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ULTRASONIC MONITORING OF BLUEFIN TUNA IMPOUNDED IN ST. MARGARET'S BAY

by

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SUMMARY

Tuna, unlike most fishes, can maintain a body temperature considerably higher than their surroundings. The impoundment of tuna within St. Margaret's Bay enabled the study of these animals within a relatively confined area and where factors such as feeding could be controlled and continuously observed. Research carried out in 1977 represented a continuation of work initiated in 1975 and 1976. By means of ultrasonic apparatus, the stomach temperature, ambient water temperature, and swimming depth of appropriately tagged bluefin were monitored for variable periods of time. The data were recorded on both analog and digital recorders.

RESUME

Les thonidés, contrairement à la plupart des poissons, sont capables de conserver une température considérablement plus élevée que celle de leur milieu. Les thonidés confinés dans la Baie de Sainte-Marguerite ont permis l'étude de l'espèce dans un espace relativement réduit, où il était possible de contrôler et observer de façon suivie des facteurs tels que l'alimentation. La recherche effectuée en 1977 est un prolongement du travail commencé en 1975 et 1976. Les appareils à ultra-sons ont permis de suivre de près, pendant des périodes d'une durée variable, la température stomacale, la température ambiante de l'eau et la profondeur à laquelle nageaient des thons rouges porteurs de marques spéciales. Les données ont été relevées sur enregistreurs analogiques et numériques.

RESUMEN

Los túnidos, contrariamente a otros peces, pueden mantener la temperatura del cuerpo bastante más alta que la temperatura ambiente. La estabulación de túnidos en la Bahía de St. Margaret ha permitido su estudio dentro de una zona relativamente limitada, y donde factores tales como la alimentación pueden ser controlados y observados en forma constante. La investigación realizada en 1977 fue una continuación de la iniciada en 1975 y 1976. Por medio de aparatos ultrasónicos pudo comprobarse, durante periodos de tiempo variables, la temperatura estomacal, la temperatura ambiente del agua, y la profundidad a la que nadaban los peces marcados. Los datos se registraron en aparatos analógicos y numéricos.

INTRODUCTION

Tuna, unlike most other fishes, can maintain a body temperature considerably higher than their surroundings (Carey and Teal, 1969). How and why this is done is of the greatest interest to physiologists. The impoundment of tuna within St. Margaret's Bay enabled the study of these animals within a relatively confined area and where factors such as feeding could be controlled and continuously observed. The current experiments represent a continuation of work initiated in 1975 and 1976 and an extension of the earlier telemetry experiments of Carey and Lawson (1973) in which temperature transmitters were forced into the stomach of temporarily restrained bluefin which were then released and followed by means of directional hydrophones.

In 1975, one of the authors (Butler) successfully introduced a temperature transmitter into the stomach of an impounded bluefin without running the risk associated with restraining such a large animal; bluefin are particularly vulnerable to such handling in the early part of the season. The procedure simply involved forcing a cigar-sized transmitter into the abdominal cavity of a food fish such as mackerel, or alternatively the mackerel was cut open, the transmitter placed within the abdominal cavity, and the incision sewn up. The bait and concealed transmitter were then attached to a string line, suspended in the water and invariably ingested by a feeding bluefin. At the time the bait was engulfed an identifier tag was speared into the animal's flank.

In 1976 the procedure was "refined". The externally implanted identifier tag was replaced by another ultrasonic package containing both a temperature and pressure transmitter to record ambient water temperature and depth respectively. This information was of particular interest because of the rapidly changing temperature profile within the bay and the bluefin's response to these changes. The only requirements for placing all three transmitters in and on the same bluefin were anticipation, speed, and accuracy with a harpoon.

In 1977 the techniques for the collection of data were rationalized and automated by personnel of the Underwater Telemetry Laboratory at the University of New Brunswick.

The recording of data continued until early November, at which time the experimental animals (the final batch within St. Margaret's Bay) were killed in preparation for their export to Japan.

EQUIPMENT

1. Transmitters

The transmitter signal was pulsed with the rate of repetition of pulses proportional (in the range of 1 to 3 per second) to the parameter (temperature or pressure) of interest. The circuit for the pressure-sensing transmitters was as given by Pincock and Luke (1975) while the temperature transmitters used the same scheme with a thermolinear element (Yellow Springs, Inc.) as the sensor. Distinguishing between the various transmitters which might be attached to the fish was made possible by assigning a different transmission frequency to each. Typical frequencies for a three transmitter system were 42, 60, and 75 kHz; pulse lengths were about 10 msec and output level about 155dB re 1uPa at 1 metre.

2. Hydrophone and Receivers

In order to achieve simultaneous monitoring of all sensors on fish, a separate receiver was used for each transmitter. The two principal requirements of the receivers were:

(a) that they were sufficiently selective to detect only the tuned signal

(b) that they produced a logic pulse on reception of a valid transmitter signal

We used two CR40 receivers (Communication Associates Inc.) and a locally developed receiver (Pincock et al., 1974). All three receivers required a signal to noise ratio of approximately 10dB for reliable detection.

A single omnidirectional hydrophone (based on a 1/2" x 1/2" PZT-5 cylinder) was used. This hydrophone was placed on the bottom as near as possible to the tuna impoundment. As this required several hundred metres of cable to reach the shore-based receiving equipment, a preamplifier with a gain of 500 was incorporated into the hydrophone. This reduced the effects of interference in the long cable.

3. Decoding

Two types of decoder were used:

(a) a digital decoder which measured the interval between the received pulses and passed the information, along with the time of day and receiver identifier, to a digital printer;

(b) an analog decoder which produced a voltage proportional to the input pulse repetition rate. This voltage was recorded on a strip chart recorder.

Originally it was anticipated that only two transmitters would be used and a two channel digital decoder was constructed. Subsequently when a third channel was required, it proved more convenient to add an analog decoder. Because of the usefulness of the analog display for observing trends during the experiment, analog decoders were later implemented for all three transmitters with the digital decoder operating in parallel for two of them.

A brief description of each type of decoder is given below:

(i) Digital Decoder

Figure 1 shows the organization of the decoder. A decoding sequence was triggered by INITIATE from the clock. The rate of occurrence of these pulses was switch selectable (10 sec, 30 sec, 1 min, or 2 min). Initially, Receiver 1 was selected and on the receipt of the first receiver pulse, the count was started counting at a rate of 1 kHz. The next receiver pulse caused the counter to be stopped. The counter thus contained the pulse period of Receiver 1 in milliseconds. This information, with the time of day and a receiver identification, was printed; Receiver 2 selected and the process repeated. The counter was then cleared and the system was idle, awaiting another INITIATE pulse.

(ii) Analog Decoder

The analog decoder organization is shown in Figure 2. The purpose of the monostable was to standardize the length of received pulses so that the results obtained were independent of the receiver used.

PRELIMINARY RESULTS

The stomach temperature of an unfed bluefin slowly fluctuated, but remained in excess of 20°C. At the time of feeding, a three phase sequence was initiated:

(1) a marked temperature drop;

(2) a continuing but gradual decline following satiation;

(3) a gradual warming to previously high levels over a period of approximately 20 hours.

These findings are corroborated by Stevens, Kanwisher, and Carey (SCRS/77/99), who in addition discuss the possible physiological basis for these temperature gradients.

It is interesting to note that the period of gradual warming (Phase 3) approximated the time to completely digest a meal, as reported by Butler and Mason (SCRS/77/93). A single daily feeding to satiation may involve up to 65 lb (30 kg) of food per bluefin per day.

The ability to maintain an elevated body temperature is obviously finite. On the basis of the author's (Butler) data for 1976, impounded bluefin died at an external water temperature of 6-7°C. This was higher than expected; wild fish have been reliably reported in waters below 5°C, for instance off Newfoundland in the late fall. Presumably the enforced confinement of the animals for the 2- to 3-month feeding season, and the unnatural feeding regimes, had impaired their ability to acclimate. At the time of death (hypothermia), the bluefin were attempting to maintain a temperature differential of approximately 16°C between stomach and ambient water temperature, and an even higher differential if certain muscle masses are considered.

The degree to which the bluefin can utilize their impoundment environment appeared to be strictly regulated by the water temperature (profile) which can change very rapidly in St. Margaret's Bay, particularly in the fall. The bluefin understandably varied their depth considerably in isothermal water but tended to remain in or above a summer thermocline. In the fall, however, the temperature gradient within a thermocline was less attractive and the bluefin generally remained above it. The occasional temperature inversion at the end of the bluefin season found the tuna restricted to the warmest subsurface water layer which was often of little vertical extent. One practical conclusion might be that an optimum impoundment population of bluefin is not simply a function of the impoundment dimensions and the number of fish, but must take into consideration the changing temperature regime.

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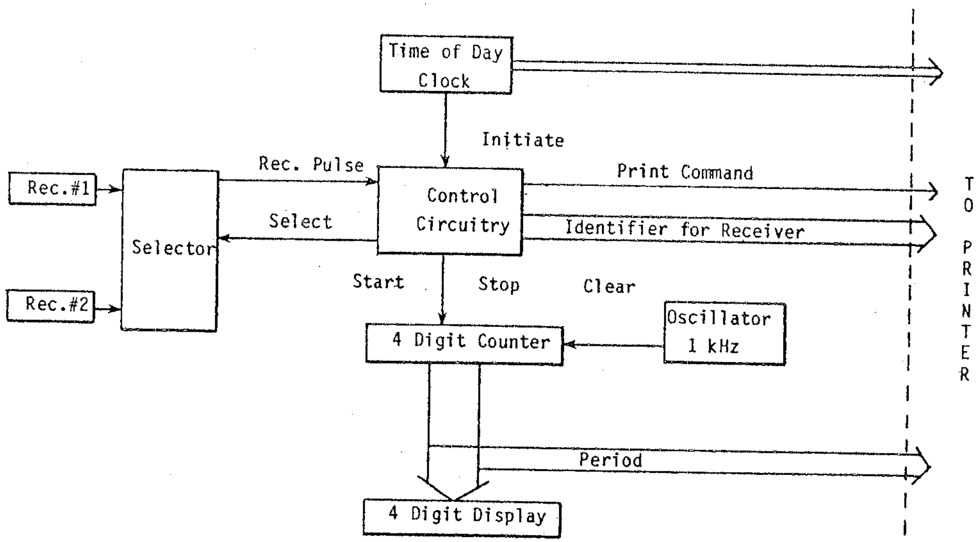

Figure 1: Digital Decoder Organization

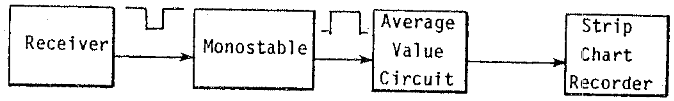

Figure 2: The Analog Decoding System Used