View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Kyoto University Research Information Repository

KURENAI

Kyoto University Research Information Repository

KYOTO UNIVERSITY

Title	<Session 5: Wildlife Tracking I>Simultaneous measurements of breaths and energy expenditure reveal the dive tactics of sea turtles
Author(s)	Okuyama, J; Tabata, R; Arai, N; Kobayashi, M; Kagawa, S
Citation	20th Symposium of the International Society on Biotelemetry Proceedings (2014): 69-71
Issue Date	2014-05
URL	http://hdl.handle.net/2433/187835
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

Kyoto University

Session 5

Wildlife Tracking I

Simultaneous measurements of breaths and energy expenditure reveal the dive tactics of sea turtles

Okuyama J[1], Tabata R[2], Arai N[1], Kobayashi M[3], Kagawa S[4]

[1] Field Science Education and Research Center, Kyoto University, Japan

[2] Graduate School of Informatics, Kyoto University, Japan

[3] Research Center for Subtropical Fisheries, Seikai National Fisheries Research Institute, Fisheries Research Agency, Japan

[4] Nature and Science Programs, NHK Enterprises, Inc., Japan

Abstract

Air-breathing divers are assumed to have evolved to apportion their time between surface and underwater periods to maximize the benefit gained from diving activities. However, whether they change their time allocation depending on the aim of the dive is still unknown. This may be particularly crucial for 'surfacers' because they dive for various purposes in addition to foraging. In this study, we counted breath events at the surface and estimated oxygen consumption during resting, foraging, and other dives in 11 green turtles (*Chelonia mydas*) in the wild. Breath events were counted by a head-mounted acceleration logger or direct observation based on an animal-borne video logger, and oxygen consumption was estimated by measuring overall dynamic body acceleration. Our results indicate that green turtles maximized their submerged time, following this with 5–7 breaths to replenish oxygen for resting dives. However, they changed their dive tactic during foraging and other dives; they surfaced without depleting their oxygen content, followed by only a few breaths for effective foraging and locomotion. These dichotomous surfacing tactics would be the result of behavioral modifications by turtles depending on the aim of each dive.

Keywords: biologging, chelonia mydas, diving physiology, metabolism, respiratory

Introduction

For air-breathing divers, underwater activity is constrained by the available amount of oxygen stored in the body. Under such physiological constraints, they are assumed to have evolved to apportion their time between surface and underwater periods to maximize the benefit gained from activities such as feeding, predator avoidance, and mating [1]. Therefore, from an ecological point of view, it is essential to understand dive-induced respiratory patterns in air-breathing divers. To understand such diving strategies/tactics of air-breathing animals, it is essential to measure both the energy expenditure during a dive and subsequent respiratory performance at the surface.

Sea turtles are ectothermic marine animals and have well-adjusted physiological functions for prolonged dives (reviewed by [2, 3]). Briefly, they have a considerably slower metabolism than do diving mammals and birds, but it is affected by water temperature and activity level [4-6]. They begin a voluntary dive with a level of oxygen in their body that approaches saturation, and they complete it at a level approaching depletion [7-8]. Their highly elastic reinforced lungs and high lung oxygen diffusion capacity allow them to reduce the time spent at the surface [9-10].

In this study, we simultaneously counted breath events at the surface and estimated oxygen consumption during resting, foraging, and other dives in green turtles (*Chelonia mydas*) in the wild. The objectives of this study were to clarify how green turtles manage their energy expenditure during a dive and subsequent respiratory patterns based on the purpose of the dive (resting, foraging, and other) under natural conditions and to determine which dive tactics they employ.

Materials and Methods

Study area and experimental animals

This study was conducted around Iriomote Island, Okinawa, Japan (24°20'N, 123°50'E). We used 11 juvenile green turtles that were hand captured by a local fisherman with the permission of the Okinawa Prefecture (Permission No. 22-3, 23-2, 24-4).

Breath events were counted using a head-mounted acceleration logger or direct observation based on an animal-borne video logger, and oxygen consumption was estimated by measuring overall dynamic body acceleration (ODBA) and using equations developed by Enstipp et al. [11] and Halsey et al. [12] to convert ODBA to oxygen consumption.

Instruments

We used various types of data loggers. To monitor breathing behavior, we used a small acceleration data logger (M190L-D2GT, Little Leonardo Co., Tokyo, Japan) or a video data logger (GoPro HD ®, Woodman Labs, CA, USA) with a custom-made waterproof case (Logical Product Co., Fukuoka, Japan. To measure depth and ODBA, multi-sensor data loggers (W1000-3MPD3GT, Little Leonard Co or LP-KUBL1101, Logical Product Co). For the detail in experimental protocol, see Okuyama et al. [13]

Results

A total of 555 dive data sets (dive duration, ODBA, and NB) by 11 immature green turtles, were extracted. The NB was significantly different among resting dives (N = 177, mean ± S.D. = 5.9 ± 2.5), foraging dives (N = 113, 2.1 ± 1.6), and other dives (N = 394, 2.3 ± 2.2) (ANOVA, $F = 171.0$, $P < 0.001$). Video observation and depth profiles showed that during resting dives, individuals took breaths without continuing to swim, although they often rotated. During this rotating behavior, the turtles kept their heads down and appeared to be engaging in locating/searching behaviors for a resting place before surfacing. During foraging and other dives, meanwhile, the turtles took breaths while continuing to feed or swim.

As for oxygen consumption per dive (V_{O2}), values were estimated at 14.54 ± 3.70, 4.01 ± 2.31, and 5.10 ± 4.57 ml kg^{-1} using Halsey's equation during resting, foraging, and other dives, respectively. Using Enstipp's equation, these values were 6.34 ± 1.69, 1.56 ± 0.82, and 2.07 ± 1.91 ml kg^{-1}, respectively. There were significant differences in oxygen consumption per dive among the dives estimated by both Halsey's (ANOVA, $F = 34.8$, $P < 0.001$) and Enstipp's equations (ANOVA, $F = 38.4$, $P < 0.001$).

The LMM analysis revealed that NB increased significantly with larger energy expenditures as estimated by both Halsey's ($X^2 = 114.7$, $P < 0.0001$) and Enstipp's equations ($X^2 = 94.6$, $P < 0.0001$), but not with water temperature ($X^2 = 0.00$, $P = 1$, for Halsey's equation only). The activity state (i.e. resting, foraging, or other dive) also significantly affected NB using both Halsey's ($X^2 = 17.7$, $P < 0.001$) and Enstipp's equations ($X^2 = 13.8$, $P < 0.01$).

Discussion

Surfacers are expected to maximize the ratio of submerged to surface time during dives so as to minimize surface time [1]. In our study, green turtles also maximized the submerged time during resting dives. However, they changed their dive tactic during foraging and other dives; they surfaced without depleting their oxygen content for effective foraging and locomotion. These dichotomous dive tactics were apparently the result of behavioral modifications by turtles depending on the aim of each dive. The dichotomy in the respiratory patterns at the surface may allow researchers to estimate the activity state of sea turtles during boat-based and aerial surveys.

References

[1] Kramer DL. 1988 The behavioural ecology of air breathing by aquatic animals. Can. J. Zool. 66, 89-94.

[2] Lutcavage ME, Lutz PL. 1997 Diving physiology. In The biology of sea turtles (eds. P. L. Lutz, JA. Musick), pp. 277-296. Boca Raton: CRC Press.

[3] Williard AS. 2013 Physiology as Integrated Systems. In The biology of sea turtles III (eds. J. Wyneken, KJ. Lohmann, JA. Musick), pp. 1-30. Boca Raton: CRC Press.

[4] Lutz PL, Bergey A, Bergey M. 1989 Effects of temperature on gas exchange and acid-base balance in the sea turtle Caretta Caretta at rest and during routine activity. J. Exp. Biol. 144, 155-169.

[5] Southwood AL, Darveau CA, Jones DR. 2003 Metabolic and cardiovascular adjustments of juvenile green turtles to seasonal changes in temperature and photoperiod. J. Exp. Biol. 206, 4521-4531.

[6] Okuyama J, Kataoka K, Kobayashi M, Abe O, Yoseda K, Arai N. 2012 The regularity of dive performance in sea turtles: a new perspective from precise activity data. Anim. Behav. 84, 349-359.

[7] Lutz PL, Bentley TB. 1985 Respiratory physiology of diving in the sea turtle. Copeia 1985, 671-679.

[8] Lutcavage ME, Lutz PL, Baier H. 1987 Gas exchange in the loggerhead sea turtle Caretta caretta. J. Exp. Biol. 131, 365-372.

[9] Lutcavage ME, Lutz PL. 1991 Voluntary diving metabolism and ventilation in the loggerhead sea turtle. J. Exp. Mar. Biol. Ecol. 147, 287-296.

[10] Lutcavage ME, Lutz PL, Baier H. 1989 Respiratory mechanics of the loggerhead sea turtle, Caretta caretta. Resp. Physiol. 76, 13-24.

[11] Enstipp MR, Ciccione S, Gineste B, Milbergue M, Ballorain K, Ropert-Coudert Y, Kato A, Plot V, Georges JY. 2011 Energy expenditure of freely swimming adult green turtles (Chelonia mydas) and its link with body acceleration. J. Exp. Biol. 214, 4010-4020.

[12] Halsey LG, Jones TT, Jones DR, Liebsch N, Booth DT. 2011 Measuring energy expenditure in sub-adult and hatchling sea turtle via accelerometry. PLoS ONE 6, e22311.

[13] Okuyama J, Nakajima K, Noda T, Kimura S, Kamihata H, Kobayashi M, Arai N, Kagawa S, Kawabata Y, Yamada H. 2013 Ethogram of Immature Green Turtles: Behavioral Strategies for Somatic Growth in Large Marine Herbivores. PLoS ONE 8, e65783.

Acknowledgements

We would like to acknowledge A. Wada, K. Watajima, H. Kamihata, T. Noda, T. Koizumi, A. Nakabayashi, T. Hashiguchi, S. Kimura, T. Matsushita, D. Hongo and the staff of the Ishigaki Tropical Station, Seikai National Fisheries Research Institute for research assistance. This study was conducted with the permission of the Okinawa Prefecture (Permission No. 22-3, 23-2, 24-4) for conducting the experiment, and the experimental protocol was approved by Animal Research Committee of Kyoto University (No. 22-4, 24-4). This study was partly supported by Grant-in-Aid for JSPS Research Activity Start-up (J.O. No. 19880017), and Young Scientists B (J.O. No. 22710236).

Author's Address

Junichi Okuyama

Field Science Education and Research Center, Kyoto University, Japan

okuyama.junichi.e7@kyoto-u.ac.jp