Herpetological Conservation and Biology 21(2):363–373.
Submitted: 15 January 2026; Accepted: 25 June 2026; Published: 31 August 2026.

Determining Population Status of Marine Turtles at the Mantanani Islands, Sabah (Borneo), Malaysia Using Novel In-water Photo-identification

Elvie Jen Teo Mei Jun[1], *Juanita Joseph*[1,4], *Chen Cheng Ann*[1], *Muhamad Ariff Ng Abdullah*[2], *and Hussien muin*[3]

[1]*Institut Marin Borneo, Universiti Malaysia Sabah, Jalan Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia*
[2]*JSK Mantanani Island Resorts, Pulau Mantanani Besar, Kampong Mantanani, 89150 Kota Belud, Sabah, Malaysia*
[3]*Sabah Wildlife Department, 5th floor, B Block, Wisma Muis, 88100 Kota Kinabalu, Sabah, Malaysia*
[4]*Corresponding author, e-mail: juanita@ums.edu.my*

***Abstract*.—Marine turtle research in Sabah, Malaysia, has historically focused on nesting beaches and a limited number of established in-water foraging areas, while comparatively little attention has been given to nearshore reef systems along the west coast. Although capture-based studies have previously documented marine turtles at the Mantanani Islands, standardized in-water assessments using non-invasive photo-identification methods have not been reported. We present the first structured in-water photo-identification survey of marine turtles at the Mantanani Islands, Sabah, Malaysia. We conducted 29 SCUBA dives across 10 sites in May and August 2024. We identified individual turtles using standardized facial photographs analyzed with I3S Pattern software. We recorded 92 turtle encounters of Green Turtles (*Chelonia mydas)* and Hawksbill Turtles (*Eretmochelys imbricata)*. Of these, we successfully identified 60 individuals from 75 usable images, yielding a recognition success rate of 91.7%. Eight Green Turtles were resighted up to three times during the survey period, indicating short-term site use. Most individuals were juveniles based on visual size estimation. External assessments showed that the majority of turtles were in good condition, although we observed barnacle encrustation, algae growth, injuries, and one case of fibropapillomatosis. Our findings complement existing capture-based research and demonstrate the value of photo-identification as a non-invasive tool for monitoring marine turtles in nearshore habitats along the west coast of Sabah.**

Key Words.—*Chelonia mydas*; *Eretmochelys imbricata*; foraging grounds; Green Turtle; Hawksbill Turtle; South China Sea; non-invasive monitoring

Introduction

Marine turtles are long-lived, migratory reptiles that play vital ecological roles in coral reef and seagrass ecosystems. Green Turtles (*Chelonia mydas*) contribute to the maintenance of seagrass meadows through grazing (Bakker et al. 2016), while Hawksbill Turtles (*Eretmochelys imbricata*) influence coral reef dynamics by feeding on sponges (Pawlik et al. 2018). Despite recent global improvements in the conservation status of Green Turtles, now listed as Least Concern on the International Union for Conservation of Nature (IUCN) Red List, Hawksbill Turtles remain classified as Critically Endangered (IUCN 2025). Both species continue to face threats from egg poaching, direct harvest, fisheries bycatch, habitat degradation, and climate change (Wallace et al. 2011; Phu and Palaniappan 2019; Joseph et al. 2021; Kirishnamoorthie et al. 2023).

Malaysia supports important nesting and foraging habitats for marine turtles. Research and conservation efforts in Sabah have traditionally focused on nesting beaches, including long-term monitoring at Turtle Islands Park, Sipadan Marine Park, and islands within the Semporna region (Haziq-Harith 2018; Migliaccio et al. 2020; Joseph et al. 2021). In-water studies have also been conducted at foraging grounds in parts of the Sulu and Celebes Sea, including Tun Mustapha Park, Lankayan, and Semporna (Palaniappan 2017; Nishizawa et al. 2016, 2018, 2024; Samsol et al. 2025). In contrast, comparatively little information is available on marine turtles occupying nearshore in-water habitats along the west coast of Sabah.

The Mantanani Islands, located off the northwest coast of Sabah, are known to support both Green and Hawksbill turtles (Pilcher 2010; Pilcher et al. 2016). Long-term research conducted by the Marine Research Foundation has documented foraging turtles at Mantanani through capture-based studies, including genetic sampling for mixed stock analysis to determine natal origins of immature turtles (Jensen et al. 2016), as well as laparoscopic examination of gonads to determine sex (Pilcher 2010; Pilcher et al. 2016). These studies established the Mantanani Islands as an important developmental and foraging habitat, particularly for immature Green Turtles.

While capture-based tagging studies have generated valuable insights into turtle population structure, growth, and movement, such approaches are logistically demanding and may induce stress to animals (Mancini et al. 2015). Consequently, non-invasive methods such as photographic identification (photo-ID) have been increasingly adopted for monitoring marine turtles (Carpentier et al. 2016; Araujo et al. 2019; Kirishnamoorthie 2023). Photo-ID relies on the unique and stable facial scale patterns of individual sea turtles, enabling long-term re-identification without physical handling (Carpentier et al. 2016). This non-invasive approach has been successfully applied across multiple sea turtle foraging grounds worldwide, including studies in the Philippines (Araujo et al. 2019; Tanangonan et al. 2025) and western Indian Ocean (Carpentier et al. 2016; Hancock et al. 2023).

Recent interview surveys and field observations conducted in 2024 indicate that the Mantanani Islands also support marine turtle nesting activity (Nazerah Kong, unpubl report). Evidence recorded included fresh turtle tracks, poached nests, and post-nesting observations of Green Turtles on nesting beaches. As Mantanani is not a designated protected area, nesting activity remains vulnerable to poaching. In response, a small hatchery was established by a local resort operator (JSK Mantanani Island Resorts) in 2024, resulting in the successful incubation of two Green Turtle nests (Nazerah Kong, unpubl report).

To date, however, standardized in-water photo-ID surveys have not been conducted at the Mantanani Islands. Baseline information on species composition, individual presence, site use, and external health condition of sea turtles remains limited for this nearshore system along the west coast of Sabah. We address this gap by applying in-water photo-ID methods to document marine turtle occurrence, resightings, behavior, and external condition at the Mantanani Islands, providing essential baseline data to complement existing capture-based research and support future conservation and monitoring efforts.

Materials and Methods

Study site.—We conducted our study in the waters surrounding the Mantanani Islands (6°42’47.38”N, 116°21’19.01”E), Sabah (Borneo), Malaysia. The island group comprises Mantanani Besar, Mantanani Kecil, and Linggisan (Fig. 1) and is accessible via a 45-min boat journey from Rampayan Jetty, Kota Belud. The islands are encircled by a 120-ha shallow lagoon characterized by silt and sand substrates and patchy seagrass beds primarily dominated by Spoon Grass (*Halophila ovalis*) and Narrowleaf (*Halophila uninervis*; Pilcher 2010).

The surrounding reef systems support diverse marine fauna and are recognized as foraging habitats for Green and Hawksbill turtles (Pilcher 2010; Jensen et al. 2016). We selected 10 dive sites around Mantanani Besar and Mantanani Kecil islands for surveys based on local ecological knowledge provided by dive operators and resort staff. The islands are inhabited by the Bajau Ubian community, whose livelihoods increasingly incorporates tourism-related activities (Nazerah Kong, unpubl report).

Photo-identification surveys.—We made field surveys from 8–11 May and 12–25 August 2024, comprising 15 field survey days. The photo-ID protocol followed Kirishnamoorthie (2023). We made SCUBA-based surveys three times (two morning dives and one afternoon dive), with each dive lasting approximately 40–45 min; however, the number of dives completed each day varied depending on sea conditions and boat availability. Surveys were undertaken at depths of 5–15 m, corresponding to known turtle foraging and resting zones (Hochscheid et al. 1999). We performed all dives in accordance with standard diving safety protocols.

Each dive team consisted of a photographer and a metadata recorder. Upon encountering a turtle, the photographer approached slowly from behind, maintaining a minimum distance of approximately 1 m to minimize disturbance. Photographs were taken using an Olympus TG-7 camera (OM System Tough, Tokyo, Japan) with underwater housing, targeting the facial profile (left and right sides where possible) and dorsal body features. Flash photography was not permitted. Concurrently, the metadata recorder documented the date, time, dive site location, species, estimated size class, depth, behavior, and visible external conditions.

Size classes were estimated visually *in situ* based on relative body proportions and reference

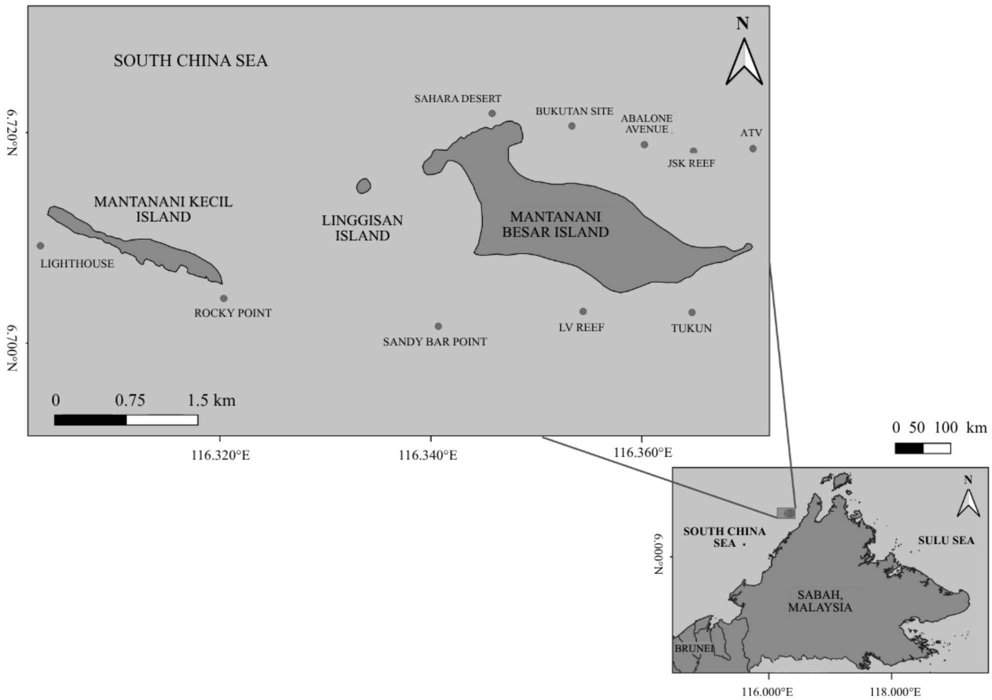

FIGURE 1. The Mantanani Islands, Sabah, Malaysia, showing dive sites surveyed during the sampling of marine turtles: Sahara Desert, Bukutan Site, Abalone Avenue, JSK Reef, ATV, Tukun, LV Reef, Sandy Bar Point, Rocky Point, and Lighthouse.

cues (e.g., flipper length and overall body size), with individuals categorized into broad classes (juvenile or adult). Behavior was classified into three categories: (1) resting, defined as individuals stationary on the substrate; (2) foraging, defined as active feeding behavior; and (3) swimming, defined as directional movement through the water column. External condition was assessed visually, including the presence of injuries, epibionts (e.g., barnacles, algae), or abnormalities such as tumors.

External health assessment.—We assessed external health condition visually based on direct observations supported by photographic records. We categorized each individual following established criteria (Kirishnamoorthie 2023) such as: (1) Good (no visible abnormalities); (2) Carapace Damage; (3) Barnacles; (4) Algae Buildup; (5) Tumor (fibropapillomatosis); and (6) Other Abnormalities (Fig. 2). We also recorded the presence of attached remoras (Echeneidae), as well as evidence of past injuries (Fig. 3). Sex was determined where possible based on tail length, with only individuals exhibiting a distinctly elongated tail classified as males, while all other individuals were recorded as unknown sex to avoid misclassification. The presence of flipper tags was also documented.

Photo-matching and identification.—We analyzed facial photographs using the Interactive Individual Identification System (I3S Pattern v.4.0.2; https://reijns.com/i3s/). Both the photo-identification protocol and I3S analytical procedures followed Kirishnamoorthie (2023), including image selection, angle control, and manual verification of candidate matches. We used only clear lateral facial images with an angle deviation of < 30° to ensure measurement accuracy. We cropped and standardized images to the same size and approximately the same visible details before analysis. The use of facial scale patterns as natural identifiers has previously been validated against physical mark-recapture data, demonstrating that photo-identification can reliably distinguish individual sea turtles without the need for external tags (Schofield et al. 2008; Carpentier et al. 2016).

For each turtle image, we marked three reference points: (1) the beak edge; (2) the inner margin of the eye; and (3) the outer scale edge (Fig. 4). The software generated a set of key points for each individual and calculated similarity scores by comparing new images against existing entries in the database. Lower similarity scores indicated a higher likelihood of a true match. We manually reviewed the 20 most probable matches suggested by the software to confirm individual identity. We

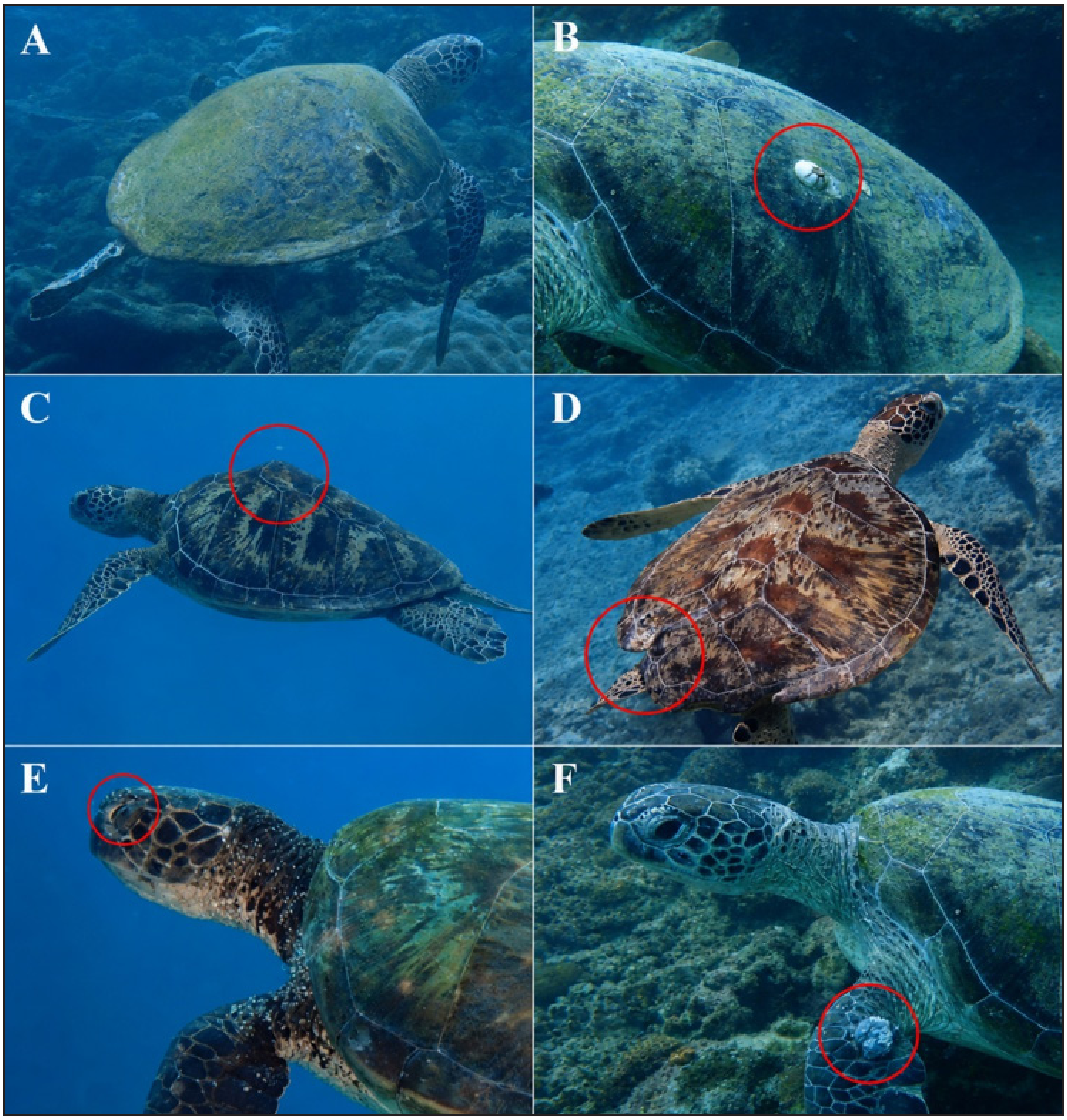

Figure 2. Body condition of Green Turtles (*Chelonia mydas*) observed at Mantanani Islands Sabah, Malaysia. (A) Individual with algae growth on the carapace. (B) Individual with a barnacle attached to the carapace. (C) Individual with a bulging carapace. (D) Individual with an injury on the left lateral carapace. (E) Individual with blindness in the left eye. (F) Individual with tumor nodules on the flipper. (Photographed by Elvie Teo).

assigned unique identifiers to confirmed matches, and we recorded associated metadata, including species, sex, size class, and facial orientation.

Statistical analyses.—We compiled dive logs and associated metadata in Microsoft Excel. We used R (v4.3.3; R Core Team 2023) for all statistical analyses . Behavioral responses to diver presence were summarized descriptively by comparing the number of turtles observed in each behavioral category (resting, swimming, and foraging) before and after diver encounters. Because all Green Turtle observations following diver approach fell into a single behavioral category (swimming), resulting in zero expected frequencies in multiple cells, inferential statistical analysis was not appropriate. We, therefore, present behavioral responses descriptively as frequencies and percentages. We only included encounters with complete behavioral records in the analysis. We assessed normality of sighting frequency data using the Shapiro-Wilk Test. Because the data were not normally distributed, we used non-parametric Kruskal-Wallis Tests to evaluate differences in sighting frequencies among dive sites.

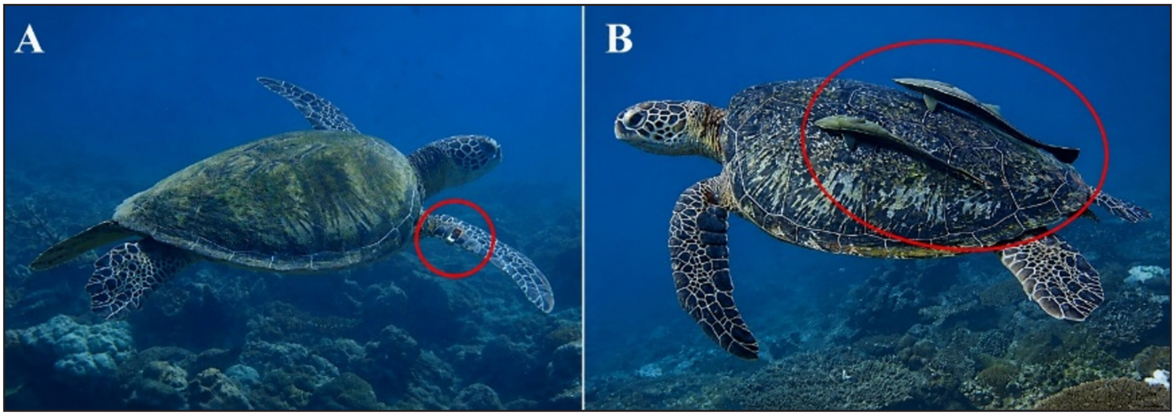

Figure 3. Other observations of Green Turtles (*Chelonia mydas*) at Mantanani Islands Sabah, Malaysia. (A) Individual observed with a tag attached to the right front flipper. (B) Individual observed with two remora fish (Echeneidae) attached to the carapace. (Photographed by Elvie Teo).

Results

Species composition, individual identification, and recaptures.—We completed 29 SCUBA dives, comprising 1,299 min of underwater survey effort. We recorded 92 marine turtle encounters across all dives. Of these, 75 encounters yielded usable facial photographs, and after photo-ID analysis, we identified 60 individual turtles, consisting of 55 Green Turtles and five Hawksbill Turtles (Table 1).

The distribution of photographs by angle was 43% left-facing images, 32% right-facing images, and 25% images capturing both sides of the face. The photo-matching process achieved a recognition success rate of 91.7%. We resighted eight Green Turtles during the study period, and we found six individuals on two occasions and two individuals on three occasions. Because matching was only possible between photographs of the same facial side, individuals photographed from opposite sides on different encounters may have not have been recognized as resightings. Consequently, the number of resighted individuals reported here should therefore be considered a conservative estimate.

Table 1. Survey effort and photo-identification outcomes for marine turtles recorded during two sampling periods (8–11 May and 12–25 August 2024) at the Mantanani Islands, Sabah, Malaysia.

	First Survey	Second Survey	Total
Total dive duration	301 min	998 min	1,299 min
Total no. of turtle sightings	18	74	92
Photo (Right)	3	18	21 (32%)
Photo (Left)	5	19	24 (43%)
Photo (Both)	5	10	15 (25%)

Spatial distribution, size class, behavioral response, and external condition.—We recorded turtles at 10 dive sites around the Mantanani Islands (Table 2). The highest number of sightings occurred at Abalone Avenue (32 turtles) and Bukutan Site (29 turtles). Sighting frequency among sites did not significantly differ ($H = 7.00$, df = 7, $P > 0.05$). We observed Green Turtles at depths ranging from 5 to 17 m, with 69% of sightings occurring between 11 and 15 m. We recorded Hawksbill Turtles at shallower depths, between 5 and 10 m.

From visual size estimation, we classified approximately 67% of Green Turtles as juveniles and 33% as adults. Hawksbill Turtles consisted of approximately 60% individuals classified as adults and 40% as juveniles. Because we assigned size classes *in situ* based on relative body proportions and visual reference cues, these size classes should be considered broad classifications rather than precise measures of maturity.

Table 2. Summary of dive sites, number of dives, and total sightings of marine turtles at 10 study sites in the Mantanani Islands, Sabah, Malaysia. See Figure 1 for location of study sites.

Dive Site	Number of Dives	Total Sightings
Sahara Desert	4	10
Bukutan Site	5	29
Abalone Avenue	4	32
JSK Reef	1	1
ATV	3	5
Sandy Bar Point	5	3
LV Reef	2	11
Rocky Point	3	1
Lighthouse	1	0
Tukun	1	0

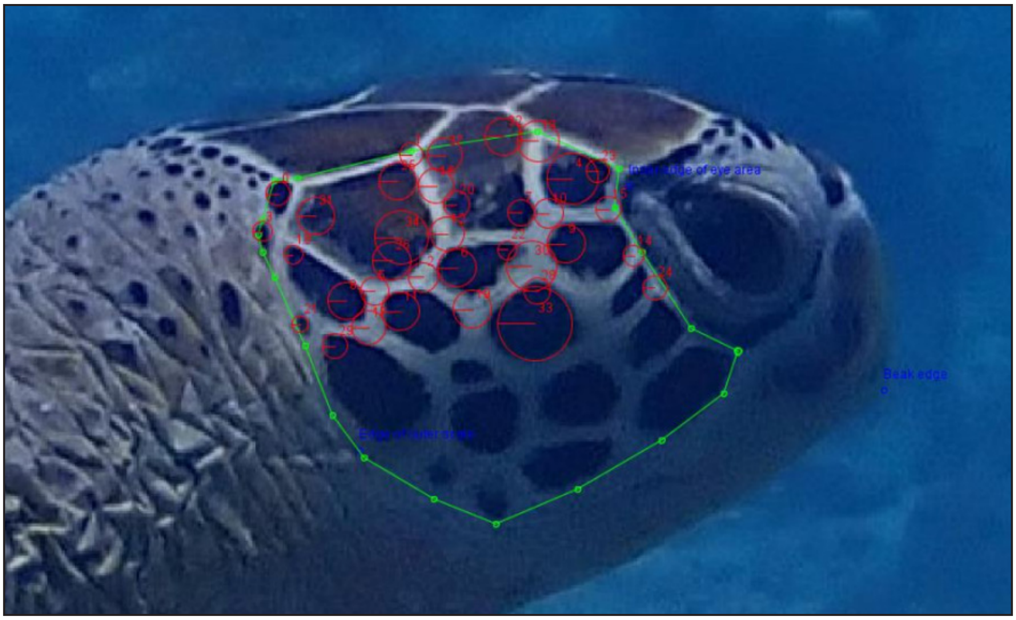

Figure 4. Lateral head scales (green outline) of the Green Turtle (*Chelonia mydas*) with reference points above the eye (blue) and extracted key points (red) used for matching images in I3S. (Photographed by Elvie Teo).

As external sexual characteristics are only reliably expressed in mature males, we could not determine the sex of juvenile turtles. We did not see any individuals exhibiting distinctly elongated tail (which would likely be adult males). Because life stage was estimated visually and adult females cannot be reliably distinguished from juveniles based on external morphology alone, we recorded all remaining individuals, including those visually classified as adults, as of unknown sex to avoid potential misclassification.

Before divers approached, 82% (45/55) of Green Turtles were observed resting, 16% (9/55) were swimming and 2% (1/55) were foraging. Following diver approach, all Green Turtles were observed swimming away from the observer. In contrast, Hawksbill Turtles showed minimal behavioral change, with three of five individuals continuing to forage after diver approach, one individual remaining swimming and one resting individual changing to swimming.

Responses of Green Turtles before and after diver encounters differed significantly (X^2 = 80.40, df = 5, $P < 0.05$). We assessed most turtles (77%) as being in good external condition. Algae growth on the carapace was recorded in 13% individuals, followed by minor barnacle encrustation (3.6%), and carapace injuries or developmental abnormalities. One Green Turtle exhibited tumor growth consistent with fibropapillomatosis. Three Green Turtles were observed with metal flipper tags, and seven individuals hosted one or more the remora Live Sharksucker (*Echeneis naucrates*). No Hawksbill Turtles showed visible injuries, disease symptoms, epibiont infestation, or external tags.

Discussion

Species composition and habitat use.—The higher number of Green Turtles compared to Hawksbill Turtles at the Mantanani Islands aligns with patterns reported for other Malaysian foraging grounds, where Green Turtles represent the primary in-water species (Pilcher 2010; Joseph et al. 2016; Nishizawa et al. 2018, 2024). This species composition likely reflects the availability of shallow reef-associated seagrass and algal resources surrounding the Mantanani Islands, which are known to favor Green Turtle foraging ecology (León and Bjorndal 2002; Joseph et al. 2016). In contrast, Hawksbill Turtles, which typically rely more heavily on sponge-dominated reef habitats, occurred at lower frequencies, consistent with their generally sparse and fragmented populations in Malaysia (Nishizawa et al. 2016; Joseph et al. 2017).

Previous capture-based studies at Mantanani similarly reported a high number of juvenile Green Turtles, supporting the role of the area as a developmental foraging habitat rather than a predominantly adult aggregation (Pilcher 2010;

Pilcher et al. 2016). We also found many juveniles, which is therefore consistent with earlier findings and indicates continuity in habitat use across different survey methods. Juvenile-biased assemblages have also been documented at other nearshore foraging grounds in Malaysia, where shallow coastal habitats provide suitable food resources and relatively stable conditions for immature turtles prior to recruitment into adult foraging or breeding migrations (Nishizawa et al. 2018, 2024). Genetic evidence further suggests ontogenetic connectivity between Mantanani and larger foraging grounds such as Brunei Bay, indicating that Green Turtles recruiting to Mantanani as juveniles may subsequently shift to more extensive foraging habitats as they mature (Joseph et al. 2016).

Photo-ID, site fidelity, and behavioral patterns.— The use of photo-ID software (I3S) demonstrates the effectiveness of non-invasive monitoring for marine turtles in nearshore reef environments. The high recognition success rate that we obtained is comparable to those reported from previous studies (Long and Azmi 2017; Araujo et al. 2019; Kirishnamoorthie 2023). As facial scute patterns in sea turtles are known to remain stable over long periods, photo-ID provides a practical tool for tracking individuals while minimizing handling stress and potential injury.

Despite the high matching success, manual verification of candidate matches remained essential, particularly when image quality varied or facial orientation deviated from the optimal lateral plane (Calmanovici et al. 2018). In addition, the relatively low proportion of individuals photographed from both left and right facial profiles may have reduced the probability of detecting all resightings. Obtaining standardized facial photographs underwater was often challenging because turtles frequently changed direction, swam away, or positioned themselves against reef structures, preventing photographs of both facial profiles from being obtained during the same encounter. Consequently, some individuals photographed from opposite facial profiles during separate encounters may not have been recognized as resightings, resulting in a conservative estimate of site fidelity. These findings highlight the importance of standardized underwater photography protocols, including prioritizing the collection of both facial profiles whenever possible to improve matching success and long-term individual identification. This also reinforces the need for a combination of automated and expert manual verification during the matching process.

Resightings of individual Green Turtles within the study period provide evidence of repeated site use at specific dive locations. While the short temporal scale of the surveys (15 non-consecutive survey days) limits inference on long-term residency, these observations are consistent with documented short- to medium-term site fidelity at other foraging grounds using photo-ID approaches (Shimada et al. 2016; Kirishnamoorthie 2023). The establishment of a photo-ID database for the Mantanani Islands therefore provides an important baseline for future monitoring, enabling the assessment of resighting rates, individual movement within the area, and changes in population structure over time.

Behavioral observations revealed clear species-specific responses to diver encounters. Green Turtles exhibited higher sensitivity, frequently interrupting resting behavior with turtles moving away following the the approach of divers, whereas Hawksbill Turtles continued foraging with minimal observable response. Similar patterns have been reported in other reef systems, where Green Turtles display stronger avoidance responses, potentially due to their reliance on resting sites and prior exposure to disturbance (Griffin et al. 2017).

Several factors may explain the observed behavioral patterns. Individual behavioral plasticity and personality traits can influence tolerance to human disturbance, with bolder individuals exhibiting reduced flight responses compared to more timid turtles, which may incur higher energetic costs due to repeated displacement from resting or foraging sites (Griffin et al. 2017). Local exposure history may also play a role. Green Turtles at Mantanani have previously been subjected to capture-based research methods, including rodeo capture and handling (Pilcher 2010; Pilcher et al. 2016). The presence of external flipper tags on several individual observed during this study indicates previous capture and handling, which may contribute to increased sensitivity to diver approaches observed in this species during non-invasive surveys.

In addition, anthropogenic pressures such as illegal harvesting and fisheries interactions, which have been reported in Sabah waters, may further influence turtle wariness and avoidance behaviour (Joseph et al. 2014, 2019). Past poaching incidents, including large-scale capture and slaughter events in Sabah, suggest that turtles in the region may associate close approaches with potential threats, thereby increasing their sensitivity to diver presence.

In contrast, Hawksbill Turtles at Mantanani have not been subjected to similar capture-based handling, which may partly explain their lower observed reactivity. Habitat-related factors may also contribute to these differences. Hawksbill Turtles are more closely associated with reef environments, which may differ in predator assemblages compared to adjacent habitats such as seagrass areas. Although predator presence was not systematically assessed in this study, variation in predation risk (i.e., from large marine predators such as sharks) could influence vigilance and behavioural responses in sea turtles. Repeated disturbance at resting sites may influence habitat use and detectability, underscoring the need for standardized, low-impact survey approaches in frequently visited reef environments.

External condition and health observations.—The generally good external condition of turtles at the Mantanani Islands suggests that the area currently supports a relatively healthy foraging aggregation. Body condition is widely recognized as an important indicator of habitat quality and energetic status in marine turtles, reflecting food availability, environmental conditions, and exposure to anthropogenic stressors (Labrada-Martagón et al. 2010; Nolte et al. 2020; Nishizawa and Joseph 2022). Most individuals we found exhibited no visible abnormalities, indicating that Mantanani presently provides suitable conditions for sustaining juvenile and adult turtles.

Nevertheless, the occurrence of carapace injuries, epibiont presence, and a suspected case of fibropapillomatosis, based on external lesions consistent with the disease, indicates ongoing exposure to environmental stressors. Epibionts such as algae, barnacles, and remoras are commonly observed on marine turtles and may reflect individual behavior, resting duration, and local environmental conditions, including nutrient availability and substrate type (Burrows et al. 2010). While mild epibiont loads are often associated with healthy individuals, heavy infestations can increase hydrodynamic drag and energetic costs during swimming and foraging (Nolte et al. 2020), and may also contribute to tissue damage, secondary infections, and compromised health conditions in sea turtles (Stacy 2018; Nolte et al. 2020)

Fibropapillomatosis has been increasingly documented at foraging grounds in Malaysia (Loganathan et al. 2021) and is often associated with degraded habitats, poor water quality, and other environmental stressors (Herbst 1994; Samsol et al. 2025). Only a single turtle exhibited external lesions suggestive of fibropapillomatosis and the absence of histopathological or molecular confirmation precludes a definitive diagnosis, but this observation highlights the importance of continued health surveillance and long-term monitoring to detect potential changes in disease occurrence at Mantanani. The observation of tagged individuals confirms ongoing research activity at Mantanani (Pilcher et al. 2016) and highlights the value of integrating photo-identification data with existing tagging and genetic datasets. Such integration can enhance understanding of individual life histories, movement patterns, and population connectivity without additional handling of turtles, thereby supporting more ethical and effective long-term monitoring of this foraging aggregation.

Conclusion.—We provide the first standardized, in-water, photo-ID assessment of marine turtles at the Mantanani Islands and establishes a baseline for non-invasive monitoring in a nearshore reef system along the west coast of Sabah. The presence of predominantly juvenile Green Turtles and repeated resightings of individuals confirms the role of Mantanani as an important developmental foraging habitat. Together with recent evidence of nesting activity reported from a separate study at Mantanani (Nazerah Kong, unpubl report), these findings further support the ecological importance of the island group for both foraging and reproduction. Although most turtles were observed in good external condition, the occurrence of injuries and fibropapillomatosis highlights the importance of continued health surveillance. Behavioral sensitivity to diver presence, particularly among Green Turtles, further underscores the need for low-impact monitoring approaches in areas experiencing increasing tourism pressure.

Photo-ID offers a practical and effective tool for long-term monitoring at Mantanani, allowing population trends, site use, and individual histories to be documented without physical handling. When integrated with existing tagging, genetic, and community-based conservation initiatives, this approach can strengthen management efforts in an area that currently lacks formal protection. Sustained monitoring and local stewardship will be critical to safeguarding this important marine turtle aggregation and informing future conservation planning along the west coast of Sabah.

Acknowledgments.—We extend our sincere gratitude to JSK Mantanani Island Resorts for their generous logistical support and accommodation throughout the duration of this study. We are especially thankful to the JSK Mantanani Dive Centre and Recreational team for their invaluable assistance, guidance, and on-site coordination during fieldwork activities. All sampling and observational procedures involving sea turtles were conducted in accordance with ethical guidelines and were authorized under the Sabah Biodiversity Centre (SaBC) Access License [JKM/MBS.1000-2/13 JLD.2 (67)] and the Sabah Wildlife Department Research Permit (JHL.HQ.600-6/1).

Literature Cited

Araujo, G., C.G. Legaspi, S. Ferber, R. Murray, K. Burdett, S. Grundy, J. Labaja, S. Snow, A. Yaptinchay, and A. Ponzo. 2019. In-water methods reveal population dynamics of a Green Turtle *Chelonia mydas* foraging aggregation in the Philippines. Endangered Species Research 40:207–218.

Bakker, E.S., J.F. Pagès, R. Arthur, and T. Alcoverro. 2016. Assessing the role of large herbivores in the structuring and functioning of freshwater and marine angiosperm ecosystems. Ecography 39:162–179.

Burrows, M.T., S.R. Jenkins, L. Robb, and R. Harvey. 2010. Spatial variation in size and density of adult and post-settlement *Semibalanus balanoides*: effects of oceanographic and local conditions. Marine Ecology Progress Series 398:207–219.

Calmanovici, B., D. Waayers, J. Reisser, J. Clifton, and M. Proietti. 2018. I3S Pattern as a mark-recapture tool to identify captured and free-swimming sea turtles: an assessment. Marine Ecology Progress Series 589:263–268.

Carpentier, A.S., C. Jean, M. Barret, A. Chassagneux, and S. Ciccione. 2016. Stability of facial scale patterns on Green Sea Turtles *Chelonia mydas* over time: a validation for the use of a photo-identification method. Journal of Experimental Marine Biology and Ecology 476:15–21.

Griffin, L.P., J.W. Brownscombe, T.O. Gagné, A.D. Wilson, S.J. Cooke, and A.J. Danylchuk. 2017. Individual-level behavioural responses of immature Green Turtles to snorkeler disturbance. Oecologia 183:909–917.

Hancock, J.M. J., Choma, L. Mainye, P. Wambi, M.R. Stelfox, M.M.R. Polyak, S. Wambua, and S. Kohnk. 2023. Using photo-ID to document and monitor the prevalence of fibropapilloma tumours in a foraging aggregation of Green Turtles. Frontiers in Marine Science 10. https://doi.org/10.3389/fmars.2023.1217683.

Haziq Harith, A.H. 2018. Marine turtle status in the Northeast Semporna Priority Conservation Area. Technical Report, WWF-Malaysia. Selangor, Malaysia. 49 p.

Hochscheid, S., B.J. Godley, A.C. Broderick, and R.P. Wilson. 1999. Reptilian diving: highly variable dive patterns in the Green Turtle *Chelonia mydas*. Marine Ecology Progress Series 185:101–112.

Herbst, L. H. 1994. Fibropapillomatosis of marine turtles. Annual Review of Fish Diseases 4:389–425.

International Union for Conservation of Nature (IUCN). 2025. The IUCN Red List of Threatened Species. Version 2023-1. https://www.iucnredlist.org.

Jensen, M.P., N. Pilcher, and N.N. FitzSimmons. 2016. Genetic markers provide insight on origins of immature Green Turtles *Chelonia mydas* with biased sex ratios at foraging grounds in Sabah, Malaysia. Endangered Species Research 31:191–201.

Joseph, J., Y.K. Chong, P.M. Palaniappan, and H.C. Liew. 2014. Genetic investigation of Green Turtles (*Chelonia mydas*) harvested from a foraging ground at Mantanani, Sabah, Malaysia. Herpetological Conservation Biology 9:516–523.

Joseph, J., G. Jolis, J. Kirishnamoorthie, S.N. Jalimin, H. Nishizawa, H. Muin, I. Isnain, and E. Saleh. 2021. Pp. 95–123 *In* The Marine Ecosystems in Sabah. Yoshida, T., and B.M. Manjaji-Matsumoto. (Eds.). Penerbit Universiti Malaysia Sabah, Kota Kinabalu, Malaysia.

Joseph, J., H. Nishizawa, J.M. Alin, R. Othman, G. Jolis, I. Isnain, and J. Nais. 2019. Mass sea turtle slaugther at Pulau Tiga, Malaysia: genetic studies indicate poaching locations and its potential effects. Global Ecology and Conservation 17:e00586. https://doi.org/10.1016/j.gecco.2019.e00586.

Joseph, J., H. Nishizawa, W.M. Arshaad, S.A.S. Kadir, SA. Jaaman, J. Bali, N.A. Jamaludin, and M. Katoh. 2016. Genetic stock compositions and natal origin of Green Turtle (*Chelonia mydas*) foraging at Brunei Bay. Global Ecology and Conservation 6:16–24.

Joseph, J., H. Nishizawa, M. Hassan, M.I. Zakariah, S.A. Jaaman, and X. Zhang. 2017. Utilization of Brunei Bay (Malaysia) as a developmental and foraging habitat for Hawksbill Turtle (*Eretmochelys imbricata*). Regional Studies in Marine Science 16:304–307.

Kirishnamoorthie, J. 2023. Photo-Identification and laser photogrammetry of Green (*Chelonia mydas*) and Hawksbill Turtles (*Eretmochelys imbricata*) foraging in Semporna waters. M.S. Thesis. Universiti Malaysia Sabah, Malaysia. 123 p.

Kirishnamoorthie, J., H. Nishizawa, J. Alin, H. Muin, and J. Joseph. 2023. Illegal tortoiseshell harvest of Hawksbill Turtles (*Eretmochelys imbricata*) in Southeast Asia: evidence from Baturua Reef, Semporna, Sabah, Malaysia. Journal of Sustainability Science and Management 18: 54–67.

Labrada-Martagón, V., L.C. Méndez-Rodríguez, S.C. Gardner, M. López-Castro, and T. Zenteno-Saví. 2010. Health indices of the Green Turtle (*Chelonia mydas*) along the Pacific coast of Baja California Sur, Mexico. I. Blood biochemistry values. Chelonian Conservation and Biology 9:162–172.

León, Y.M., and K.A. Bjorndal. 2002. Selective feeding in the Hawksbill Turtle, an important predator in coral reef ecosystems. Marine Ecology Progress Series 245:249–258.

Loganathan, A.L., P. Palaniappan, and V.K. Subbiah. 2021. First evidence of chelonid herpesvirus 5 (ChHV5) infection in Green Turtles (*Chelonia mydas*) from Sabah, Borneo. Pathogens 10:1404. https://doi.org/10.3389/fmars.2023.1185111

Long, S.L., and N.A. Azmi. 2017. Using photographic identification to monitor sea turtle populations at Perhentian Islands Marine Park in Malaysia. Herpetological Conservation and Biology 12:350–366.

Mancini, A., I. Elsadek, and B. Madon. 2015. When simple is better: comparing two sampling methods to estimate Green Turtle abundance at coastal feeding grounds. Journal of Experimental Marine Biology and Ecology 465:113–120.

Migliaccio, O., G. Jolis, P. Bondong, E.A. Boro, and A. Tuuga. 2020. Nesting activity of *Chelonia mydas* and *Eretmochelys imbricata* at Pom-Pom Island, Sabah, Malaysia. Marine Turtle Newsletter 160:8–13.

Nishizawa, H., and J. Joseph. 2022. Differences in the morphological body condition index of sea turtles between species and size classes. Journal of the Marine Biological Association of the United Kingdom 102:479–485.

Nishizawa, H., J. Joseph, and Y.K. Chong. 2016. Spatio-temporal patterns of mitochondrial DNA variation in Hawksbill Turtles (*Eretmochelys imbricata*) in Southeast Asia. Journal of Experimental Marine Biology and Ecology 474:164–170.

Nishizawa, H., J. Joseph, Y.K. Chong, S.A. Syed Kadir, I. Isnain, T.A. Ganyai, S.A. Jaaman, and X. Zhang. 2018. Comparison of the rookery connectivity and migratory connectivity: insight into movement and colonization of the Green Turtle (*Chelonia mydas)* in Pacific-Southeast Asia. Marine Biology 165:77. https://doi.org/10.1007/s00227-018-3328-9.

Nishizawa, H., J. Joseph, G. Jolis, I. Isnain, H. Muin, S. Johari, and E. Saleh. 2024. Variations in body condition of Green Turtles (*Chelonia mydas*) in two nearby foraging grounds indicate their sensitivity to foraging habitats. Aquatic Conservation: Marine and Freshwater Ecosystems 34:e4038. https://doi.org/10.1002/aqc.4038.

Nolte, C.R., R. Nel, and M.C. Pfaff. 2020. Determining body condition of nesting Loggerhead Sea Turtles (*Caretta caretta*) in the southwest Indian Ocean. Journal of the Marine Biological Association of the United Kingdom, 100: 291–299.

Palaniappan, P. 2017. Morphometric analysis of resident Green Sea Turtles (*Chelonia mydas*) in Mabul Island, Sabah, Malaysia. International Journal of Fisheries and Aquatic Studies 5:174–178.

Pawlik, J.R., T.L. Loh, and S.E. McMurray. 2018. A review of bottom-up vs. top-down control of sponges on Carribean fore-reefs: what's old, what's new, and future directions. PeerJ 6:e4343. https://doi.org/10.7717/peerj.4343.

Phu, J.L., and P. Palaniappan. 2019. Recaptured wild Green Turtles (*Chelonia mydas*) with newly documented boat strike injuries in Mabul Island, Sabah, Malaysia. Chelonian Conservation and Biology 18:265–272.

Pilcher, N.J. 2010. Population structure and growth of immature Green Turtles at Mantanani, Sabah, Malaysia. Journal of Herpetology 44:168–171.

Pilcher, N.J., D. Pilcher, F. Pilcher, J. Williams, and M. Bassa. 2016. Changes in sex ratio among a foraging population of Green Sea Turtles *Chelonia mydas* at Mantanani, Sabah, and implications for turtle management. Technical Report, Marine Research Foundation, Kota Kinabalu, Malaysia. 12 p.

R Core Team. 2023. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://

www.R-project.org/.

Samsol, S., M.U. Rusli, K. Jeethvendra, H. Nishizawa, H. Muin, and J. Joseph. 2025. Hematological and blood biochemical variations, and their correlation with body condition in wild-foraging sea turtles of the Celebes Sea. Sains Malaysiana, 54:959–974.

Shimada, T., R. Jones, C. Limpus, R. Groom, and M. Hamann. 2016. Long-term and seasonal patterns of sea turtle home ranges in warm coastal foraging habitats: Implications for conservation. Marine Ecology Progress Series 562:163–179.

Schofield, G., K.A. Katselidis, P. Dimopoulos, and J.D. Pantis. 2008. Investigating the viability of photo-identification as an objective tool to study endangered sea turtle populations. Journal of Experimental Marine Biology and Ecology 360:103–108.

Stacy, N., J.M. Lynch, M.D. Arendt, L. Avens, J.B. McNeil, C. Cray, R.D. Day, C.A. Harms, A.M. Lee, M.M. Peden-Adams, et al. 2018. Chronic debilitation in stranded Loggerhead Sea Turtles (*Caretta caretta*) in the southeastern United States: morphometrics and clinicopathological findings. PLoS ONE 13:e0200355. https://doi.org/10.1371/journal.pone.0200355.

Tanangonan, J.B., F., Wakebe, M., Shimakoshi, Y., Hattori, M., Nishikawa, and K. Tsureishi. 2025. In-water photo-ID to estimate foraging movements of Green Turtles *Chelonia mydas* in Apo Island, Negros Oriental, Philippines. Bulletin of Marine Science 101:315–323.

Wallace, B.P., A.D., DiMatteo, A.B., Bolten, M.Y., Chaloupka, B.J., Hutchinson, F.A., Abreu-Grobois, et al. 2011. Global conservation priorities for Marine Turtles. PLoS ONE 6(9): e24510. https://doi.org/10.1371/journal.pone.0024510.

Elvie Jen Teo Mei Jun holds a degree in Marine Science from Universiti Malaysia Sabah (UMS). She has been actively involved in marine conservation and sustainability initiatives in Sabah, including coordinating grassroots conservation efforts. During her time at UMS, she coordinated student-led conservation activities through her role as President of the Mariners Club. She has also represented Malaysia in several international exchange programs, contributing to knowledge sharing and engagement in marine conservation at the regional level. (Photographed by Tasia Talbert).

Juanita Joseph is an Associate Professor at the Institut Marin Borneo, Universiti Malaysia Sabah. She obtained her Ph.D. from Royal Holloway, University of London, UK, and holds an M.Sc. degree from Universiti Putra Malaysia. With nearly 30 y of experience in sea turtle research and conservation, her work focuses on marine turtle molecular ecology, as well as the assessment and conservation of nesting and foraging habitats. She is actively involved in marine turtle research and conservation at the state, national, and regional levels, particularly within the Asia-Pacific region. (Photograph courtesy of Institut Marin Boreno, Universiti Malaysia Sarah).

Chen Cheng Ann is an Associate Professor at the Institut Marin Borneo, Universiti Malaysia Sabah. He obtained his Ph.D. in Marine Biology from Universiti Malaysia Sarawak. His research interests encompass marine biodiversity, taxonomy, and ecological assessments across coastal and island ecosystems in Southeast Asia. He has been actively involved in marine biodiversity surveys and conservation related studies in Sabah, contributing to the understanding and monitoring of marine fauna in the region. (Photographed by Yusdi Ismail).

Muhamad Ariff Ng Abdullah is the Deputy General Manager of JSK Mantanani Island Resorts, Sabah, Malaysia. With extensive experience in the hospitality industry, he has held various leadership roles in international hotel chains across Malaysia and the region. He is actively involved in sustainable tourism and conservation initiatives in Mantanani Islands, supporting efforts in marine conservation, including sea turtle protection and community-based environmental programs. His work bridges tourism operations with conservation practices to promote responsible island management. (Photograph courtesy of JSK Mantanani Island Resorts Sdn Bhd).

Hussien muin has dedicated 41 y of service to the Sabah Wildlife Department and currently serves as a Wildlife Officer at the Sandakan Wildlife Office. Since 2017, he has also taken on the role of Marine Turtle Species Manager for Sabah under the department. His work focuses on enforcing wildlife legislation and overseeing marine turtle conservation activities carried out by local communities and tourism operators across Sabah. Through this role, he has been directly involved in monitoring, coordination, and ensuring that conservation efforts are effectively implemented on the ground. Muin has also represented Sabah in various turtle conservation programmes at the state, national, and regional levels, contributing to broader efforts in marine turtle management and protection. (Photograph courtesy of Sabah Wildlife Department).