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The Relationship between the Number of Breaths and Diving Profile of a Nesting Green Turtle, *Chelonia mydas*

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ABSTRACT

In this study, the relationship between dive duration, activity level during the dive and the number of breaths during post-dive surface duration of one free-ranging nesting green turtle, *Chelonia mydas,* was examined using two acceleration data loggers. Breathing was extracted from the static acceleration and depth data of the head-mounted data logger. The overall dynamic body acceleration (ODBA), which has been used as an index of activity levels per unit time of a dive, was calculated from tri-axis dynamic acceleration data of the carapace-attached data logger. The number of breaths during post-dive surface duration divided by ODBA significantly increased with longer dive duration. The number of breaths during post-dive surface duration divided by dive duration significantly increased with larger ODBA during a dive. The results suggest that the number of breaths was regulated by dive duration and activity level during a dive.

Key words: Diving physiology, respiratory behavior, overall dynamic body acceleration

INTRODUCTION

For air-breathing aquatic animals, breathing at the water surface is a limiting factor in all underwater activities such as foraging, resting, mating, and predator-avoidance. Therefore, it is essential from the ecological point of view to understand dive-induced breathing patterns in aquatic animals. In sea turtles, they breathe between dives multiple times, so the number of breaths is considered to be associated with previous dive condition. In fact, previous studies have investigated the relationship between the number of breaths and dive duration (Lutcavage and Lutz 1991), the difference of the number of breaths between active and resting dives (Lutz et al. 1989), and the relationship between the number of breaths and activity levels (Kawabata et al. 2010). However, these previous studies were conducted only for captive sea turtles, and for wild turtles only the relationship between post-dive surface duration, which was used as an alternative to breathing performance and dive performance, has been investigated (Okuyama et al. 2012). The objective of this study was to investigate how the number of breaths changes with activity levels and dive duration of a free-ranging nesting green turtle, *Chelonia mydas*. To achieve this objective, we measured breathing and activity levels of the turtle simultaneously, using two acceleration data loggers.

MATERIALS AND METHODS

Field work

Field work was conducted from July 20th to 29th in 2009 at Ishigaki Island, Japan. One nesting female green turtle was used in this experiment. Standard straight carapace length and body weight of the turtle were 100.9 cm and 130 kg, respectively. When the green turtle had completed nesting on Ibaruma beach, two acceleration data loggers were attached and the turtle released. One acceleration data logger (W1000-3MPD3GT; Little Leonardo Co., Tokyo, Japan) was affixed to the carapace using epoxy putty (Konishi Co., Ltd. Osaka, Japan) and two-component epoxy resin (ITW Industry Co., Ltd. Osaka, Japan) for measuring dive depth at 1 Hz and acceleration of the turtle at 8 Hz. The other logger (M190L-D2GT; Little Leonardo Co., Tokyo, Japan) was affixed to the head for detecting two-axis head accelerations at 32 Hz. We removed the data loggers when the turtle returned to nest later that season and had completed nesting.

Data analysis

Accumulated data in each logger were downloaded to a computer and analyzed by using IGOR Pro ver. 6.2 (WaveMatrics Inc., USA) and Ethographer v2.00 (Sakamoto et al. 2009). Acceleration sensors were calibrated to *g* by rotating devices through known angles in all three spatial planes. The periods when the turtle was on land were removed from the analysis. Dive was defined as the period when the depth was >1m for more than 1 minute. Recent studies have suggested that acceleration can serve as a proxy for the rate of energy expenditure in free-living animals (Wilson et al. 2006). This is because energy is required for mechanical work and activity can account for a large proportion of the variation in metabolic costs. In this study, we calculated overall dynamic body acceleration (ODBA, defined in Wilson et al. 2006) as an index of activity level during a dive. ODBA was calculated from the sum of dynamic acceleration extracted from 3-axis acceleration data. Breath events were extracted by detecting head angle, which was calculated from the static acceleration following the procedure of Okuyama et al. (2010). Briefly, static acceleration was extracted by using a low-path filter (IFDL; WaveMatrics), because static acceleration is represented as low frequency acceleration signal. We defined breathing behavior as occurring when the pitch was >35° and the water depth was <0.25 m. The number of breaths was then counted during post-dive surface duration of each dive.

Based on Okuyama et al. (2012), the number of breaths of the wild sea turtles seems to be regulated by dive duration, activity level per unit time of a dive (which is represented as mean ODBA) and water temperature. Because the water temperature did not vary during the recording period (See results), the number of breaths during post-dive surface duration is assumed to relate to both dive duration and mean ODBA during a dive in this study. To demonstrate more clearly the relationship between the number of breaths and dive duration in the absence of any effect of mean ODBA, we standardized the number of breaths by dividing it by mean ODBA. Also, for the relationship between the number of breaths and mean ODBA, we standardized the number of breaths by dividing it by dive duration.

RESULTS

Data for a total of 361 dives and 1,313 breaths were obtained from a free-ranging nesting female turtle for 76.8 hours, from 24th to 27th July, 2009. During the recording period, water temperature was 29.2 ± 0.5 ^{o}C, which was almost constant throughout. The minimum number of breaths was one and maximum was 13 during a single dive cycle. According to the regression analysis, the number of breaths significantly increased with longer dive duration (Fig. 1; R^2 = 0.41, *ANOVA*, $F_{1,359}$ = 246.3, P < 0.0001) and larger mean ODBA (Fig. 2; R^2=0.08, *ANOVA*, $F_{1,359}$ = 30.1, P < 0.0001).

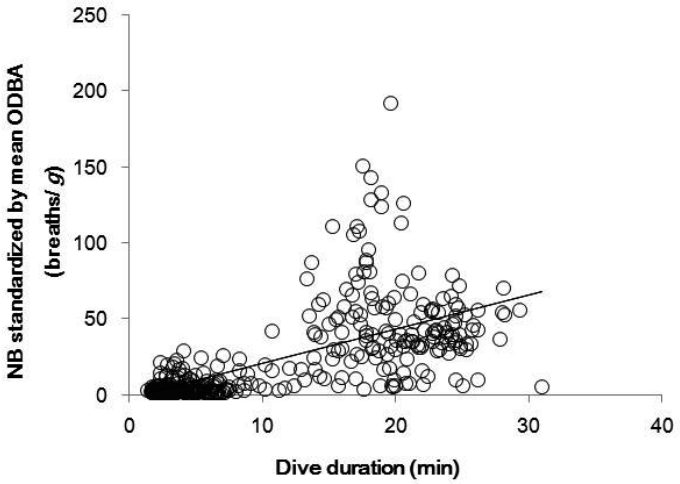

Fig. 1. Relationship between the number of breaths, standardized by mean ODBA, and dive duration. Regression line is represented as y = 2.25 x -1.87.

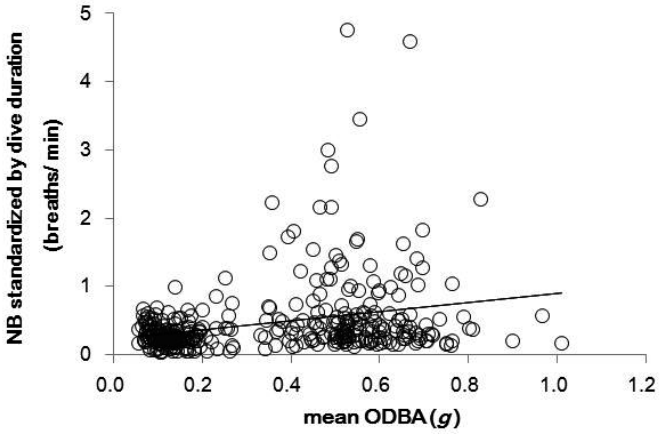

Fig. 2. Relationship between the number of breaths, standardized by dive duration and mean ODBA. Regression line is represented as $y = 0.66\,x + 0.23$.

DISCUSSION

Our results indicate that the number of breaths during post-dive surface duration was regulated by both dive duration and activity level. Post-dive surface duration was known to be regulated by both dive duration and activity level in sea turtles (Okuyama et al. 2012). Therefore, post-dive surface duration could be proportional to the number of breaths, that is, time for respiratory behavior. Larger number of breaths after a longer dive and with a larger activity level was consistent with the previous study conducted in the experimental tank (Kawabata et al. 2010), implying that these relationships did not change between the experimental tank and the wild. Therefore, green turtles seem to increase the number of breaths when they dive for long time and with larger activity level.

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