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First record of nesting ecology and tumor-forming disease in endangered Green Turtles (*Chelonia mydas*) on Taiping Island, Taiwan

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Abstract

Taiping Island is an important sea turtle nesting site in Taiwan. However, information on the nesting ecology on Taiping Island is still limited. The present study was conducted between 26 April and 3 June 2023 with the objective of collecting primary data on the sea turtle species that nest on the island. A total of 20 individual nesting green turtles were identified. No other sea turtle species were recorded nesting during this period. Five percent of nesting sea turtles had external tumors. The mean curved carapace length of all nesting female turtles was 98.2 cm. A total of 28 clutches were detected during the survey. The mean re-nesting interval was estimated to be approximately 10 days. The majority of nests were located in the north of the island. The southern region of the island has the highest number of documented sandy cliffs, which may affect the nesting behavior of sea turtles. To protect this endangered species, the authorities should first consider using more natural methods to protect the coastline, such as dune restoration. Furthermore, it is advised that long-term monitoring programs be established on Taiping Island to gather supplementary data, including information on nesting ecology and the comprehensive health assessment of nesting turtles.

Keywords: *Chelonia mydas*, escarpments, nesting beach, nesting ecology, Taiping Island

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Introduction

A total of five species of sea turtles have been recorded in Taiwan, including the green turtle (*Chelonia mydas*; endangered), hawksbill turtle (*Eretmochelys imbricata*; critically endangered), olive ridley turtle (*Lepidochelys olivacea*; vulnerable), loggerhead turtle (*Caretta caretta*; vulnerable) and leatherback turtle (*Dermochelys coriacea*; vulnerable) (Chou *et al.*, 2023). Green turtles have been documented nesting in Taiwan, including Xiaoliuqiu Island, Lanyu Island, and Wan-An Islands (Chen and Cheng, 1995; Cheng *et al.*, 2008, 2009; Ng and Matsuzawa, 2021). Wan-An Island is a nesting site that has been identified as the index site, exhibiting the highest number of green turtle nests observed and recorded on a regular basis among the other sites (Ng and Matsuzawa, 2021). Cheng *et al.* (2018) additionally documented a significant decline in the green turtle population on Wan-An Island, with only two nesting females remaining. In contrast, the Lanyu Island population demonstrated periodic increases in abundance, reaching a maximum of 24 nesters every 3 ± 5 years without exhibiting any long-term decline (Ng and Matsuzawa, 2021). Regular monitoring of the green turtle nesting sites has been conducted in Taiwan (including Xiaoliuqiu Island, Lanyu Island, and Wan-An Islands), but so far, efforts have not been undertaken in Taiping Island in the South China Sea. Taiping Island is the largest island in the Spratly Islands, situated in the South China Sea (Hsu *et al.*, 2024) (Fig. 1A). Although interview data from Taiping Island (Cheng, 1996) indicated that green and hawksbill turtles come ashore to lay eggs in the area, little is known about the nesting ecology of sea turtles throughout Taiping Island. This study was conducted on Taiping Island in April and June 2023. Our objectives were 1) to find sea turtle nests on different beaches and 2) to identify beaches with high numbers of nests and nest densities for nesting turtles.

Materials and Methods

Animal Ethics: This study was approved by the Ocean Conservation Administration (Permit no. 1120001149). No marine turtles were specifically held in laboratory facilities for the purposes of this investigation. The study was conducted in accordance with the local legislation and institutional requirements.

Location and Study Subjects: Taiping Island is about 0.5 square kilometers, measuring approximately 1,300 meters in length and 360 meters in width (Cheng, 1996; Jeng, 1998). Taiping Island is covered with lowland tropical rainforest and reaches an average topographic height of 3.8 m (Fang and Li, 1994). The entire island is made up of guano-covered sand, consisting mainly of medium to well-sorted coarse-grained sand with an interstitial water content of 6% (by weight) (Cheng, 1996). Jeng (1998) pointed out that the complex topography of Taiping Island is typical of tropical coral reefs. Scleractinian corals dominate shallow areas (1–3m) with high diversity and cover. Deeper slopes (below 15m) are home to alcyonarians and gorgonarians. Well-developed reef flats and terraces occur on the east and west sides of the island (Jeng,

1998). The Taiping Island beach was divided into four sectors, designated as Eastern (Approximately 7,700 square meters), Western (Approximately 7,600 square meters), Northern (Approximately 17,300 square meters), and Southern (Approximately 30,000 square meters) (Fig. 1A). Most of the vegetation was discovered on the eastern, northern and southern beaches. The nesting beaches were divided into four distinct zones: the edge of the vegetation, the open beach zone in front of the escarpments, the open beach zone, and the vegetated zone. A series of beach surveys was conducted between the 26th of April and the 3rd of June, 2023. The patroller conducted a daily beach patrol between 19:30 and 05:30, surveying Taiping Island beach to record and tag (Flipper tagging) nesting female turtles and gather data on nesting ecology. When a nesting turtle was encountered, the curve carapace length (CCL min) and curve carapace width (CCW) of the turtle were measured using a flexible measuring tape. Additionally, the date, location, turtle species, and outcome of nesting events were recorded and categorized as either successful or unsuccessful (false crawl or aborted nest) in accordance with the criteria established by Reavis *et al.* (2022) and Barbier *et al.* (2023).

Result and Discussion

A total of 20 successful nesting green turtles were recorded. Means of CCL, CCW, and track width (TW) of egg-laying females were 98.2 ± 4.04 (range: 91–102), 88.9 ± 3.91 (range: 82–96), and 95.6 ± 5.11 (range: 85–107) cm, respectively. It is interesting to note that one of the 20 nesting turtles exhibited a grossly visible tumor formation (Fig. 1C), which is strongly suspected to be fibropapillomatosis (FP) (Van Houtan *et al.*, 2010). To the best of our knowledge, no nesting sea turtles with tumor-forming disease have been recorded in Taiwan (Li *et al.*, 2017; Li and Chang, 2020; Li *et al.*, 2022; Li *et al.*, 2023). Although the tumor we found in the nesting turtle was not confirmed by cytology or histopathology, future studies should investigate the potential effects of FP on the health of nesting turtles on Taiping Island.

It was found that 49.10% (27/55) and 50.90% (28/55) of nesting turtle encounters were unsuccessful nesting events and successful nesting events, respectively. A total of 28 clutches, 18 on the north beach and 10 on the south beach, were observed during the night patrol (26 April to 03 June) (Table 1). More than half of the individuals (65%, $n = 13$) only landed and nested only once, while 6 (30%) individuals nested twice, and one individual (5%) nested three times. The re-nesting females nest at an average time interval of 10.44 days. The majority of clutches were observed at the edge of vegetation (67.9%; 19/28), followed by the open beach zone before escarpment (14.3%; 4/28) (Fig. 1B), the open beach zone (14.3%; 4/28), and the vegetated zone (3.6%; 1/28) (Table 2). In addition, a total of 27 false crawls (also called aborted nesting attempts) were recorded during the study (Table 1).

All nesting females recorded in this study were identified as green turtles, and none of the tagged turtles had been previously released in Taiwan or were migratory individuals from other regions. In

accordance with previous surveys conducted in other regions of Taiwan, all of the nesting turtles observed were green turtles (Cheng *et al.*, 2000; King *et al.*, 2013; Cheng *et al.*, 2018; Ng and Matsuzawa, 2021). Previous interviews conducted on Taiping Island indicated that green turtles and hawksbill turtles were observed to come ashore to lay eggs in the area (Cheng, 1996).

However, no hawksbill turtles were observed to have come ashore to lay eggs during this field survey. In addition, Hsu *et al.* (2024) used drone surveys to show that the area around Taiping Island is home to a remarkably high density of green turtles, with an estimated population of around 1,000 individuals per square kilometer.

Table 1 The successful and unsuccessful nesting events of green sea turtles recorded at Taiping Island

Nesting beaches	Successful nesting events			Unsuccessful nesting events		
	Number of clutches	Number of body pits	Number of egg chambers	Number of aborted nesting attempts	Number of body pits	Number of egg chambers
Northern beach	18	25	18	12	13	1
Southern beach	10	22	14	12	15	4
Eastern beach	0	0	0	3	4	1
Western beach	0	0	0	0	0	0
Total	28	47	32	27	32	6

Table 2 The selection of nesting sites by green turtles at Taiping Island

Locations	Number of clutches
The edge of vegetation	19
The open beach zone before the escarpments	4
The open beach zone	4
The vegetated zone	1
Total	28

The smallest nesting turtle in our study, with a CCL of 91 cm, was smaller than in Cheng's previous study at Taiping in 1996 (Cheng, 1996). The data indicate that the CCL of the two green turtles recorded on the beach at Taiping Island that were about to return to the sea was 96 and 100 cm, respectively (Cheng, 1996). The occurrence of smaller nesting turtles in numerous locations has prompted concerns regarding the potential decline in the reproductive capacity of turtles (Mortimer *et al.*, 2022). Previous studies have indicated that the CCL of nesting turtles in certain regions is gradually decreasing, which is also correlated with a decline in the number of nesting turtles annually (Hatase *et al.*, 2002; Shanker *et al.*, 2003; Ilgaz *et al.*, 2007). Nevertheless, in certain regions, data indicates a reduction in the size of nesting turtles accompanied by an increase in the number of clutches (Weber *et al.*, 2014; Le Gouvello *et al.*, 2020; Hays *et al.*, 2022; Pritchard *et al.*, 2022). A decline in the CCL of nesting turtles in a specific region may be attributable to the deterioration of the habitats where they are found, in addition to the influx of younger individuals into the nesting population (Le Gouvello *et al.*, 2020; Mortimer *et al.*, 2022).

In terms of nesting sites, previous interviews on Taiping Island indicated that the majority of nesting sites were located on the less developed south-east coast (Cheng, 1996). However, the results of this survey demonstrated that the largest number of nests were situated on the north coast (18/28). A total of 28 clutches were observed during the survey period, which lasted for less than two months. Previous interviews on Taiping Island have estimated the number of nests to be between 10 and 100 per year (Cheng, 1996). Furthermore, previous data indicate

that the total number of annual nests on Wan-An Island and Lanyu Island is approximately 4-55 and 4-67, respectively (Ng and Matsuzawa, 2021).

In terms of the length of the nesting interval in this study, the mean interval between nests was 10.44 days (SD = 1.33). The interval between nesting attempts varies from one to several weeks among different marine turtle species (Dornfeld *et al.*, 2015; Robinson *et al.*, 2017). Among the five marine turtle species, leatherback turtles have the shortest mean internesting interval (9.7 days, range: 8.0-12.1 days), followed by green turtles (12.6 days, range: 8.3-23.0 days), hawksbill turtles (14.9 days, range: 12.9-16.2 days), loggerhead turtles (16.8 days, range: 12.0-25.1 days), and olive ridley turtles (26.3 days, range: 18.0-32.0 days) (Robinson *et al.*, 2022). The number of days between egg-laying in green turtles is influenced by the temperature of the sea. Higher sea temperatures result in shorter intervals between egg-laying, although this is not observed in leatherback and hawksbill turtles (Sato *et al.*, 1998; Hays *et al.*, 2002; Robinson *et al.*, 2022). Further efforts should focus on determining whether this phenomenon occurs in nesting green turtles on this island.

The majority (67.9%) of turtle clutches on Taiping Island were observed at the edge of beach vegetation, with most of these located on the north coast. The presence of natural vegetation on beaches has been shown to have a cooling effect on egg nests, leading to increased hatching rates and a reduction in sex ratio bias (Reboul *et al.*, 2021). Nevertheless, four clutches were observed in the open beach zone before the escarpments. The configuration of sand dunes along the shoreline results in the formation of natural barriers characterized by elevated or precipitous slopes of sand

where the water meets the land (Lyons *et al.*, 2020). The presence of sand escarpments may act as a barrier to the nesting of marine turtles (Witherington *et al.*, 2011; Hirsch *et al.*, 2022). For example, leatherbacks (*D. coriacea*) that encountered steep escarpments due to beach erosion exhibited a higher frequency of abandoned nesting attempts and a greater propensity

to deposit their eggs in high-risk areas (Rivas *et al.*, 2016). The documentation of sand escarpments can facilitate the identification of geological trends, which may be employed to infer the potential for erosion and accretion of sand, as well as the availability of land for the construction of nests.

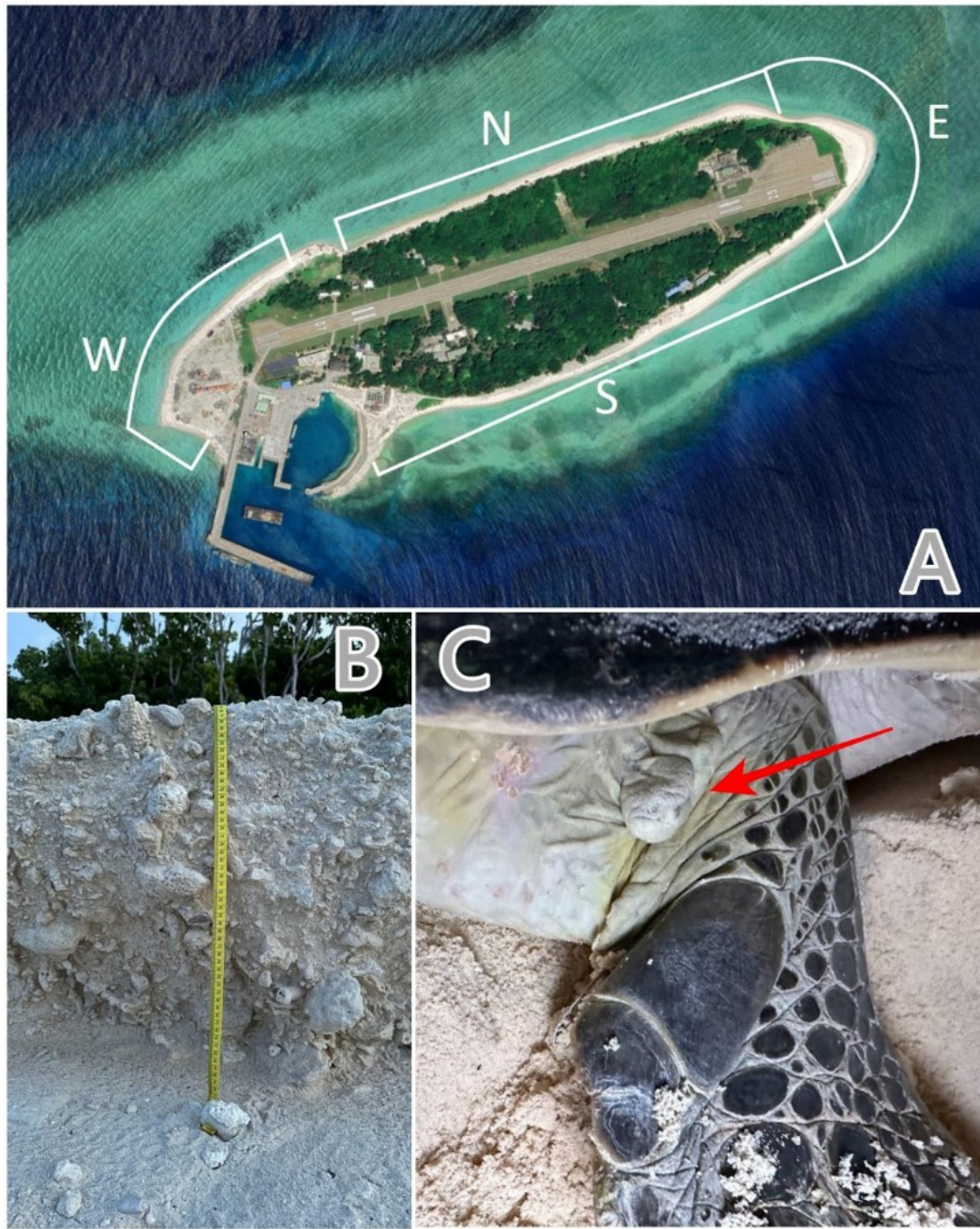


Figure 1 A. The image of Taiping Island (E = Eastern beach; W = Western beach; N = Northern beach; S = Southern beach). The image was obtained from Google Earth in 2024. B. The sand escarpments on the nesting beach pose a challenge for sea turtle nesting. C. The image shows a FP tumor (arrow) on the hind flipper of a nesting green turtle.

The overall successful nesting event of this population during this survey was 50.91 %, which is slightly lower than the 52.6% recorded for green turtles in the northwestern Gulf of Mexico (Shaver *et al.*, 2020). A recent study in Peninsular Malaysia showed that the nesting success rate of the green turtle was 66.7 % (Mohd *et al.*, 2021). Furthermore, a study of green turtle nesting behavior on Raine Island, Australia, found

nesting success rates of 45%-57% (Hamann *et al.*, 2022). A total of 27 false crawls (aborted nesting attempts) were recorded during the study (Table 1). Both the construction of the body pit and the digging of the chamber steps are the first stages of the nesting process; if the body pit or the digging of the chamber steps was completed but stopped before the eggs were laid, this activity was considered an aborted nesting

attempt (also known as a false crawl) (Barbier *et al.*, 2023). The aborted nesting attempts observed at La Roche Percée beach were attributed to three main factors: anthropogenic disturbance, improper substrate for nesting, and other undetermined factors (Barbier *et al.*, 2023). For example, the presence of humans around the turtles, lights on the beach, and dog harassment were identified as potential sources of disturbance. Repeated aborted nesting attempts could lead to substantial energy expenditure, potentially compromising the overall energy budget for the entire nesting season (Hamann *et al.*, 2022). It is important to note that the specific causes of these aborted nesting attempts could not be determined in this study. Further investigation is necessary to elucidate the underlying factors.

As a result of the circumstances described above, Taiping Island may currently be home to the largest known nesting population of green turtles in Taiwan. Monitoring the distribution of sea turtle nests provides insights into the dynamics of the beach ecosystem and the importance of protecting these nests. It is imperative that coastal managers carefully consider the impact of sand escarpments on sea turtle nesting behavior, as these structures have been shown to negatively impact the nesting habits of nesting turtles. It is further recommended that long-term monitoring programs be established on Taiping Island for the purpose of gathering additional data, including information on nesting ecology and a comprehensive health assessment of nesting turtles. Furthermore, collaboration with local stakeholders or government agencies could help ensure the continuous collection of data essential for the effective management and protection of this population.

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