses emitted by the ranging unit. These echoes are transformed into electrical energy and displayed on a calibrated cathode-ray tube that shows distance and direction; the depth of the fish can be calculated.

The four receivers, each of which is connected to one of the four detecting transducers, use a t-r-f-circuit with a band pass of $\pm$ 1 kc. For accurate and dependable operation a delicate balance between the receivers must be maintained and a signal level of 5 microvolts is required at the receiver grids.

In view of electronic developments since the original design of the tracking system, our equipment is obsolete and improvements must be made to increase the dependability and accuracy of our observations on fish behavior. In a new tracking system, a single channel would replace the four-channel receiver to eliminate the delicate balance necessary between channels for accurate tracking. A front-end switching unit would separate azimuth and elevation signals received from a sonic tag and activate an improved servo-system to aim echo-ranging equipment at a tagged fish. A high-gain circuit would be employed but the bandpass would be decreased to about 500 cycles or less. This would effectively increase the range of our present tag by eliminating some of the signals or noise now received with the 1 kc band pass. A reduction in noise will also increase the duration that the tag signal can be detected.

New equipment will include a tunable receiver capable of detecting signals over a wide range of frequencies. This will allow us to select a tag frequency most suitable to the water condition, and minimize signal attenuation in turbulent water and in a marine environment. This type of receiver will eliminate the precise adjustment of tag signal that is now necessary before use and enable us to continue tracking a tagged fish regardless of any frequency shift that might be caused by temperature or pressure changes. The ability to utilize lower frequencies will enable us to reduce the size of the sonic tag by nearly one-half, while maintaining the present characteristics. Also, it is conceivable that several tags of different frequencies could be employed at the same time, so that more than one fish could be tracked in a specific area.

We have emphasized the development of automatic tracking equipment in anticipation of long-term fish behavior studies when fish might be tracked for days or weeks. It is possible, however, to develop a simpler system that could be mechanically positioned by aurally differentiating signal strength; thus, with two or more systems fish could be tracked by triangulation. However, this type of equipment would probably be limited to specific areas from stationary observation points.

The ability to utilize sonic equipment to observe in detail the behavior of individual adult salmon has been adequately demonstrated. Although we will continue to use the present tracking system to accumulate data on salmon behavior, efforts are being directed toward the design and production of new equipment to realize fully the potential of this research tool. A new tracking system design will be based on our experiences coupled with the latest advances in sonic and electronic engineering. The increased accuracy, reliability, and sensitivity will enable us to consider the use of this tool in a marine environment for extensive observations on salmon and other species of fish, some shellfish and marine mammals.

In our development programme we have accumulated considerable experience in the use of sonic equipment in small boats. We gladly offer our assistance in the installation and operation of equipment, the interpretation of data or in tagging-tracking operations. We are hopeful that other fishery agencies will utilize this research tool and contribute basic as well as practical information on behavior patterns of aquatic animals.

## Summary

An early sonic tag used for 3 years has been replaced by an improved device. A new plastic tag now in use is 0.6 inch in diameter, 1.8 inches long, and weighs 4—6 grams in water. A continuous 132 kc signal can be traced at a distance of 500 to 1200 feet for 24—60 hours. The range can be increased to over 1500 feet for more than 5 days by increasing the length of the tag.

The tag is constructed in two sections: (1) the transducer oscillator unit and (2) the battery unit. It withstands water pressure at depths of over 100 feet. Fall-run chinook salmon (*Oncorhynchus tshawytsha*) and blueback salmon (*O. nerka*) are not affected by the sonic or physical properties of the tag.