VIII. DEVELOPMENT OF A MICRODATA TAG FOR STUDY OF FREE RANGING MARINE ANIMALS

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Abstract

We developed a microdata logger to obtain information on behavior, ecology and physiology of free-ranging maeine animals. Our first effort emphasized miniaturization of the data logger to broaden the range of selection of trarget species. The size of the newly developed data tag was 19.0 mm in diameter and 75 mm in length record 512,000 bits of data in totol within 12 channels with 12 bits resolution (1/4,000 resolution). We successfully obtained data on swimming depth, water temperature, core body temperature, swim velocity, heart rate and other processes from marine mammals, diving birds, reptiles and fishes.

Introduction

Despite modern technological achievement, the underwater world still remains remote with regard to free-ranging marine animals owing to difficulty in access to animals. In this context, studies on behavior, ecology and physiology of the animals under natural conditions are strongly restricted owing to limited techniques available to obtain information from the animlas by means of direct observation and measurement.

To obtain such information, a miniaturized mechanical Time Depth Recorder (TDR, 25 mm in diameter, 85 mm in length) was developed (Naito *et al.*, 1990); its miniaturization as an analogue type recorder was lamost at its limit. However, much more downsizing could be expected by adoption of a digital data recording system because of recent advances in the technology of microelectronic devices, which remarkably increase the utility of the data recorder. The size range of the study species can be broadened from marine mammals to fishes and other animals. In addition, a smaller instrument causes less pain and has less effects on animal behavior (Wilson *et al.*, 1986; Watanuki *et al.*, 1992). Not only from the point of view of downsizing but also of the type of collected data, a microelectronic digital system is albe to collect simultaneously a greater variety of data with higher resolution.

Our purpose was to develop a miniaturized data logger and use it as an ordinary animal tag, while keeping high performance in acquiring amount, quality and types of data. The final objectives of this study are to contribute to behavioral, ecological and physiological studies on a marine animals by developing new electronic devices which lead to a comprehensive understanding of how the animal lives and maintains its physiological and ecological balance in its interaction with the biological, chemical and physical environment over an extended period.

Materials and Methods

Several functional components of the data tag, such as size and form, memory size, data resolution, and number of data channels are limiting to its utility. Our first effort was mainly focused on building a smaller sized data tag while maintaining a certain level of tag performance. Size ot the tag is mainly determined by the size of the circuit board, how compactly the part (memory chips, AD converter, MPU, etc.) are mounted, and how finely the circuits are printed. Thus the parts are carfully selected with the aim of minimizing the board size.

The microdata logger is composed of a housing, battery, sensors and logger. As housing we selected an aluminum tubular case because of its light weight and lower cost. The housing is 19.00 mm in diameter and 75 mm in length. Total weight, including battery and logger, is 30 g in air and 10 g in freshwater. Maximum strength of the housing is adequate for a depth of 500 m. The aluminum housing is coated with black alumite to prevent oxidation. We selected 5 CR 1616 batteries as a unit to obtain the 15V. The logger is composed of two boards: an analog board connected to the sensors and a memory board on which memory chip, CPU and quartz for the clock are mounted. We selected the 8 bits flush memory chip (INTEL-28F0085A) which can sustain memory even after battery exhaustion. We used MAXIM-MAX 168 and MITSUBISHI-M37476E8-FP for the AD converter and the MPU respectively. These are mounted on the circuit board. As sensors, FUJIKURA-FPB-82A, NIKKISO-YSI-ITP 014-21 are used for measuring pressure and temperature.

Results

The first field experiment was conducted using the new data tag on Adélie penguin at Davis Station (Australia), Antarctica, in 1992/1993 to measure diving behavior (dive depth, dive duration, etc.). We used the data tags equipped with only pressure sensor. Although we encountered several problems, the basic tag performance, in size, memory capacity, resolution, and housing was satisfactory for the study.

The second experiment was conducted on the Japanese cormorant at Teuri Island, Hokkaido, in June, 1993, to study diving in relation to foraging and breeding success. Recovery rate of the data tag was not so high as for penguins. Four tags out of 6 were not recovered while 15 from 18 were recovered from the Adélie penguins. This low recovery rate resulted from failure to recapure the birds. We also used the data tags on king cormorants at Macquarie Island, Australia in the southern ocean in 1993/1994 summer to conduct the same type of study as was done on the Japanese conrmorant. In this study, we measured stomach temperature in order to measure feeding rate of the bird during diving. Stomach temperature decreases when cold bait is swallowed by the bird, and temperature

increases according to the amount of food taken. This may indicate the timing and amount of food taken during diving. In order to test this principle, the data tags were fed to the birds and entered their stomach. They were recovered when the bird vomits both bait and data tag at the nest to feed the chicks. The data satisfactorily indicated a clear drop in stomach temperature. We also used the dat tag as a conductivity recorder to measure when the birds were sitting on the sea surface or flying. In this experiments we used the dat tag as a saltwater
on-off switch and obtained reliable data.

To study the free-ranging fish behavior, we attached 19 data tags on the flounders and released them at 15 km off the Niigata coast in Japan Sea during 1993 and 1994. Of 19 released fish, 6 taged fish were successfully recaptured between 9 and 14 days after release by set nets and data tags were returned to us. One tag was malfunctioned. However we could obtain swim depth and water temperature data from 5 fish.

We also used the data tags to measure diving behavior of free-ranging porpoise. For this purpose we developed a new release system based on the prototype release system earlier developed for the loggerhead sea turtle. It includes a float, time-scheduled releasing cutter and the data logger, and is able to work even at a depth of 500 m. The system was deployed on the back of harbor porpoise which was caught accidentally by set net the Usujiri coast, Hokkaido. The porpoises were released on 2 and 25 May, 1994. One was recaptured 2 days afterward, and the system was retrieved from this porpoise before the releaser worked. The other was picked up 124 days later by local people. Only two and four days of water temperature and dive depth data were initially obtained from the free-ranging cetaceans.

Discussion

In this study, we developed a 12 bits data tag to obtain high resolution data. However, because of inadequate accurracy of sennsors, the data tag dose not assure absolute data accuracy. Particularly, depth accuracy is difficult to obtain. The pressure sensor we used include errors caused by temperature effect (2.5%, 5°C-35°C), off-set drift (2.5%, 5°C-35°C), nonlineality (0.5% for full scale) and hysteresis (0.5%). Taking these effects into account, we examined the logger in a pressure tank and estimated its absolute accuracy as less than 3-5%. Although we adopted 0 m adjust program in each dive to avoid drift effect and although animals might not experience a large temperature change, it was still enough to use an 8 bits AD converter to obtain 3% accuracy. However, in this study we expected to obtain relative accuracy as well as absolute accuracy. For measuring animal behavior, it is also important to measure analogous change in fine-scale, even if absolute measurement is difficult. A 12 bits AD converter is able to give us fine scale analogous data within 10 cm accuracy in relative depthy. High resolution in relative depth change will give some kind of noise in time serial data. We examined this under natural wave conditions. We could measure the wave effect on data. In our data obtained from the flounder showed such noise when fish entered water shallower than 10 m. In deeper water the wave is smoothed and no noise was observed. The tide will affect data as well. However, the effect of relative change of depth on animal behavior, depth change occurs in time scale shorter than the tidal scale (0.0093 cm/sec for a 2 m tide). Thus, it seemed to be negligible in measuring such relative change of depth. For temperature, the sensor we used has $\pm$ 0.1°C accuracy. To ensure $\pm$ 0.1°C of actual accuracy, the minimum required resolutionn is 10 bits against 720 span for -22°C-50°C range. Thus, so far as temperature $\pm$ 0.1°C accuracy was assured.

We developed the microdata logger to use as an archiving data tag and tested it in a variety of target animals from marine mammals to fish. The experiments were successfully conducted except for initial unecpected errors of both hardware and software. However, once these problems were solved, the tags showed high reliability as instruments for research.

IX. FISHWAYS FOR UPSTREAM DIADROMOUS MIGRANTS

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Abstract

This paper presents a short review of some recent advances in fishway technology such as new types of fishways and new data on velocities in fishways and on fish swimming ability. It also includes new concepts such as maintaining a fishway's effectiveness in high water stages and the need to offer equal opportunity for successful migration to all diadromous migrants.

1. Evolution of streaming-type fishways

Types of fishways

Fishways can be broadly classified into three types:
pool-type, streaming-type and operation-type. Pool-type fishways consist of a series of pools separated by baffles, such as
pool-weir fishway and vertical-slot fishway Streaming-type fishways do not have baffles and pools, even though some have vanes such as Denil fishway, and have continuous flow from top to bottom in the unit channel. The operation-type fishway, such as fish locks and lifts, cannot fulfill its function without some operation.