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# Preliminary Studies in the Development of a Gastric Battery for Fish

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# PRELIMINARY STUDIES IN THE DEVELOPMENT OF A GASTRIC BATTERY FOR FISH[1]

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In 1956 Parker S. Trefethen described an external ultrasonic tag for tracking fish. This tag was designed for use on adult king salmon, Oncorhynchus tshawytsca, and was subsequently used to track these fish above Bonneville Dam (Johnson, 1957). Although this tracking system was the best available at that time several limitations to its use were evident: the transmitter and power supply were large and thus impractical for use on small fish, and the unit was attached externally and was likely to influence movement, and the life of the battery was very short (17 hours). Succeeding transmitters were somewhat longer-lived and smaller (Novotny and Esterberg, 1962). However, they were externally attached to the fish and their use still limited by a short battery life (up to 10 days).

Because of the need to track small fish over longer periods of time without significantly affecting their movement, the Research Section of the Nebraska Game, Forestation and Parks Commission contacted the Electrical Engineering Department of the University of Nebraska regarding development of a small ultrasonic transmitter which could be placed in the stomach of a fish. Further, the transmitter was to have an operational life of six months or more. Since available power supplies did not meet the need, a battery consisting of metal plates emersed in the gastric acids in the fish's stomach was proposed. Studies to determine the feasibility of such a battery were begun in September, 1962. Preliminary tests indicated that largemouth bass, Micropterus salmoides, and northern pike, Esox lucius, were sufficiently tolerant of selected metals (gold, copper, cadmium, nickel and zinc) in their stomach to justify experimentation with gastric batteries. Since peristalsis and regurgitation resist retention of items in the stomach, it was necessary to devise a means for holding tested objects without unduly affecting the fish. This consisted of a harness constructed of a 1/16-inch diameter plastic rod which attached around the isthmus of the fish and extended down the gullet into the stomach (Kendle and Morris, 1965). Additional work was designed to study in greater detail the tolerance of the fish to the tested items and to determine the optimum metals for the battery.

The selection of metals was based principally on capabilities to produce power in the gastric acid. Seven batteries were constructed to test the following combinations of metals: copper and cadmium, nickel and cadmium, gold and cadmium, copper and zinc, gold and zinc, gold and aluminum, and cadmium and zinc. The metals were cut into plates, each affording one squre inch of total surface area. This approximate size was observed throughout this and subsequent experiments. Each battery contained two plates separated about 0.07 inches. Preliminary tests of the batteries

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were made in polyethelene containers containing a prepared electrolyte of 0.5 percent hydrochloric acid. This exceeded the hydrochloric acid concentration normally found in the gastric environment of Esox sp. (Barrington, 1957); hence, the rate of erosion of the metals was faster and the current produced greater than would be expected in a fish's stomach.

Voltage and short-circuit current of each battery was measured daily for 20 consecutive days or until the battery ceased functioning. After 15 days all but the gold-cadmium battery had ceased operation as a result of disintegration of one or both plates. At the end of this test the gold-cadmium battery was in good working order and producing 3.5 milliwatts of power. Although the gold-zinc battery produced more power initially (9 milliwatts), the zinc plate disintegrated rapidly and the battery ceased operation after five days. Later tests with gold-zinc batteries indicated a life of 40 to 45 days in the stomachs of largemouth bass.

Because a long-life battery was desired, gold-cadmium batteries were placed in fish to determine the life of the battery. In addition the fish's reaction to the battery-harness unit and the possibility of metal toxicity of a chronic nature were investigated.

The batteries used were constructed by wrapping a thin sheet of cadmium onto the rod harness and placing a polyethelene spacer over it before the 22-carat gold sheet was wrapped over the spacer. This spacer was wrapped spirally around the cadmium sheet with about 0.2 inches separating each wrap. Sizes of the battery components are presented in Table 1. Once the battery was formed on the rod an enameled No. 30 copper wire was soldered to each of the two metal plates and fastened along the rod.

After placement in the fish the leads were run out of the fish's mouth and connected to a small float at the water's surface in a 15-gallon aquarium. This arrangement allowed the investigator to measure the voltage and short-circuit current whenever desired.

Under these conditions with the battery in a northern pike, voltage averaged 0.46 volts with a range of 0.26 to 0.64 volts and short-circuit current averaged 0.65 milliamperes with a range of 0.04 to more than 1.000 milliamperes (needle deflected off 1 milliampere scale) during the 13 days of testing. The voltage obtained from the gold-cadmium battery appeared to vary with the temperature of the water in the test aquarium whereas there was no apparent relationship between short-circuit current and water temperature. Thus, the output of the battery in average water temperatures of 57, 65 and 70 degrees Farenheit averaged 0.20, 0.37 and 0.50 milliwatts respectively. The effects of ingested food on the output of the battery was not noted as the northern pike did not feed during the 13-day study. The output of this battery was considered sufficient to operate the prototype transmitter.

An additional experiment was designed to evaluate long-term effects, particularly toxicity, and to indicate potential battery life.

Of 20 northern pike used in the experiment, five were fitted with harness-cadmium plate units, five were fitted with harness-gold plate

Table 1. Dimensions of the gastric battery components.

| Dimension | Component | | |
|---|---|---|---|
| | Gold plate | Cadmium plate | Spacer |
| Length | 1.13 inches | 1.25 inches | --* |
| Width | 0.45 inches | 0.40 inches | 0.06 inches |
| Thickness | 0.01 inches | 0.01 inches | 0.006 inches |

* Length of spacer dependent upon tightness of wrap

units, and five were fitted with harness-battery (cadmium-gold) units. Each battery had a 680-ohm resistor connected across the poles to simulate the anticipated current drain of the ultrasonic transmitter. The remaining five northern pike served as controls and were not fitted with harnesses or other objects though in all other ways they were treated in the same manner as the experimental fish.

For 51 days the 20 northern pike were held in concrete and glass tanks of approximately 175 gallon capacity. The tanks contained creek chubs, Semotilus atromaculatus (Mitchill), which were replaced as the northern pike ingested them. The harness-plate units and the harness-battery units apparently did not affect the feeding activity of the fish as the mean rate of feeding was the same for both control and experimental groups. Each group consumed about one creek chub per northern pike each five days. No evidence of metal toxicity was recorded for the fish.

With completion of the 51-day feeding study, four of the experimental fish fitted with harness-battery units were used in an experiment to yield further information on battery longevity, and on tolerance of the fish for the harness-battery unit. These experimental fish were placed in a 0.1-acre pond containing suitable forage. Three of the northern pike were subsequently recovered. The first, removed from the pond 87 days after it had been fitted with the harness-battery unit, was in poor physical condition probably resulting from an improper fit of the harness. The second and third northern pike, recovered 164 days and the third 226 days after insertion of the harness-battery unit, were in good physical condition although the harnesses had caused some wearing away of tissue in the isthmus regions.

Each battery was visually examined after removal from the fish and no erosion of the plates was evident. The batteries removed from the second and third northern pike were placed in 0.5 percent hydrochloric acid and voltage was measured with a vacuum-tube voltmeter. These batteries which had 680-ohm resistors connected across the plates produced as much power (about 0.1 milliwatts) as they had prior to insertion into the fish.

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## Literature Cited

Barrington, E. J. W. 1957. The alimentary canal and digestion, p. 109-161. In Margaret E. Brown (ed.) The Physiology of Fishes. Academic Press Inc. New York.

Johnson, James H. 1957. Sonic tracking of adult salmon at Bonneville Dam, 1957. U. S. Fish and Wild. Serv., Fish. Bull. 60: 471-485.

Kendle, Earl R. and Larry A. Morris. 1965. A device for holding objects in the stomachs of fish. Trans. Amer. Fish. Soc. 94: 193-194.

Novotny, J. and G. F. Esterberg. 1962. A 132 kilocycle sonic fish tag. Progr. Fish Cult. 24: 139-141.

Trefethen, Parker S. 1956. Sonic equipment for tracking individual fish. U. S. Fish and Wild. Serv., Spec. Sci. Rept. Fish. No. 179, 11 p.

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