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A new technique for monitoring grazing behavior of Hawksbill turtles (*Eretmochelys imbricata*) using acceleration data loggers

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ABSTRACT
Grazing behavior of sea turtles is important to understand their behavioral ecology. However, there is a shortage of effective techniques available for monitoring the grazing behavior accurately over a long period. In this study, the grazing behavior of hawksbill turtles (*Eretmochelys imbricata)* was monitored with acceleration data loggers which recorded depth, temperature, and accelerations in two axes. A Juvenile hawksbill turtle was attached with two acceleration data loggers on both head and carapace. During the experiment, we recorded the behavior of turtles on the underwater digital video camera. Their behaviors were distinguished into four patterns through the acceleration profiles and the underwater observation as follows; resting, swimming, grazing and breathing. The new technique can clarify when and where turtles graze quantitatively as well as time allocation of their behavior patterns.

KEYWORDS: hawksbill turtle, acceleration data logger, grazing behavior

INTRODUCTION

Feeding ecology is very important to understand the biology and ecology of animals. To date a great number of scientists have researched grazing or forage behavior of animals by observation using camera, video camera and human eye. Observations are the normal method to research the grazing behavior, but can not be conducted in the place where scientists unable to approach. As for marine animals behavioral research, direct observations are not feasible in the field because most foraging takes place below the sea surface or at great distance from land. Attachment of data-recording devices to animals can greatly facilitate the collection of meaningful data (Wilson et al., 1986). During the last decade, development of devices has provided more data in detail about the behavioral ecology and physiology. Using the acceleration data loggers, Yoda et al. (2001) developed a new technique for monitoring the behavior of free-ranging penguins. They showed that an acceleration profile could be used for detecting fine-scale movements. Acceleration data logger also shows the body angle from the low frequency component of acceleration profile and dynamic movement such as tail beat of salmons (Tanaka et al., 2001), beat stroke of sea birds (Watanuki et al., 2002), flipper stroke of Weddell seals (Sato et al., 2003) from the high frequency component.

Sea turtles are progressive animals for biotelemetry and have been equipped with various devices such as satellite transmitters and data loggers which revealed their migration and diving behavior in the open water. To date, however, there is a shortage of effective techniques available for monitoring foraging and grazing behavior of sea turtles accurately for long periods. Feeding ecology of sea turtles differs between species, populations and life stages (Mortimer, 1995). Hawksbill turtles forage some kinds of sponges mainly, although the species of sponges differ a little between their living areas (Meylan, 1984). It was also reported they fed on tunicates, bryozoans, mollusks and algae which it scraped off the reef faces (Carr and Stancyk, 1975).

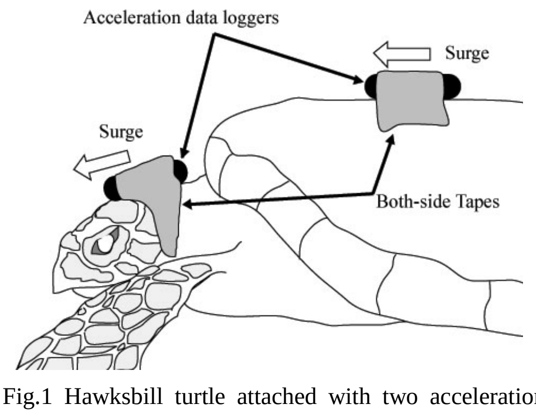

Fig.1 Hawksbill turtle attached with two acceleration data loggers. Arrows represent each monitoring direction.

In this study, we monitored the grazing behavior of

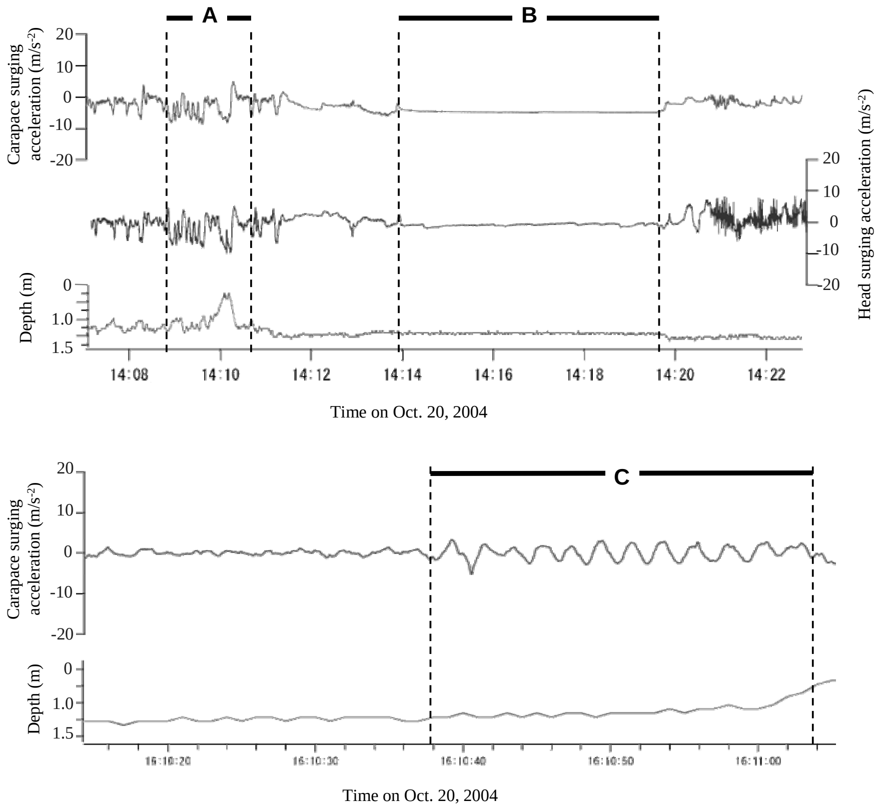

Fig.2 Profiles of carapace surging acceleration, head surging acceleration and depth during (A) the breathing behavior, (B) the resting behavior and (C) the swimming behavior. In lower graph, the carapace surging acceleration profile was filtered out to extract the acceleration fluctuation caused by swimming using 0.3 Hz low pass filter.

hawksbill turtles (*Eretmochelys imbricata)* with two acceleration data loggers in the breeding tank.

MATERIALS AND METHODS

The experiment was conducted in the breeding tank (H × L × W=1.2m × 12m × 10m) where a turtle can swim freely at Yaeyama station, National Center for Stock Enhancement, Japan. A hut was arranged in the corner of the tank for resting. Feeding area was also arranged in the edge of the tank, in which some green algae, anchovies and squids were set as a feed sample. All feed samples were fastened on the concrete block with a plastic net, and set on the bottom of the tank. The green algae were selected because a major part of the stomach contents of some juvenile hawksbill turtles were this species as a result from autopsy. The anchovy and the squid are the feed of the breeding turtles in this station.

Four juvenile hawksbill turtles were attached with two acceleration data loggers (UME190-D2GT: 15mm diameter, 48mm length, 19g in air; Little Leonardo Corp., Tokyo, Japan) on both head and carapace using both-sides tape (Fig.1). The acceleration data logger can record depth at 1 s intervals, and surging acceleration (head and flipper movements and body angle) at 1/16 s intervals. The measuring range of the accelerometer is ± 39.2ms^{-2} with a resolution of 0.0096ms^{-2}.

After handling, the turtles were released in the tank and left for a while to recover from handling for attachment of data loggers. Their foraging behavior recovered within a few hours. During the experiment, we recorded the behavior of turtles on the underwater digital video camera. The acceleration profiles were compared by visual analysis of the videotapes.

The acceleration sensor along the longitudinal body axis of the head and the carapace measured surging accelerations, which are affected by both the forward movements of the animal and gravity (Yoda et al., 2001, Tanaka et al., 2001, Sato et al., 2003). High frequency variations in the head surging acceleration caused by the grazing behavior were filtered out using 0.8 Hz low pass filter (IFDL Version 3.1; WaveMatrics, Inc., USA). Also, in the carapace acceleration caused by the flipper stroke, they were filtered out using 0.3 Hz low pass filter.

RESULTS

The behaviors of four juvenile hawksbill turtles in the breeding tank were distinguished into four patterns through the acceleration profiles and the underwater observation as follows; resting, breathing, swimming and grazing.

The resting behavior was defined as the behavior in which turtles were still on the bottom of the tank. Acceleration profiles during the resting behavior have no shift and no fluctuation (Fig.2). The breathing behavior was defined as a series of behaviors which were ascending from the bottom, floating on the surface and a descending movement from the surface at breathing. When the turtles breathed, up-down variations of depth profile show obviously the breathing behavior (Fig.2).

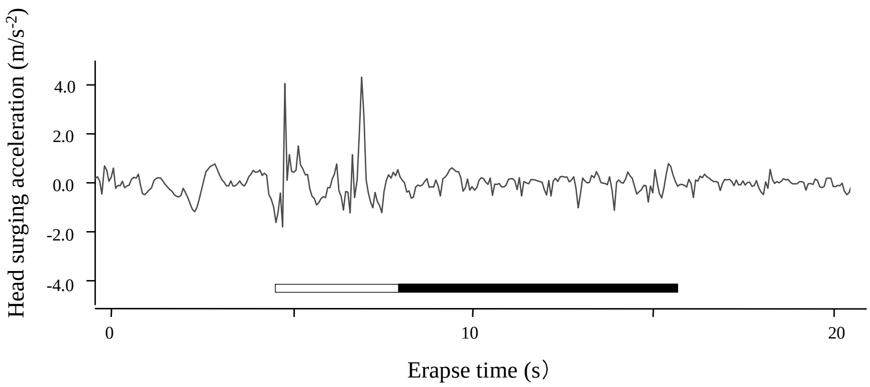

Fig.3 Typical profiles of head surging acceleration. This acceleration profile was filtered out to extract the acceleration fluctuation caused by grazing using 0.8 Hz low pass filter. White and black horizontal bars show the period of bite and mastication phases in the grazing behavior.

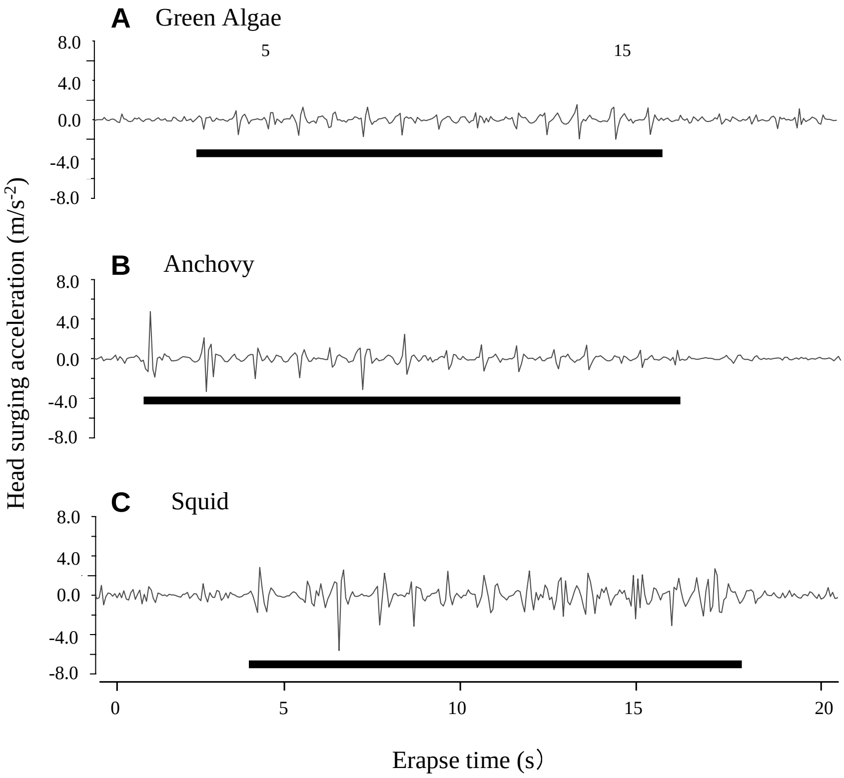

Fig.4 Head surging acceleration profiles during the grazing behavior for (A) Green Algae, (B) Anchovy and (C) Squid. These acceleration profiles were filtered out to extract the acceleration fluctuation caused by grazing using 0.8 Hz low pass filter. Black horizontal bars show the period of the grazing behavior

The swimming behavior is defined as the behavior during the time when there were fluctuations at a constant frequency in the carapace acceleration profiles caused by the flipper stroke. Therefore these fluctuations were seen in the acceleration profile with the low frequency component removed from the original profile using the low pass filter (Fig.2). One cycle of these constant fluctuations showed one stroke of their flippers from the result of the video analysis.

In order to detect the grazing behavior of turtles, it was necessary to filter out the head acceleration profile as well as the swimming behavior. The grazing behavior was defined as the behavior during the time when the head acceleration had some fluctuations while the carapace acceleration had little or no fluctuations. The acceleration profiles from this behavior have characteristic fluctuations and more than 0.8 Hz frequency (Fig.3&4). We monitored 111 grazing behaviors during the experiment. By the categories of food, there were 68, 10, 24 and 13 behaviors for the green algae, the anchovy, the squid and the others, respectively. According to the video analysis, the grazing behavior consisted of two phases, which were bite phase and mastication phase (Fig.3). In some wave fluctuations of the surging acceleration during the grazing period, these two phases were clearly identified by the magnitude and frequency. However, in many wave fluctuations, these two phases have ill-defined borders so that these phases were unable to be identified quantitatively. Fig.5 shows the differences of the head surging acceleration and the foraging period between three foods. There were significant differences in the degree of the head acceleration at peak amplitude (Kruskal – Wallis test, $P<0.01$) and in the duration of foraging behavior (Kruskal – Wallis test, $P<0.01$), although the multiple comparisons among these three feed samples did not present significant differences. However, the total data showed no relation between the degree of the head acceleration and the foraging periods.

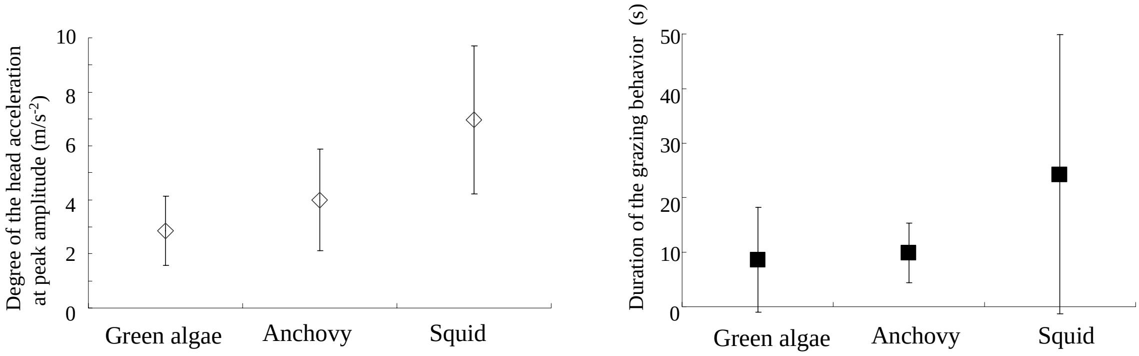

Fig.5. The differences of the head surging acceleration at peak amplitude (*left*) and the foraging period (*right*) during the grazing behavior for Green Algae, Anchovy and Squid. Mean values and standard deviations are indicated by rhomboid and square marks and vertical bars.

DISCUSSION

In this study, we set up three foods; green algae, anchovy and squid. The head accelerations characteristics during the grazing period were significantly different between foods. It was clear, however, there were large variations in the head acceleration characteristics of each food caused by the size and the shape (Fig.4). Additionally, ambiguity of borders between bite and mastication phases produces more difficulty in the identification of what juvenile hawksbill turtles feed on by the quantitative acceleration characteristics. More importantly, there are no frozen squid and anchovies as the prey of turtles in the natural habitat. Additionally there has been no report that wild hawksbill turtles graze on anchovy and squid. If hawksbill turtles would graze on them, in this study, the feed samples were fixed on the bottom of the tank so that we have to monitor the grazing behavior for the feed samples in swimming. Therefore, we can not regard these results of the acceleration analyses as the criteria for what the turtles feed on, although these seem to become the criteria of size, shape and hardness of prey. Anyway, these results merit the further study in natural environment.

Two acceleration data loggers provide the information of the behavior and attitude of juvenile hawksbill turtles, which let us know four behavior patterns, i.e. resting, breathing, swimming and grazing. These techniques enable us to clarify their behavior patterns and their time allocation spent for each pattern quantitatively in the natural habitat, and to be a powerful tool to understand the behavioral ecology of turtles.

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