HATCHLING TRANSPORT OF LOGGERHEAD TURTLES IN THE NORTH PACIFIC

Takashi Kitagawa, Hiromi Kudo and Shingo Kimura

Ocean Research Institute, University of Tokyo,
Nakano 1-15-1, 164-8639, Tokyo, Japan
E-mail1: takashik@ori.u-tokyo.ac.jp

ABSTRACT

Using an advection and diffusion model for particle tracking in three dimensions, the hatchling transport process of loggerhead, *Caretta caretta* and green turtles, *Chelonia mydas* in the North Pacific was investigated. Loggerhead hatchlings were transported eastward to northeastward by the Kuroshio from their nest, Yakushima Island, and were transported 2770 km on average over 60 days (46 km/d). These indicate that the Kuroshio enables loggerhead hatchings and juveniles to spread out without them using up their energy. In addition, transported by the Kuroshio provides them with a significantly lower mean ambient water temperature (20.7±4.1°C) than that around the nest (24.0±0.5°C). In contrast, green turtle hatchlings were transported northwestward from their nest, the Ogasarawa islands, and their mean location after 60 days was no more than 323 km away from their nest. The mean ambient water temperature during transport showed little difference from that around the nesting islands (24.5°C). These suggest that their thermal condition relatively stable in their early life in comparison with loggerhead turtles.

INTRODUCTION

Five sea turtle species can be found in the water around Japan. Of these, three species nest on Japanese coasts: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and hawksbill turtle (*Eretmochielys imbricata*). Above all, loggerhead turtles have broad nesting ranging around Japan and they nest most frequently on Yakushima Island (Kudo et al. 2002). In contrast, green and hawksbill turtles have a limited nesting range on islands south of Japan. Green turtles nest most frequently on the Ogasawara Islands (Fig. 1).

On entering inshore, hatchings swim vigorously and continuously offshore for about 24 hours. This period is called "the frenzy". Hatchlings are then believed to spend the next period of their life in oceanic area, drifting passively in ocean currents before appearing in coastal feeding areas (Carr and Meylan 1980; Hays and Marsh 1997). This period has been termed "the lost year" since the exact length of time turtles spend drifting is unknown (Carr 1967, 1987; Hamnar 1988; Hays and Marsh 1997). Their coloration, small size, agility and so on perhaps make oceanic observations difficult in this period (Witham 1980).

In this study, in order to elucidate the life history of loggerhead turtles during the lost year, we adopted a numerical advection and diffusion model for particle tracking in three dimensions and investigated hatchlings transport process from their nesting island, Yakushima Island, in the North Pacific, comparing to that for green turtles from their nest the Ogasawara Islands. We also examined their transport distance and thermal preference comparing to those for green turtles.

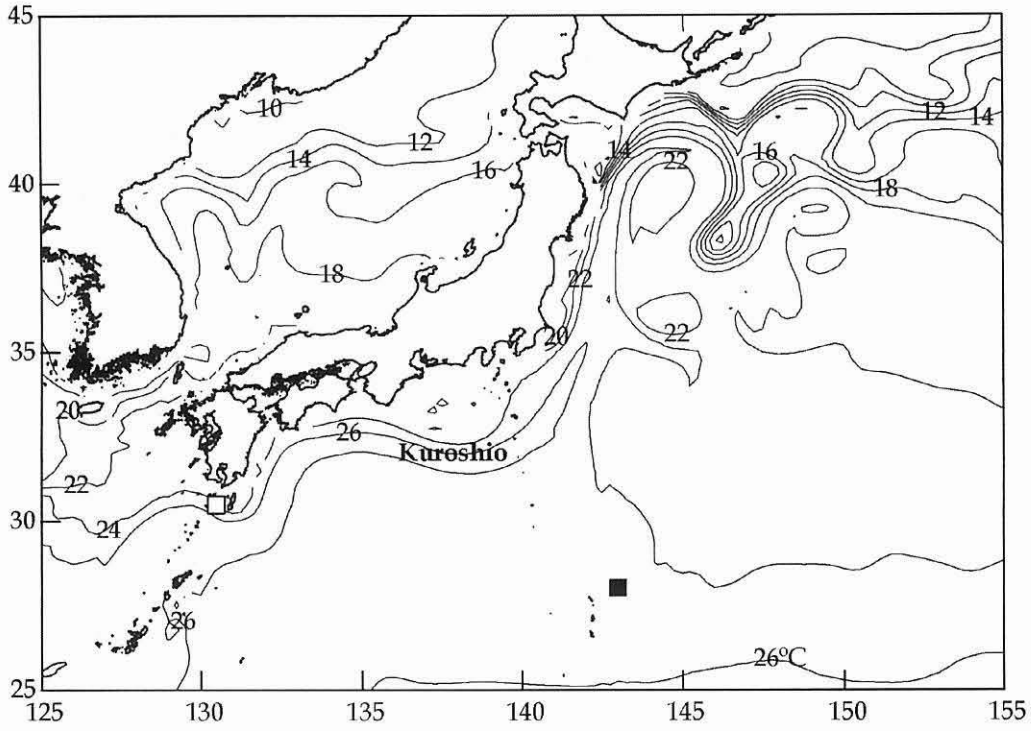

Fig. 1 Horizontal distributions of sea surface temperature and release locations for of loggerhead and green turtle.

METHODS

The modeled ocean circulation is based on the OCCAM (Ocean Circulation and Climate Advanced Model) developed at the Southampton Oceanography Center in the United Kingdom (Webb et al. 1998; Kimura et al. 1999; Saunderes et al. 1999). The model has a spatial resolution of 0.25 degree-grid and upper 5 level layers with every 20 m depth were taken into our calculation.

For diffusion of tracers, 5x102 m^2s^{-1} was adopted as the horizontal eddy diffusivity according to Kim (2002), while 0 m^2s^{-1} was adopted as the vertical eddy diffusivity because we assumed that turtles were always drifting at the sea surface. Average flow field and sea surface temperature in the middle of August were used to calculate hatchling trajectories using an off-line trajectory-tracking method. For the purpose of this study, 50 particles were deployed at 30.5°N 130.5°E near Yakushima Island for loggerhead turtels, at 28°N 143°E near the Ogasawara Islands for green turtles, respectively (Fig. 1).

All the particles were distributed at the depth of 5 m and tracked for 60 days. In the present study, their active horizontal and vertical migration were not considered since the behavior was not confirmed quantitatively and this study was a first step to understand their migration.

RESULTS AND DISCUSSION

Figure 2 shows hatchlings trajectories of loggerhead and green turtle for 25 days. Loggerhead turtles left from Yakushima Island, are immediately entrained into the Kuroshio and the majority of them are quickly transported northeastward. By contrast, green turtles diffused from near the Ogasawara Islands due to the weak ambient current velocities although they were shifted in the westward. Figure 3 shows hatchlings locations of loggerhead and green turtles on the 60th day after release. Loggerhead turtles were transported east to northward further from Yakushima Island. This is perhaps owing to the Kuroshio. In contrast, green turtles did not apart so much from the nesting islands though some individuals were transported northward and others were westward. This result indicates that their transport process does not always depend on their ambient current velocities. Figure 4 shows transport

distance of loggerhead and green turtles after 60 days. As a result, the loggerhead turtles were transported about 2800 km on average from the nesting island, and the mean transport rate was 46 km/day. The 60th day locations were also about 1500 km away from the natal island (Fig. 4). These indicate that the Kuroshio enables loggerhead hatchings and juveniles to spread out with low their energetic costs. Contrarily, green turtles' transport rate was only 12 km/day, and they were transported 720 km. Further, their locations after 60 days was no more than about 300 km on average away from their nest (Fig. 4). These values for green turtles were significantly lowered than those for loggerhead turtles (Mann-Whitney test, $p<0.0001$, Table. 1). Figure 5

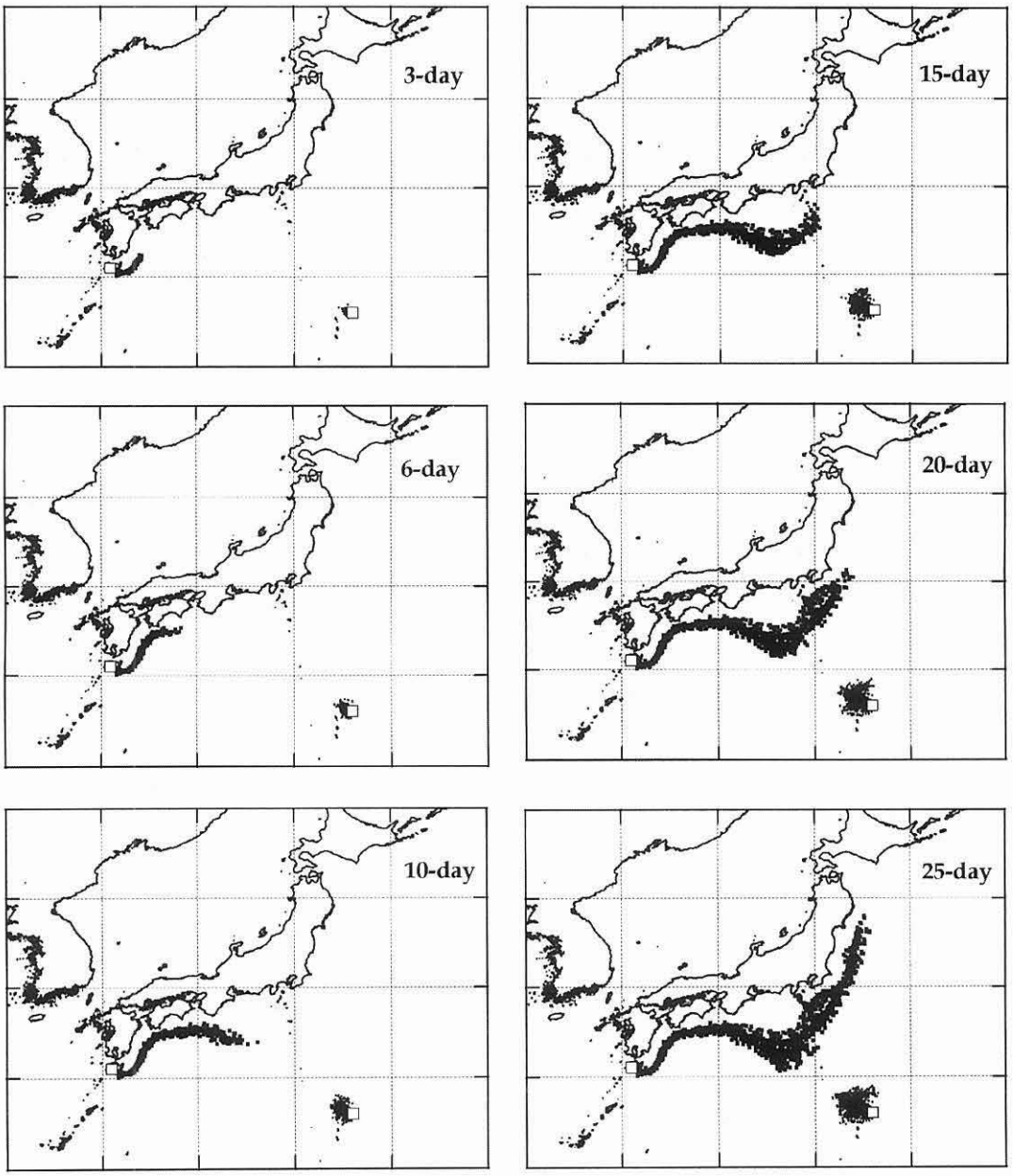

Fig. 2 Hatchlings trajectories of loggerhead and green turtle for 25 days calculated by an advection and diffusion model. Release locations for loggerhead and green turtle were also shown by squares.

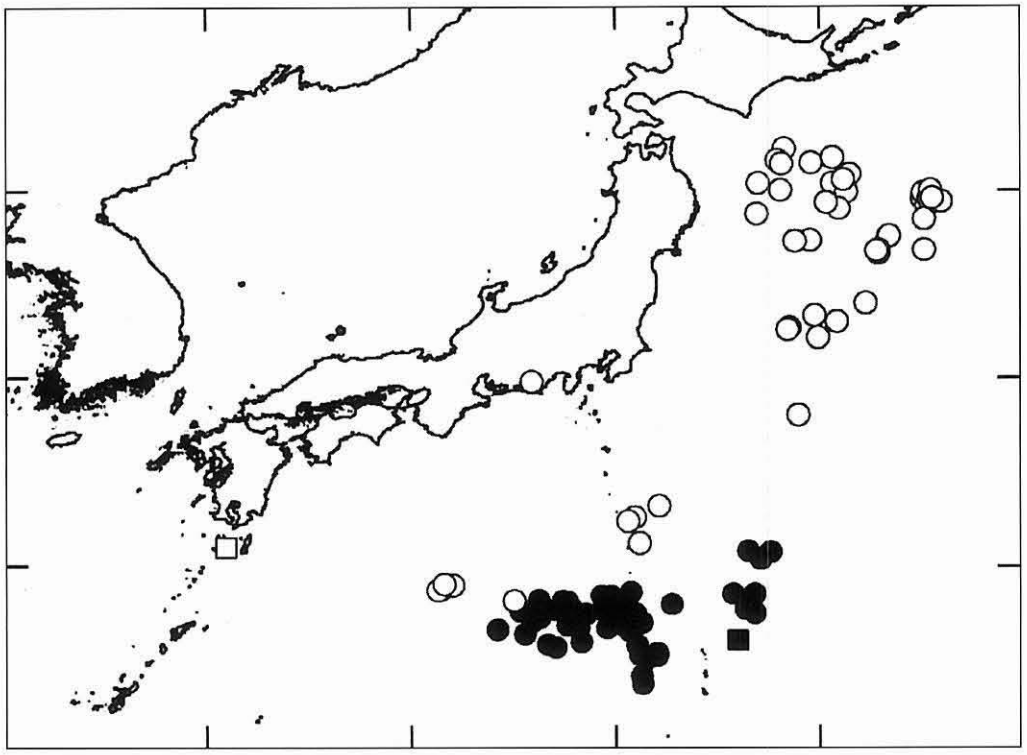

Fig. 3 Hatchlings locations of loggerhead (a) and green turtles (b) on the 60th day after release. Release locations for of two species were also shown by squares.

shows ambient temperatures of two turtle species after 1 and 60 days. Regarding loggerhead turtles in Fig. 5(a), transport by the Kuroshio provided them with significantly lower ambient temperatures (20.7±4.1°C mean±S.D.) than those around the nesting island (24.0±0.5°C, Mann-Whitney test, $p<0.0001$). On the other hand, ambient temperatures for green turtles showed little difference from those around the nest (24.0°C, Fig. 7(b)), suggesting that their thermal condition relatively stable in their early life in comparison with loggerhead turtles.

In this study, we showed the passive process for turtle hatchlings movements by the physical environment. As future tasks, we will formulate a modeling and simulation framework that will predict their response behavior to environmental cues such as ambient temperature and thermal structure, salinity, ocean current, food density, and so on in order to describe spatial and temporal dynamics of the turtle assemblage.

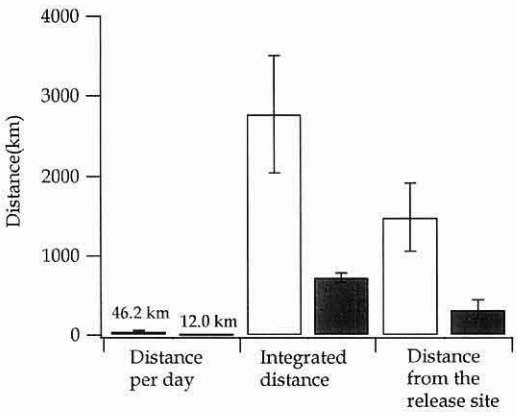

Fig. 4 Transport distance per day, integrated distance, and distance from the release site for loggerhead (open column) and green turtles (solid column) after 60 days.

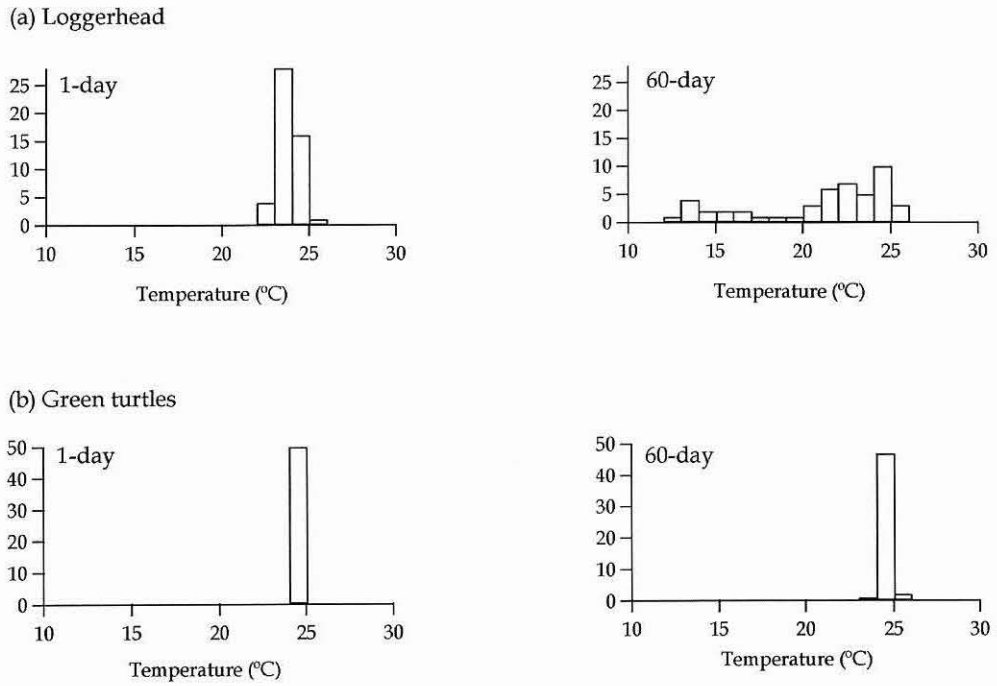

Fig. 5 Histograms for ambient temperatures of loggerhead (a) and green turtles (b) after 1 and 60 days. Sample size was 50 in all cases.

Table.1 Mean transport rate, transport distance, and distance after 60 days from the start point (km±SD) for loggerhead and green turtle hatchlings.

	Loggerhead turtles	Green turtles	Mann-Whitney test p value
Start point	Near Yakushima Island 130.5°E 30.5°N	Near the Ogasawara Is. 143.0°E 28.0°N	
Mean transport rate per day	46.2 ±12.1	12.0 ±0.97	p<0.0001
Mean transport distance over 60 days	2770.3 ±725.3	719.7 ±58.0	p<0.0001
Distance after 60 days from the start point	1481 .8 ±431.7	322.7 ±115.4	p<0.0001

Table 1. Mean transport rate, transport distance, and distance after 60 days from the start point (km ±SD) for loggerhead and green turtle hatchlings.

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