

Original article

# Flipper beat frequency and body acceleration of loggerhead turtles *Caretta caretta* swimming in a set net

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## Introduction

Turtle releasing system (TRS) has been developed to reduce incidental death of sea turtles in set nets [1]. Inside of a submerged bag net of set nets is quite unusual environment for sea turtles, so it is necessary to understand behavior of turtles in the bag net of set nets to proceed development of the TRS. Sea turtles start pushing their head up to the roof net in the bag net to go up to the surface to breathe, and this is known as characteristic behavior of turtles in the bag net [2].

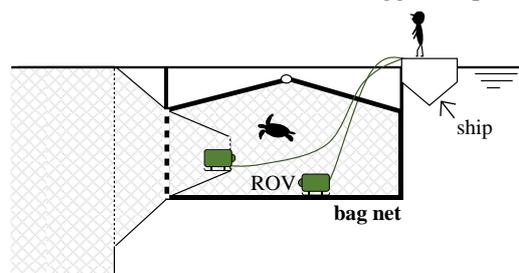
Flipper beat frequency has been used as an index of swimming effort of sea turtles [3], because they swim by propulsive force by fore flippers [4]. In addition, ODBA (overall dynamic body acceleration, *cf.* [5]) obtained from acceleration data logger attached to animals has been often used as an index of oxygen consumption or exercise intensity [6]. In this study, we investigated flipper beat frequency and ODBA of turtles swimming or pushing up in the set net, and clarified the relationship with depth and water temperature.

## Materials and methods

Experiments were conducted in Aug. and Nov. 2013, Jun. 2014, Jul. 2015, and Sep. 2016 in a bag net (30×10×10m) of a set net in Mie pref., Japan. Fifteen wild loggerhead turtles (SCL: 63.3~89.6cm) were used in the experiments. A video camera (HDR-AS100V, Sony Inc.), an acceleration data logger (W1000-3MPD3GT/ W380-PD3GT, Little Leonardo Co.), and a depth logger (DEFI-D20, JFE Advantech Co., Ltd.) were attached on the carapace of each turtle, and one turtle was put into the bag net (Fig. 1). Observation was started after the 15 mins' domestication time. Setting condition of the bag net varied in each period of experiment. In Aug. 2013, the bag net was set as its roof net was located on the surface during observations, so turtles could breathe over the roof nets. In the subsequent experiments, the bag net was submerged after domestication, so turtles could not breathe during observations. In the experiments in Jul.

2015 and Sep. 2016, the roof net of the bag net was made as 20 degrees' quadrangular pyramid (TRS-introduced).

Flipper beat frequency was obtained from video images (Fig. 2), and ODBA and water temperature were obtained from the acceleration data logger, respectively.



**Fig. 1.** An example of overview of experiments with submerged bag net with the TRS. Observations were conducted in the bag net. A turtle was always observed by ROVs with keeping enough distance.



**Fig. 2.** A capture image from the video camera attached on the carapace of a turtle. The video camera captured turtle's fore flipper and head. Flipper beat frequency was obtained from frame-by-frame analysis.

## Results

Turtles alternated series of pushing up and swimming in the bag net. Flipper beat frequency of the turtles swimming in the bag net varied between approximately 0.2 to 1.5 Hz during thirty minutes' observations, and it tended to increase in ascent leading to pushing up unlike in natural environment [7]. For the flipper beat frequency during ascent more than 5m, there were three patterns in change of flipper beat frequency as follows; increasing with elapsed time, no significant relation with elapsed time, and decreasing with elapsed time. Table 1 shows the number of each pattern observed per each

experimental period. In the experiments with submerged bag net (after Nov. 2013), most of ascent lead to pushing up, and flipper beat frequency increased with time elapsing in most of these ascents. In Jul. 2015, there was a significant difference in the rate of the patterns between actions after ascent ( $P < 0.01$ , Chi square test for goodness of fit).

ODBA during swimming had no significant relationship with elapsed time (Pearson's correlation coefficient,  $P > 0.05$ ). On the other hand, ODBA during pushing up increased with time elapsing in 9 out of 12 experiments (Pearson's correlation coefficient,  $P < 0.05$ , Fig.3).

Flipper beat frequency and ODBA had a positive correlation with water temperature ( $P < 0.05$ ). And there was also a positive correlation between flipper beat frequency and ODBA ( $P < 0.05$ ).

**Table 1.** Number of actions after ascent according to the patterns of flipper beat frequency during ascent per each experimental period

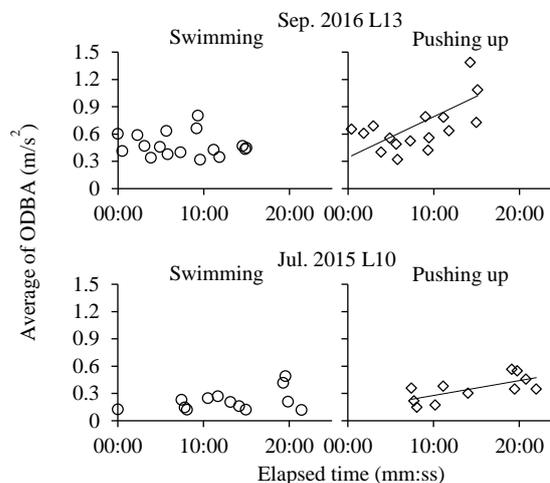
Date	Patterns of flipper beat frequency during ascent	Number of actions after ascent	
		Breath or Pushing up	Swimming
Aug. 2013	Significant increase	2	2
	Not significant	10	10
	Significant decrease	2	2
Nov. 2013	Significant increase	2	0
	Not significant	3	0
	Significant decrease	1	0
Jun. 2014	Significant increase	2	0
	Not significant	0	0
	Significant decrease	0	0
Jul. 2015	Significant increase	8	1
	Not significant	6	6
	Significant decrease	1	3
Sep. 2016	Significant increase	6	0
	Not significant	6	3
	Significant decrease	2	1

## Discussion

Turtles pushed up the roof net after ascent in most experiments with submerged bag net, and flipper beat frequency increased with ascent in most cases. Flipper beat frequency of sea turtles decreases with ascent in nature [7], and it is common in marine mammals and birds [8]. Thus, increasing of flipper beat frequency with ascent is thought to be specific to the turtles in the submerged bag net. ODBA increased with time elapsing in most experiments, and it showed five or more times larger values than that in swimming in some experiments. It indicates that the extent of pushing up becomes larger gradually with time elapsing.

Sea turtle is a poikilothermic animal, and body activity becomes lower with decreasing of water temperature [9]. In this study, there were positive relationships between water temperature and flipper beat frequency, ODBA, respectively. From these results, turtles in the bag net of the set net also swim more actively in high temperature in the range of this study.

The effect of water temperature on the behavior of the turtles in the bag net should also be known. And the time that the exercise intensity of the turtles become small since the turtles start pushing up need to be evaluated.



**Fig. 3.** Examples of change of average of ODBA during swimming and pushing up. Upper shows an experiment in Sep. 2016 with turtle L13, and lower shows an experiment in Jul. 2015 with turtle L10. Left shows results during swimming, and right shows pushing up.

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