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TRACKING OF GREEN TURTLES *CHELONIA MYDAS* IN THE ANDAMAN SEA USING PLATFORM TRANSMITTER TERMINALS

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ABSTRACT

Three models of Platform Transmitter Terminals (PTTs) were attached to four green turtles (*Chelonia mydas*) from the Andaman Sea in 1995 and 2000. After release from Phuket and Similan Islands, each turtle revealed its unique migrating route. Two turtles (the 6-month old and the sub-adult female reared in captivity for 6 years) went to the southwest coast of Thailand while the third post-nesting one went to northwestern coast. The fourth post-nesting turtle went to Andaman Islands, India. The destinations of these turtles were identified as sea grass habitats. The duration of PTTs signals was 3–32 days. During cruising and foraging, the adult turtles swam 18–66 and 2–12 km/day, respectively. The fourth turtle spent 9 ± 2 % on the sea surface each day. The circadian surface time was highest after sunset and decreased exponentially afterwards. This study revealed that the post-nesting turtles migrated to several feeding grounds. Collaboration among countries within the region is required to promote the survival of sea turtles in this region.

INTRODUCTION

Migration patterns are known as important tools for conservation and management of sea turtles. Several studies employing satellite transmitters have revealed that turtles migrate for very long distance between feeding and nesting grounds (Balazs, 1994; Balazs *et al*., 1995; Luschi *et al*., 1996). The result of having such long migrations leads to collaboration among countries for efficient conservation of sea turtles in each region (Liew *et al*., 1995). Studies employing molecular markers revealed that there was a great separation between green turtles living in Atlantic Ocean and Pacific Ocean (Bowen *et al*., 1992; Bowen and Karl, 1997). Unfortunately, most recent studies neglected an important nesting area, Indian Ocean.

In order to add a piece of the jigsaw to understanding migration patterns of green turtles, platform transmitter terminals (PTTs) were attached to green turtles living in the Andaman Sea. We tested the efficiency of three models PTTs. The major aim of this study is to determine the migration routes of nesting green turtles. Additional information such as swimming behavior, surface time and sea surface temperature were also reported.

MATERIALS AND METHODS

Three models of PTTs were employed: the Trial, Telonics ST18 and Kiwisat101. The specification of these PTTs is listed in Table 1. The Trial PTTs was connected to the turtle with a monofilament that attached to a man-made hole on a posterior scute. The other two models were attached to the cleaned second mid-scute of the turtles. Putty and epoxy glue were used to adhere the PTTs. Subsequently, carbon fiber cloths soaked with epoxy glue were placed over the PTTs and part of the mid-scute. The turtles were kept dry for least 1–2 hr before releasing to ensure that the glue was fully hardened. In addition, the turtles

Table 1 Specification of three platform transmitter terminals (PTTs) employed in the study.

Company	Model	Duty cycle (hr/day)	Sending Power (watt)	Salt-water switch	L cm	W cm	H cm	WT g	Battery life, day	Obtained information
NTT CODOMO and Kyoto University	The Trial	24	0.5	No	4	3	-	-	180	Position
Telonics, USA	ST18	8	0.5	Yes	13.4	4.7	2.1	200	255	Position
Sirtrack Limited, New Zealand	Kiwisat 101	24	1.0	Yes	18	8.5	5	610	150	Position, surface time and surface temperature

were tagged with external Inconel tags and internal microchip tags (Table. 2). The position signals from the PTTs were obtained via ARGOS. The positions data are classified into 7 classes (3, 2, 1, 0, A, B, and Z) depend on the calculated error during linking to the satellites. Class 1, 2 or 3 indicates that the position has accuracy within 200, 500, or 1,500 m, respectively. Class A or B indicates that there is two or three satellite link ups respectively, without any accuracy calculated. Class O shows that the position is not accurate and Class Z means no position is assigned.

Four green turtles (*Chelonia mydas*) namely *Panwa1*, *Panwa2*, *Sri Nuan* and *Kayano* were attached with PTTs as shown in Table 2. *Panwa1* was a 6-month old turtle. *Panwa2* was caught from the sea around Phuket and reared at Phuket Marine Biological Center for 6 years. *Sri Nuan* and *Kayano* were wild females which came to lay eggs at Huyong, Similan Islands. At the time as we were tagging, *Sri Nuan* had laid eggs for the 6th time in that year. The records from The Third Fleet of Royal Thai Navy showed that *Sri Nuan* also came to lay eggs at the islands 3 years ago. *Kayano* was recorded being in her first egg laying year since there was no record of egg laying at the islands during past 4 years.

The position data were plotted using global information system (GIS). Only the data in class 1, 2, 3, and A were used. The additional information on seagrass habitats in Thailand was obtained from Chansang and Poovachiranon 1994 and Poovachiranon and Chansang 1994. The minimum accumulated migrating distance (D_m) in kilometer was calculated as,

$$A \times \sum_{i=1}^{n} \sqrt{(y_{i+1} - y_i)^2 + (x_{i+1} - x_i)^2}$$

where; A is a conversion constant from a degree to km, which equals 111.12; Y_i and X_i are decimal degrees of latitude and longitude, respectively. The swimming speeds were interpreted from slopes between accumulated migrating distance and time. In addition, the swimming speed was classified as cruising or foraging using the visual judgment of the plotted locations in GIS system. The speed unit was reported as km/day instead of km/hr since there may be a difference between day and night. All sampling errors were calculated as confidence interval at 95%.

RESULTS AND DISCUSSION

The PTTs

The signal durations from PTTs-attached turtles lasted much less than the specification (see Table 1, the Trial: 3 days, Telonics ST18: 21 days, Kiwisat101: 32 days). Several reasons can be given: 1) since, the Trial PTTs was connected to the turtle by a monofilament, a chance of losing part was high; 2) the Telonics ST18 and

Table 2 Information of PTTs-attached green turtles (*Chelonia mydas*) from the Andaman Sea.

Turtle Name	Sat ID	PTTs	External Tag	Internal Tag	Attached Date	Released Place	WT kg	L cm	W cm
Panwa1	-	NTT	-	-	Sep 15th, 95	Phuket	-	30	25
Panwa2	19277	Telonics ST18	*Left* TH/P 0471 *Right* TH/P 0470	*Left* 116479195A *Right* 116563472A	Mar 7th, 00 10:05	Phuket	93	88	78
Sri Nuan	19278	Telonics ST18	*Left* TH/P 0417 *Right* TH/P 0420	*Left* 017-864-343 *Right* 020-341-840	Jun 10th,00 4:45	Similan Islands	-	119	100
Kayano	18683	KiwiSat 101	*Left* TH/P 0470 *Right* TH/P 0477	*Left* 116479195A *Right* 116563472A	Sep 5th, 00 18:50	Similan Islands	-	110	90

Kiwisat101 might have been detached or the antenna might have been broken when the turtles rubbed their backs on hard substrates or during mating; 3) The turtles might have been caught by fishing gears. An experiment using 4 dummy PTTs attached to green turtles in outdoor pond (Arai *et al.*, unpublished data) showed that the attachment using the same technique as this study lasted more than 2 months. However, the PTTs' antennae were either bent or broken. Thus, it is likely that the signal lost (when using Telonics ST18 and Kiwisat101) was because of broken anternnae (or even detachement) particularly during the turtle's stay in the feeding grounds. The attachment using glue and carbon fiber proved to last longer than monofilament.

The number of data per day retrieved from the Trial PTTs was lowest (0.7 times/day) among the three PTTs models. Comparison between Kiwisat101 and Telonics ST18 showed that Kiwisat101 sent two times higher number of data per day than Telonics ST18 (4.0 ± 0.9 times/day VS 1.6 ± 0.3 times/day). However, this is because Kiwisat101 has higher sending power (1 watt) compared to Telonics ST18 (0.5 watt). Besides, Kiwisat101 was turned on 24 hr a day while Telonics ST18 was turned on 8 hours a day only. The number of signals was high during 4:00–11:00 and 16:00–21:00 (local time, Fig. 1). Despite lower numbers of signals, the smaller size of the Trial PTTs allows a chance to tag a small size turtle (*i.e.*, 20–30 cm curved carapace length). Further development of the Trial PTTs, thus, offers a possibility to track the feeding grounds of those juvenile turtles.

The proportion of location classes obtained from Kiwisat 101 and Telonics ST18 is shown in Fig. 2. The proportion of un-used location classes obtained from Kiwisat101 (33%) was lower compared to Telonics ST18 (52%). Kiwisat101 thus proved to be better than Telonics ST18 in both quantity and quality of information

The tracks and speeds

All PTTs-attached turtles migrated to different directions (Fig. 3).

Panwa1 went to a small island (98°24′N 7°45′E), 4.3 km far from the released point. There were only 2 signals received within 3 days. The swimming speed was 1.4 km/day.

Panwa2 swam average 18 km/day to the southeastern direction and reached the seagrass habitats 8 days later. She spent 3–4 days in this habitat. D_m was 215 km in 12 days. The last position recorded was 98°24′N 7°45′E.

Sri Nuan went in a northeastern direction from Similan Island and reached to a seagrass habitat in 3 days. She had spent about 7 days feeding in this area before went back to lay eggs for the 7th time in this year at Similan Island (13 days after the previous eggs laying). Later on, she went to the same feeding ground. Her last position was detected at 98°13′N 7°27′E. *Sri Nuan* swam 35–46 km/day when cruising between nesting and

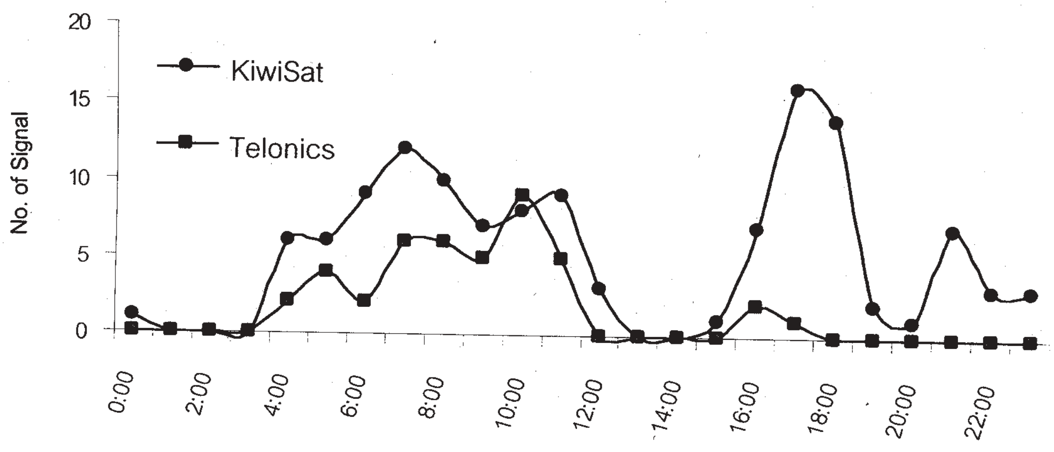

Figure 1 Circadian pattern of signals obtained from Kiwisat101 and Telonics ST18. The data with location classes 0 and Z were excluded from further calculation.

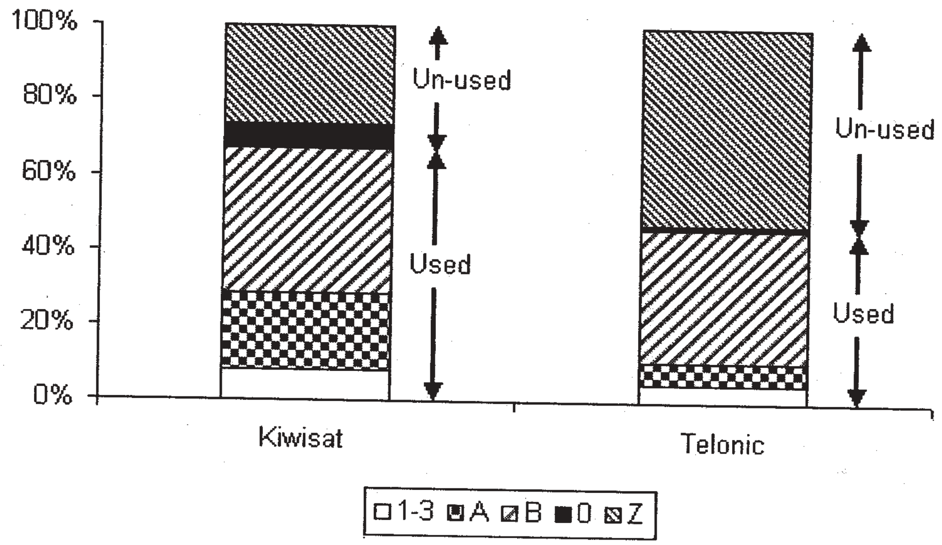

Figure 2 Quality of the retrieved data classified as 7 location classes ranged from the best to the worst: 3, 2, 1, A, B, 0 and Z (see material and method for more detail).

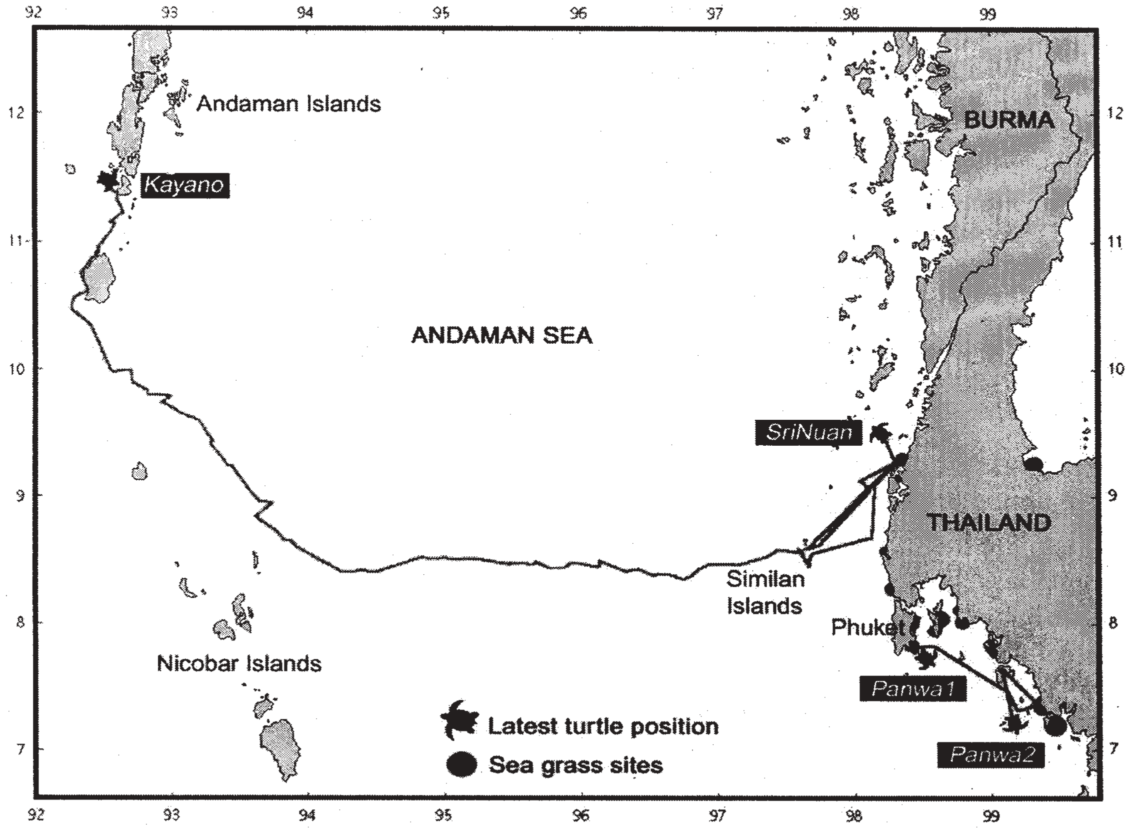

Figure 3 Migration routes to PTTs-attached green turtles (*Panwa1*, *Panwa2*, *Sri Nuan* and *Kayano*) released from Phuket and Similan Islands in 1995 and 2000.

feeding grounds. During her stay in feeding ground, she swam 2–4 km/day. D_m was 524 km in 27 days.

Kayano travelled to the Andaman Islands, India (640 km far from Similan Islands). She swam 66 km/day for 15 days to reach the destination (Woodmason bay, Rutland Island, Andaman Islands) and stayed there until the signal ceased at 92°37′N 11°26′E. D_m was 1,174 km in 31 days. The destination of *Kayano* was a seagrass/seaweed habitat (Mahadevan and Easterson, 1983). Even though, the data obtained from *Panwa1* was too little to conclude anything, the successful track of *Panwa2* revealed that a captive turtle was able to find a food habitat (*i.e.*, a seagrass bed). The post-nesting turtles, *Sri Nuan* and *Kayano*, went back to different foraging grounds. The result is in agreement with other satellite tracking studies that green turtles which nest on the same beach possess different foraging sites (Balazs, 1994 and Luschi, 1996).

The swimming speed of tracked turtles increased with the increasing size of animal. The juvenile turtle, *Panwa1*, swam much slower (1.4 km/day) compared to the adult turtles in this study, *Sri nuan* (46 km/day) and *Kayano* (66 km/day). Similar average swimming speeds of adult green turtles calculated from satellite-linked data were reported by Lushi *et al.*, 1996 (37–61 km/day) and Balazs, 1994 (38–48 km/day).

This study revealed that green turtles from at least two feeding grounds (Andaman Islands and west coast of Southern Thailand) lay eggs at Similan Islands. Thus, conservation of green turtles in the Andaman area would require collaboration among countries in the region.

The surface temperature and sea surface time

The sea surface temperature was quite constant at 29.6 ± 0.1°C. Surface time counter of the PTTs attached to Kayano showed that she spent 9 ± 2 % surfacing each day. The amount of surface time studied by Balazs (1994) employed the same technique and showed similar figures (4–5%). The diurnal pattern of surface time demonstrated that *Kayano* spent the highest surface time as soon as it was dark (Fig. 4). The average surface time during day (6:00–18:30) was 6 ± 1 % and 16 ± 5 % at night. The lower surface time during day may be explained by feeding behavior and behavioural mechanisms to avoid enemies.

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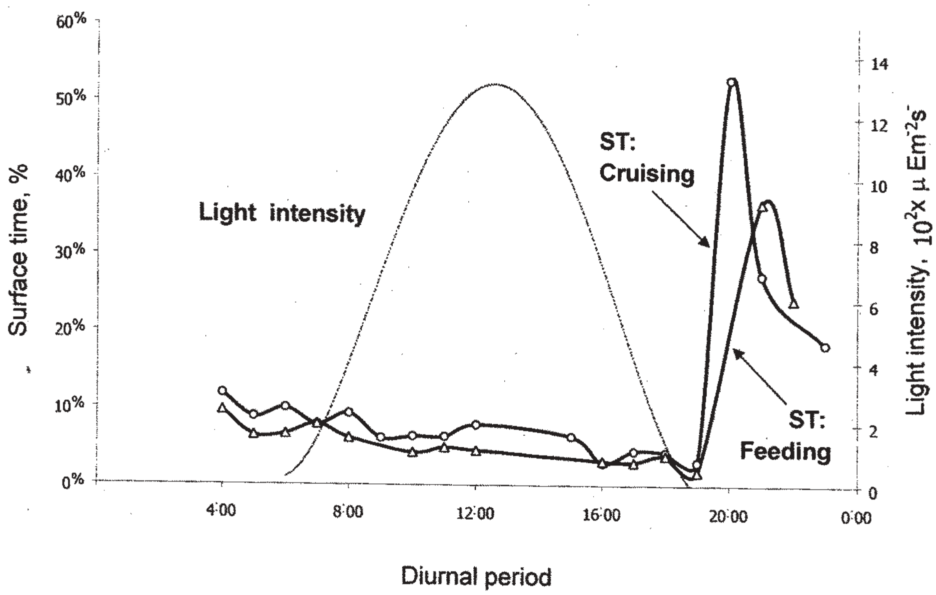

Figure 4 Circadian pattern of sea surface time obtained from surface time counter in PTTs attached to the post-nesting green turtle, *Kayano*.

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