# 三陸沿岸域に来遊するアカウミガメ *Caretta caretta* の潜水行動解析

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## I. はじめに

太平洋に生息するアカウミガメ(*Caretta caretta*)は主に日本列島南岸で孵化したのち、数千キロにも及ぶ回遊を行いながら成長し、採餌海域にたどりつく。のちに性成熟に達した成体は採餌海域と繁殖場の間を回遊する。近年、本種は著しい産卵数の減少が報告されており、生存を脅かす一因として漁具への混獲が指摘されている(Hatase et al. 2002)。適切な保護方法の確立には、本種の海中における詳細な行動の把握が必要である。一生の大半を海中で過ごす本種の行動研究は困難であったが、動物装着型記録計（データロガー）の発達にともない自然環境下における詳細な行動研究が可能となった。そこで本研究では、三陸沿岸域に来遊するアカウミガメにデータロガーを装着し、情報の少ない採餌期の潜水行動を三次元的に解析し、どのような潜水が移動行動に貢献しているのかを明らかにすることを目的とした。また、直線的な移動を行う際の遊泳方向の方位決定メカニズムを野外データより検討する事を目的とした。

## II. 方法

2006 年 8-10 月、岩手県大槌湾付近の定置網によって混獲されたアカウミガメ(*Caretta caretta*) にデータロガー(3MPD3GT、リトルレオナルド)を装着し、大槌湾中央部より放流した（図１）。本研究では自動切り離しシステム(Watanabe et al. 2004)を採用し、放流後 6-15 時間後に実験個体から自動的に切り離され海面に浮上したデータロガーを回収し、5 個体の潜水行動のデータを得た。データロガーは滞在深度、経験水温、遊泳速度、遊泳方向をそれぞれ 1 秒間隔で、前肢の動きと体の傾きをそれぞれ 1/32 秒間隔で記録した。実験個体の潜水行動は得られた深度データを用いて 6 個の潜水タイプに分類した（図２）。またJohnson & Tyack (2003)の計算法を用いて潜水行動の三次元的な軌跡を描いた。次にウミガメがどのようにして直線的な移動を行っているかを調べるため、直線的な移動が 30 分以上続いた期間を抜き出し、どのタイプの潜水が多く行われたかを検討した。直線移動期間に特に頻繁に行われていた 2 タイプの潜水に関して、遊泳方向の変化を１秒間隔で調べ遊泳方向の方位決定メカニズムについて検討した。

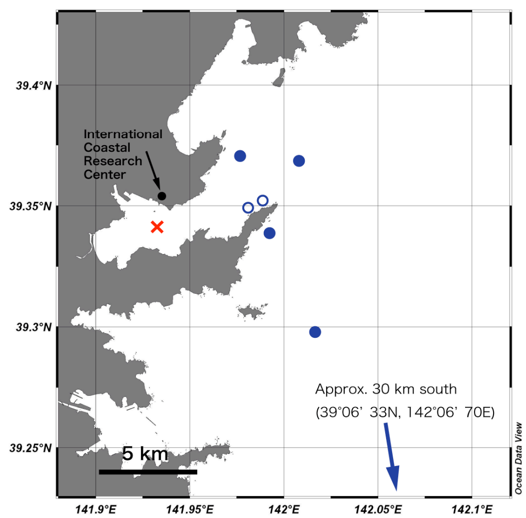


図1．調査地（岩手県三陸沿岸域）
X、●、○はそれぞれ実験個体の放流地点、データロガーの回収位置と大槌湾内の定置網の位置を示す。

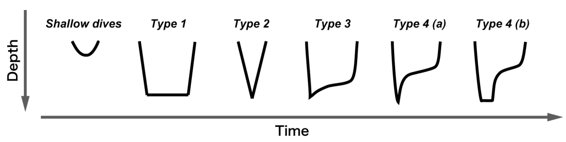


図2．アカウミガメの潜水タイプ

## III. 結果および考察

大槌湾中央部で放流された 5 個体は湾口または湾外へと遊泳した（図１）。全 66.5 時間中、合計 1220 回の潜水がみられた。ウミガメが直線的に移動したとき、Type-3 および浅い(Shallow)潜水が多くみられ(図３)、これらの潜水時間はそれぞれ全直線移動期間の 41%と 20%を占めた。このとき Type-3 潜水は間に数分間の水面滞在をはさみながら連続的に行われた(図３(A))。Type-3 潜水時ウミガメはある一定の方向に向かって遊泳を行っていた。しかし潜水開始時と終了時の遊泳方向の差 (図４①)と潜水時間の間および潜水深度との間に、共に有意な正の相関がみられた。これより潜水中に遊泳方向にずれが生じていることがわかった。また連続した２つの Type-3 潜水において (図３(A))、２つの潜水の潜水開始時の遊泳方向の差 (図４②) は、１つ目の潜水の潜水開始時と潜水終了時の遊泳方向の差 (図４①)より有意に小さかった。この連続した潜水の間（水面滞在時）に、ウミガメの遊泳方向は著しく変化した。このことからウミガメが水面滞在時に潜水中に生じた遊泳方向のずれを修正している可能性が示唆された。一方、同じく直線移動期間に多くみられた連続した浅い潜水時 (図３(B))、ウミガメはある一定の方向に向かって遊泳した。連続した浅い潜水期間の遊泳方向のばらつきは連続した Type-3 潜水間の水面滞在時よりも有意に小さかった。これらより、ウミガメは深い深度に滞在しているときよりも、水面滞在時や浅い深度に滞在しているときに、より確かに遊泳方向を認識していることができると考えられる。今まで数多くの操作実験によってウミガメは地球上に存在する地磁気を用いて定位する能力があることが証明されている (Lohmann & Lohmann 2006)。しかし、もし自然環境下におけるウミガメが地磁気を用いて定位しているとしたら、地磁気は水中にも存在しているので、Type-3 潜水の間の水面滞在時における方向探索行動とみられる著しい遊泳方向の変化が説明できない。よって本研究では、水面もしくは浅い潜水深度でより強く得られる情報がウミガメの遊泳方向の地磁気より強い決定要因になっている可能性を示唆した。

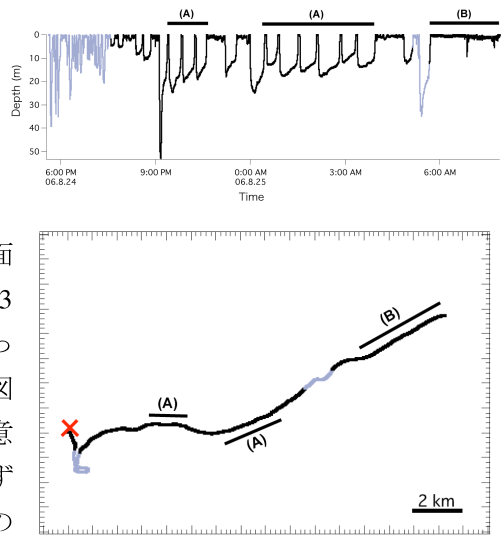


図３．ウミガメの潜水行動の一例
黒は直線移動期間、灰色はその他を示す
A)は Type-3 潜水、(B)は浅い 潜水をそれぞれ示す.
X は放流地点を示す
(上図) 時系列深度データ
(下図) 水平的な軌跡

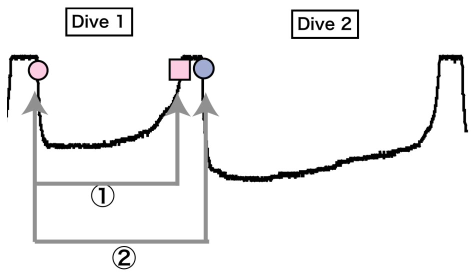


図４．連続した Type-3 潜水のイメージ図
○は潜水開始時、■は潜水終了時を示す。
①、②は遊泳方向の差を比較した組み合わせを示す。

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# Fine-scale diving behaviour of loggerhead turtles, *Caretta caretta*, migrating Sanriku coastal water

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Keywords: loggerhead turtle, diving behaviour, data logger, orientation

## I. Introduction

Pacific loggerhead turtles (*Caretta caretta*), once they hatched at southern coast of Japan, migrate over thousands kilometers to foraging grounds. Once they reached sexual maturity, they shuttle between foraging and breeding grounds. Recently, it has been reported that the number of nesting loggerhead turtles have been declined, and one of the major threats could be accidental catch by fishery gears (Hatase et al. 2002). It is urgently required to understand their underwater behaviour for proper conservation of this threatened species. Recent development in animal-borne recorder (data logger) threw a light on understanding of their diving behaviours. In this study, to understand fine-scale diving behaviours, data loggers were deployed on loggerhead turtles migrating to Sanriku coastal water. The objectives of this study are to find out any dives reflecting turtles' traveling behaviour, and to examine fine-scale orientation of turtles during travel under natural environment.

## II. Methods

During August to October 2006, data loggers (3MPD3GT, Little Leonardo, Tokyo) were attached to loggerhead turtles (*Caretta caretta*) accidentally caught by set nets around Otsuchi Bay, Iwate. Instrumented turtles were released from the center of the Otsuchi Bay (Fig.1). In this study, auto-releasing system (Watanabe et al. 2004) was used. By retrieving data loggers automatically released by turtles after 6 to 15 hours after the release, diving data of 5 turtles were obtained. Data loggers recorded depth, temperature, swim speed and heading at 1-s intervals, respectively, and flipper movements and body angles at every 1/32 s, respectively. Each dive was categorized into 6 dive types according to the shape of dive in the time-depth plot (Fig. 2). Applying calculation introduced in the study by Johnson & Tyack (2003), 3-dimentional traces of dives were reconstructed. To find out what dives reflected turtles' traveling behaviour, any period that turtles kept travel straightly for 30 min were examined. For dominant dive types during the straight travel period, headings during dives were analyzed at 1-s intervals to discuss possible orientation mechanism in turtles.

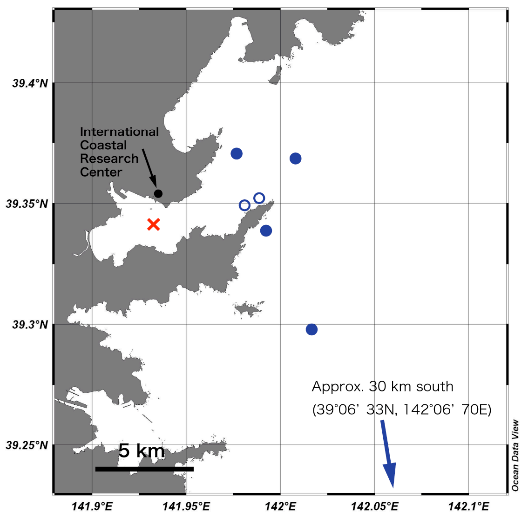


Fig.1. Map of study site at Sanriku coastal water, Iwate
Point of turtle release, locations of logger recoveries sited, and positions of set net in Otsuchi Bay were indicated as X, ●, and ○, respectively.

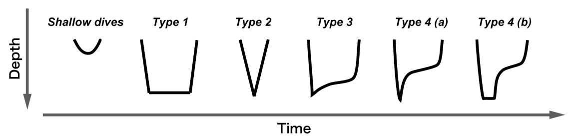


Fig.2 General shape of each dive type performed by loggerhead turtles

## III. Results and Discussion

Five turtles released at the center of Otsuchi Bay swam toward the mouth or outside of the Otsuchi Bay (Fig.1). In total, 1220 dives were recorded during 66.5 hours. During periods of straight travel, turtles performed many Type-3 and shallow dives (Fig.3), which accounted 41% and 20% of total straight travel duration. Many of Type-3 dives during straight travel periods were consecutive with a few minutes of surfacing periods in between 2 dives (Fig3 (A)). During Type-3 dives, turtles swam toward a certain direction. However, difference in heading direction between at the start of dive and the end of a Type-3 dive (Fig4.①) were significantly positively correlated with both dive duration, and maximum dive depth. It revealed that heading direction deviated during dives. For 2 consecutive Type-3 dives, differences in heading directions between at the start of 2 consecutive dives (Fig.4②) were significantly smaller than that between at the start and the end of a dive (Fig. 4①). During surface periods in between consecutive Type-3 dives, heading direction changes rapidly. Therefore, it was suggested that turtles corrected their heading direction at the surface. On the other hand, during consecutive shallow dives (Fig.3 (B)), which also frequently observed in the periods of straight travel, turtles swam toward a certain direction. Variations in heading during consecutive shallow dives were significantly smaller than that in surface period during consecutive Type-3 dives. The result suggested that turtles could sense the direction of travel better at the surface or at the shallow depth, rather than deep underwater. Many controlled experiments had been proved that turtles have ability to use geomagnetic cues for their orientation (Lohmann & Lohmann 2006). Turtles in this experiment, however, showed rapid heading changes during surface periods in between Type-3 dives, which may be direction-searching behaviour. If turtles strongly relied on geomagnetic information, such searching behaviour would not be necessary because geomagnetic information does exist underwater. Therefore, it is suggested from this study that orientation mechanisms of free ranging turtles relied more on some information, which is more available at the surface (e.g. continuous incoming waves from the mouth of the bay), than geomagnetic cues.

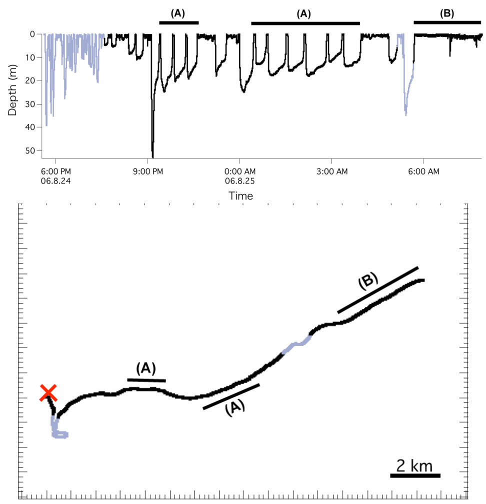


Fig.3. An example of travel by instrumented turtle
Black indicates the periods of straight travel whereas grey indicates other periods. (A) indicates Type-3 dives and (b) indicates shallow dives, respectively. X is the releasing point.
(Top) Time-series depth profile
(Bottom) Horizontal path

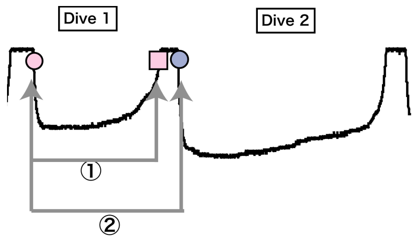


Fig. 4. An illustration of consecutive Type-3 dives
○ indicates the start of dive and ■ indicates the end of the dive
Differences in heading direction were compared in combination showed in ① and ② .

**References**

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