Comparing Epoxy and Para Rubber Glue for Attaching Satellite Tags to Juvenile Green Sea Turtles: Implications for Behavior and Growth

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ABSTRACT

This study aimed to investigate the efficiency of epoxy and para rubber glue for attaching artificial satellite tags to juvenile green sea turtles (*Chelonia mydas*). Two groups of 10 juvenile *C. mydas* each were monitored for two months before and after tag attachment. Measurements and analyses of straight carapace length (SCL), straight carapace width (SCW), weight, and behaviors were conducted. The results showed that there were no significant differences in the final SCL, SCW, and weight of the turtles between the two adhesive treatments. However, the average daily gains in SCL and SCW were significantly different before and after the attachment of epoxy. The most frequently observed behavior in both adhesive groups was buoyancy, which decreased in frequency after tag attachment in both treatments. Other behaviors, such as scratching, startle responses and underwater movement also exhibited changes after attachment, varying with the type of adhesive used. The study demonstrated that natural adhesive materials serve as an alternative method for attaching satellite tags to rapidly growing juvenile sea turtles, minimizing injury and maintaining flexibility to prevent changes in carapace shape. Overall, the findings suggest the potential for using natural adhesive materials in future satellite tagging efforts to minimize negative impacts on sea turtles.

Keywords: *Chelonia mydas,* Epoxy, Green sea turtle, Growth and behavior, Para rubber glue, Satellite tagging technique

INTRODUCTION

The green sea turtle (*Chelonia mydas*) is considered one of the large, long-lived sea turtles. It lives in shallow tropical and subtropical waters around the world (Limpus *et al*., 1994a; Limpus and Chaloupka, 1997). They are found in various coastal areas of Thailand, including the Andaman Sea on the west coast and the Gulf of Thailand on the east coast (Chantrapornsyl, 1993; Settle, 1995; Wang *et al*., 2021). Their habitats include seagrass beds, coral reefs, and other coastal environments (Kobayashi *et al*., 2008; Hart *et al*., 2010; Winton *et al*., 2018). *C. mydas* is known to play a crucial role in maintaining the health of marine ecosystems (McDermid *et al*., 2007; Morreale, 2009 Hernández *et al*., 2014). Scientists and conservation organizations in Thailand have conducted research and monitoring programs to gain a better understanding of the population dynamics, nesting behavior, migratory patterns, and health of green sea turtles. Furthermore, the sea turtle populations has declined due to anthropogenic threats such as plastic consumption, boat propeller injuries, global warming, bycatch, habitat loss, and predation. (Lutcavage *et al*., 1997; Bugoni *et al*., 2001; Chaloupka *et al*., 2004; Lewison *et al*., 2004a; 2004b; Lewison and Crowder, 2007; Soykan *et al*., 2008; Hawkes *et al*., 2009; Witt *et al*., 2010; Keller, 2013)

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Similar to other sea turtles, *C. mydas* migrates from either breeding or feeding purposes across all age groups (Limpus *et al*., 1992; 1994a; 1994b; Limpus and Nicholls 1994; Musick and Limpus, 2017). The migratory route of adult *C. mydas* can cover long distances, ranging from hundreds to thousands of kilometers between feeding grounds and nesting beaches (Bowen *et al*., 1996; Lahanas *et al*., 1998; Bolten *et al*., 2003). When sea turtles reach reproductive maturity, mated female turtles come ashore to lay their eggs on the beach. After completing the nesting process, the female green turtles return to the ocean, leaving the eggs to hatch and hatchlings to begin their own journey (Bolten *et al*., 2003). Juvenile green turtles also exhibit migration patterns during their early life stages, foraging along coastlines which they find abundant food resources and protection from predators (Godley *et al*., 2003; Makowski *et al*., 2006; Schofield *et al*., 2010; Casale *et al*., 2012; Lamont *et al*., 2015; Musick and Limpus, 2017). This early life stage is known as "the lost years" because the exact locations of the turtles were largely unknown (Musick and Limpus, 2017). Many studies have attempt to track and understand these migration patterns (Luschi *et al*., 2006; Godley *et al*., 2008; Hays *et al*., 2010; Mansfield *et al*., 2021).

Various methods have been applied for tracking migratory routes, such as visual identification, satellite tracking and acoustic tagging (Vander Zanden *et al*., 2015; Musick and Limpus, 2017). Visual identification helps researchers track sea turtles through unique markings on their shells or using photo identification techniques. This method allows for long-term monitoring of individual turtles, providing insights into their movement patterns and site fidelity (Carpentier *et al*., 2016). Satellite tracking and acoustic tagging involve attaching a transmitter to the turtle's shell or implanting it in its body, which can then be detected by satellites and underwater receivers, respectively (Hays and Hawkes, 2018). In the past, tracking hatchlings and juveniles was challenging due to the lack of small-scale tracking technologies capable of remotely monitoring their movements for extended periods, ranging from weeks to months. Data availability was limited, with observations primarily conducted in habitats near the shore (Papi *et al*., 1995).

The satellite tags have been used to study habitat utilization and migration patterns in sea turtle for a long time (Balazs *et al*., 1996). For instance, Al-Mansi *et al*. (2021) utilized satellite tags to monitor the nesting behavior and migration routes of green turtles in Ras Baridi, Red Sea. Moreover, various methodologies have been compared to satellite tags attachment to the carapaces of juvenile sea turtles, aiming to minimize the impact on their growth and welfare. Satellite tags have typically been attached to the turtles' carapaces using epoxy materials (Balazs *et al*., 1996; Mitchell, 2000; Seney *et al*., 2010). Additionally, there has been a comparison between the use of flexible acrylic silicone attachments and harnesses made of elastic fabric, taking into account the growth rate of sea turtles (Mansfield *et al*., 2012). Mansfield *et al*. (2021) experimented with adhesive materials such as urethane adhesives, including products like 3M 5200™, 3M 5200 Fast Cure (FC)™, and 3M 4200. Despite the reliance on chemical materials for these adhesives, no negative impacts on sea turtles have been reported. Instead, the studies have highlighted the benefits of using satellite data to understand sea turtle habitats.

Furthermore, it is important to note that mixing the two components of epoxy generates heat, which could potentially affect the soft shell of juvenile sea turtles. As they mature, their shells become harder. An alternative adhesive, natural para rubber glue remains stable at room temperature and dries upon exposure to air through water evaporation. This glue also possesses a flexible quality that may be better suited for the rapid growth of juvenile sea turtles.

Because the growth rate of juvenile sea turtles in the 'lost year' group is very high (Miller, 1997; Seney *et al*., 2010), they are likely to be affected by the adhesive used for tag attachment. Therefore, this study will compare the growth and behavior of sea turtles after the attachment of artificial satellite tags using both chemical and natural adhesives. These materials offer a novel method for attaching satellite tags, especially for rapidly growing sea turtles. They have the potential to reduce injuries associated with adhesion reactions and to increase flexibility, thereby preventing alterations to the shape of the carapace. This research aims to minimize the negative impact of satellite tag attachments on sea turtles and the environment.

MATERIALS AND METHODS

Choice of the tested animals and experimental design

The eggs of the green turtle (*Chelonia mydas*) from Sane Bay, Phuket, Thailand, were collected in March 2022 and incubated for 58 days. The 20 juveniles *C. mydas* used in the experiment were all 3 months and 12 days old. The average straight carapace length (SCL) was 10.27±0.04 cm, the average straight carapace width (SCW) was 9.16±0.02 cm, and the average weight was 188.77±0.28 g. The experiment was set up with two treatments: using epoxy and para rubber glue. Ten (10) juvenile *C. mydas* were randomly assigned to each of the two treatments. Initial measurements of SCL, SCW, and weight for the sea turtle in the epoxy treatment were 10.31±0.09 cm, 9.17±0.13 cm, 189.00±5.17 g, respectively, and for the para rubber glue treatment were 10.22±0.09 cm, 9.13±0.09 cm, and 188.44±4.22 g, respectively. The turtles were fed pre-soaked commercial feed pellets at 1:0.5 w/v ratio of pellet to water for small-sized marine carnivorous fish (460 $g\cdot kg^{-1}$ crude protein on dry matter basis, Pro feed 903; Thai Union Feed mill Company Limited, Thailand). They were fed twice per day, at 09:00 a.m. and 04:00 p.m. The amount of food given was 4–6% of their body weight per day. Additionally, the tanks were cleaned, and a complete water exchange was done daily at 10:00 a.m.

Tag attachment trial

Two types of adhesives materials were used to attach the satellite tags to the turtle carapaces. The first adhesive was ALTECO Epoxy Putty&Steel (ALTECO INC). The second adhesive was para rubber glue, specifically designed for sea water conditions. The trial tags were modified from rubber (Figure 1). They imitated the Telonics model SeaTrKr-4170-4, with dimensions of 1.78 cm in width, 3.89 cm in length, and 1.30 cm in height, resulting in a weight of 9.5 g (Manfield *et al*., 2012). To attach the tags, the carapace was cleaned with sandpaper followed by 70% ethyl alcohol, and then air dried. The tags and adhesive materials were

Figure 1. The trial tags modified from rubber as an imitation of Telonics model SeaTrKr-4170-4, i.e., a width of 1.78 cm, length of 3.89 cm, and height of 1.30 cm.

aligned on the carapace, overlapping vertebral scutes from I to IV, and slightly overlapping the adjacent coastal scutes (Figure 2). The carapace needed to be kept moist during attachment by water spraying on the body, except for the attachment area. After attaching the artificial satellite tags, all green sea turtles were suddenly released into a fiberglass tank with a diameter of 148 cm and a height of 74 cm, filled with 250 L of sea water once both adhesive materials had dried.

Data collection and analyses

The SCL and SCW was measured using a MITUTOYO 300 mm Vernier caliper with an accuracy of 0.05 mm. The average daily gains (ADG) and total weight were measured using an OHAUS digital scale (PRSERIES model) with precision to two decimal places. Eight types of behaviors were observed in each individual juvenile for 10 min before the experiment, including surface swimming, underwater moving, buoyancy, diving, rubbing (the act of rubbing the shell against the edge of the pond), frightening (changing direction and speed rapidly), scrubbing (brushing the back of the shell with a flipper), and biting. The floating ability of the tagged juveniles, specifically the carapace height over the water surface (CHW), was captured by photographing the turtles in a floating position (Figure 3). The images were saved with the turtle carapace oriented at a 90-degree angle to the camera, and then imported into Good Note Version 5.9.34 for CHW measurement. These measurements were recorded bi-monthly, both before and after the installation of the satellite transmitter model. The number of observed behavior expression and all collected variables were tested for the differences between pre- and post-attachment periods using a paired-sample t-test with a 95% confidence level. The statistical analysis was performed using SPSS® 26 for Windows.

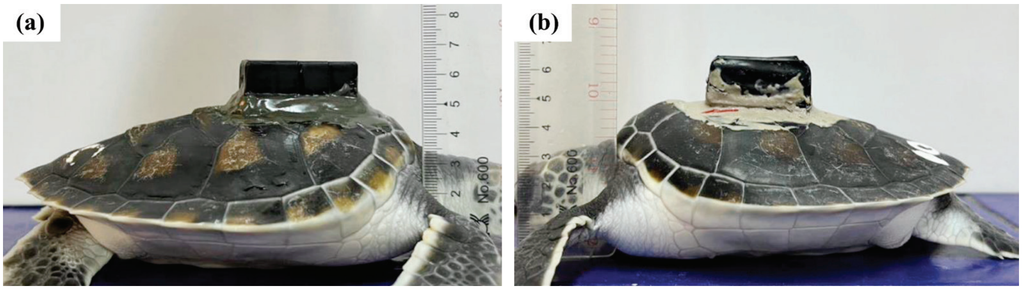

Figure 2. Tag and adhesives materials aligned on the carapace: (a) epoxy; (b) rubber glue adhesive.

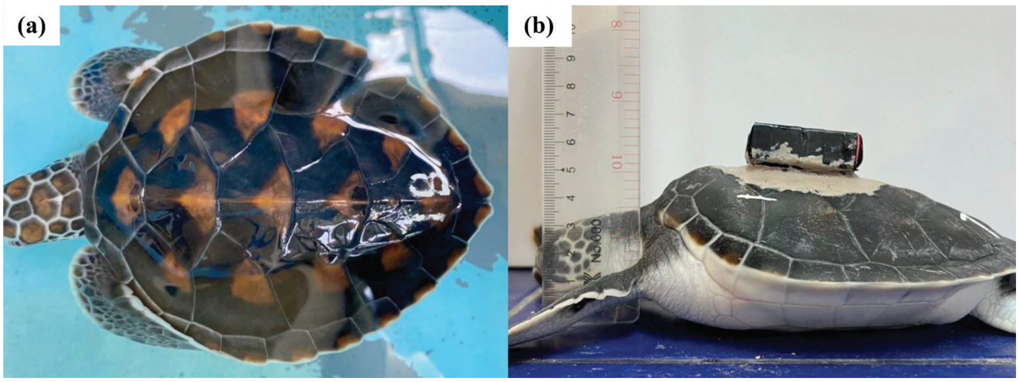

Figure 3. The height of carapace over the water surface, HCW: (a) photo shooting, when the turtle was in a floating position; (b) the turtle carapace oriented at a 90-degree angle.

RESULTS AND DISCUSSION

Growth

After two months of the experiment, juveniles of *Chelonia mydas*, approximately 5 months old, showed growth to an average straight carapace length (SCL) of 14.71±0.73 cm and and straight carapace width (SCW) of 13.27±0.59 cm, with an average weight of approximately 511.21± 66.61 g (Table 1). Drying times were 4.27±0.76 h for para rubber glue and 0.56±0.76 h for epoxy. The shorter drying time for epoxy compared to para rubber glue is due to epoxy being a thermosetting polymer, where para rubber glue is the water-based. Consequently, when para rubber glue dries, the adhesion time of epoxy on turtles (n = 10) lasted an average of 17.40±4.75 days. In turtles with an attachment period of 18 days or longer, the central carapace subsided, and the second scale from the head collapsed, leaving a mark from the epoxy adhesion (Figure 4b). This mark typically disappeared within 4.20±1.22 days because the soft shell of the juvenile *C. mydas* can recover when they are young (Seney *et al*., 2010; Mansfield *et al*., 2012). The adhesion duration of para rubber glue was 13.50± 2.95 days, with no observed changes in the carapace or marks after the material loosened (Figure 4a). The final SCL, SCW, and weight of the juvenile *C. mydas* were not significantly different between the two adhesives (p>0.05), although the volume used in the para rubber glue treatment was slightly higher than that in the epoxy treatment. (Table 1). The necessity for a higher volume of para rubber glue ensured a tight attachment; however, the weight of dried para rubber glue was less than that of epoxy. Nonetheless, the average daily gains (ADG) in terms of SCL and SCW for the juvenile *C. mydas* were significantly different before and after attachment in the epoxy treatment (Table 2a), but no significant differences were found in the para rubber glue treatment across all tested ADGs (Table 2b). This

Table 1. The mean±SD of the final straight carapace length (SCL), straight carapace width (SCW) and weight of experimented juvenile *Chelonia mydas* from 2 different adhesives, where p≥0.05 indicate non-significant difference between mean values in the same row.

Variables	Epoxy	Para rubber glue	p-value
Final SCL (cm)	14.61±0.64	14.81±0.82	0.775
Final SCW (cm)	13.16±0.46	13.37±0.71	0.429
Final weight (g)	505.16±56.30	517.25±76.92	0.871

Table 2. The mean±SD of average daily gain (ADG), straight carapace length (SCL), straight carapace width (SCW) and weight of experimented juvenile *Chelonia mydas*, before and after the attachment where p<0.05 indicate significant differences between mean in the same row.

(a) Epoxy

ADG (cm·day^{-1})	Before	After	p-value
Final SCL (cm)	0.09±0.02	0.04±0.02	0.005
Final SCW (cm)	0.09±0.03	0.04±0.02	0.004
Final weight (g)	7.43±2.08	6.66±2.73	0.609

(b) Rubber glue

ADG of Body	Before	After	p-value
ADG of SCL (cm·day^{-1})	0.10±0.02	0.11±0.04	0.564
ADG of SCW (cm·day^{-1})	0.09±0.01	0.10±0.05	0.475
ADG of weight (g·day^{-1})	7.47±1.02	8.51±4.37	0.624

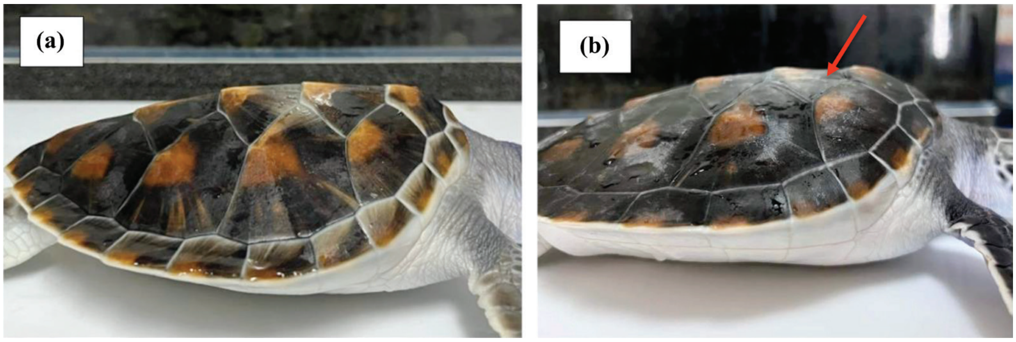

Figure 4. The shell of sea turtle after the adhesive material loosen, (a) para rubber glue; (b) epoxy.

difference is likely due to the hardness of epoxy when fixed on the shell of *C. mydas*, resulting in lower ADGs compared to para rubber glue.

Behaviors

The most frequently observed behaviors in both experimental sets were staying at the water surface. In the epoxy group, the frequency before adhesive attachment was found to be 6.87±2.57 times within 10 min, which then declined to 4.87±1.79 times per 10 min. In the para rubber glue group, the frequency before adhesive attachment was 6.27±0.82 times within 10 min, and after attachment, it was 5.00±2.74 times within 10 min (Table 3). Behaviors such as edge scrubbing, exhibiting fright responses, and biting were least observed in the epoxy group before adhesive attachment. After adhesive attachment, frequencies of scrubbing and biting increased significantly ($p<0.05$) to 0.67±0.15 and 0.27±0.15 times per 10 min, respectively. The adhesive attachment influenced scrubbing and biting behaviors significantly ($p<0.05$). In the para rubber glue group, there was a significant increase in surface swimming behaviors after adhesive attachment from 3.06±0.86 to 4.53±0.84 times per 10 min, along with a decrease in diving behaviors from 1.47±0.06 to 0.33±0.58 times per 10 min. The use of para rubber glue had a significant impact on surface swimming and diving behaviors ($p<0.05$).

Buoyancy

Before the application of the epoxy materials, carapace height over water surface (CHW) was 1.11±0.25 cm. However, after attaching the material, CHW was lower than the water surface, at -1.26±0.59 $cm \cdot turtle^{-1}$ (Table 4). This difference was found to be statistically significant when compared to the buoyancy characteristics observed before bonding ($p<0.05$) (Table 4). With the rubber glue, The CHW was measured at 1.03±0.13 cm. After attaching the material, the CHW decreased to 0.40±0.13 $cm \cdot turtle^{-1}$ (Table 4). The rubber adhesive material significantly affected the turtles' buoyancy behavior at a statistically significant level compared to their previous buoyancy behavior before attachment ($p<0.05$).

The attaching time of the material was observed to be different. The duration for para rubber glue was higher than epoxy, as most para rubber glues are water-based and can have the issue of slow drying (Boonrasi, 2020). According to Chantrapornsyl *et al*. (2011), the minimum drying time was 30 min. The epoxy treatment leaves a subsided mark on the top of the carapace, which typically disappears within 4.20±1.22 days (Seney *et al*., 2010; Mansfield *et al*., 2012). The duration of the peeling process in both materials corresponded to the average daily growth rate of turtles, comparing the period before and after the application of the material. It was found that the turtles treated with epoxy exhibited a significant decrease in the daily rate of carapace growth after the material was applied. In contrast, turtles attached with para rubber glue showed a significant continued increase in daily growth rate. Consequently, turtles attached by epoxy experienced deformation and collapse of the carapace, while para rubber glue can adhere

Table 3. Comparison of average frequency of behaviors exhibited (mean±SD of times per 10 min) before and after adhesive material attachment in turtles (n = 20, 10 turtles·group^{-1}), where $p<0.05$ indicate significant difference between means in the same row.

Treatment	Behavior	Before	After	p-value
Epoxy	Surface swimming	3.67±1.20	4.53±2.17	0.454
	Underwater moving	1.80±1.87	2.07±1.48	0.772
	Buoyancy	6.87±2.57	4.87±1.79	0.100
	Diving	0.87±0.90	1.00±0.97	0.845
	Rubbing	2.60±1.98	4.53±1.60	0.270
	Scrubbing	0.00±0.00	0.67±0.15	0.022
	Frightening	0.00±0.00	0.00±0.00	1.000
	Biting	0.00±0.00	0.27±0.15	0.016
Rubber glue	Surface swimming	3.06±0.86	4.53±0.84	0.017
	Underwater moving	0.87±0.90	2.00±0.94	0.171
	Buoyancy	6.27±0.82	5.00±2.74	0.286
	Diving	1.47±0.06	0.33±0.58	0.039
	Rubbing	2.37±1.18	5.27±1.88	0.076
	Scrubbing	0.67±0.15	0.33±0.33	0.099
	Frightening	0.00±0.00	0.00±0.00	1.000
	Biting	0.00±0.00	0.07±0.15	0.374

Table 4. The mean±SD of carapace height over water surface (CHW) to show the buoyancy comparison the measurement before and after epoxy and rubber glue attachment (n = 20), where $p<0.05$ indicate significant difference between means in the same row.

Treatment	CHW before	CHW after	p-value
Epoxy (cm)	1.11±0.25	-1.26±0.59	0.000
Para rubber glue (cm)	1.03±0.13	0.40±0.13	0.002

Note: The positive value means the carapaces were over water surface, and the negative value means carapaces were under water surface.

and provide water resistance and flexibility (Yoksan, 2008). It does not adversely affect turtle growth or carapace deformation. It is clear that epoxy affects the subsided mark on the same spot of the top of the juvenile sea turtle shell. Although para rubber glue has less impact on the growth rate of sea turtles than epoxy adhesive, the average lifespan of epoxy adhesive on the back of turtles is longer than rubber adhesive. Therefore, the adhesion properties of para rubber glue will be taken into account for the development of next-generation para rubber glue.

Behaviors were compared before and after the gluing process. It was found that the adhesion of the material affected certain behaviors of the turtles in both experimental sets. The use of epoxy increased aggressive behavior, with turtles exhibit biting, swimming, and rubbing against the edges of the pond. This attaching with epoxy might cause the turtles to experience higher levels of stress and discomfort, as expressed through biting behavior (Rajagopalan *et al*., 1984). The application of epoxy also affected the buoyancy characteristics of the turtles, causing an increase in submersion and reducing the area of the dorsal carapace emerging from the water. Since the weight of the modified tag, including epoxy, was 14.74±1.75 g, it had a negative effect on the buoyancy characteristics. In contrast, the use of para rubber glue resulted in a decrease in diving behavior and an increase in surface swimming. Additionally, diving behavior was affected by the weight of the para rubber glue, combined with the simulated materials weighing 10.07±0.45 g, lighter than epoxy. The presence of air bubbles in para rubber glue made it more difficult for turtles to dive, resulting in a reduction in their diving behavior and an increase in surface swimming. Para rubber adhesives have a similar effect on buoyancy as epoxy, but the turtle's buoyancy still shows some variation. Only the height of the carapace that emerges from the water was reduced compared to its height before attaching the material.

When comparing the height of the carapace that emerges above the water while floating, turtles with epoxy attachment were found to have lower carapace heights than those with para rubber attachment. There was a statistically significant difference in buoyancy above water between the turtles in the epoxy attachment group and those in the para rubber glue group. This indicates that the para rubber glue is lightweight and doesn’t disturb the turtle's normal buoyancy much. Regarding the appearance of the turtle’s carapaces after the material has come off, it was observed that turtles attached with epoxy had deformed carapaces. In contrast, turtles attached with para rubber glue showed no sign of deformity. It is packed with properties such as salt-water resistance and low weight, ensuring optimal performance. The following steps were performed multiple times on each sea turtle to achieve the desired results without causing any deformations in the carapace.

CONCLUSIONS

The study revealed that the turtles attached with epoxy experienced carapace deformation and a decrease in their daily growth rate. In contrast, turtles attached with rubber glue exhibited continued growth without adverse effects, including during the attaching and drying time between the two materials. The study observed changes in turtle behaviors, such as increased aggression with epoxy bonding and reduced diving behavior with rubber glue. Furthermore, buoyancy characteristics were affected differently by the two adhesives: turtles with epoxy attachment showed higher carapace heights above water, while those with para rubber glue maintained normal buoyancy but exhibited reduced diving behavior.

After material removal, the appearance of the carapaces indicated deformations in turtles bonded with epoxy, whereas those attached with para rubber glue showed no deformations. The study proposes several recommendations aimed at minimizing the impact on turtle behavior and well-being when using adhesive materials for research purposes. These suggestions include developing quicker-drying formulations of para rubber glue, assessing the adhesive's compatibility with various turtle species and shell textures, extending the study duration for comprehensive data collection, and conducting age-specific research. The primary goal is to prioritize environmentally friendly and turtle-safe alternatives, with a special focus on options such as para rubber glue. This substance offers excellent adhesion, cost-effectiveness, water resistance, fire resistance, non-toxicity, and environmental sustainability, all contributing to reduced environmental pollution. The study highlights the need for new adhesive materials that minimize impact on turtles and advocates for the involvement of rubber growers in creating beneficial para rubber glue. This glue could be used in future studies of the behaviors of other sea turtle species through satellite tagging.

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LITERATURE CITED

Al-Mansi, A.M., A.Z. Sambas, B.A. Abukaboos, A.H. Al Zahran, A.S. Abdulaziz, A.A. Almasabi, R.S. Alkreda and J. Miller. 2021. Satellite tracking of post-nesting green sea turtles (*chelonia mydas*) From Ras Baridi, Red Sea. **Frontiers in Marine Science** (8): 758592. DOI: 10.3389/fmars.2021.758592.

Balazs, G.H., R.K. Miya and S.C. Beavers. 1996. **Procedures to attach a satellite transmitter to the carapace of an adult green turtle, *Chelonia mydas*.** Proceedings of the 15th Annual Workshop on Sea Turtle Biology and Conservation 1996: 21–26.

Bolten, A.B., K.A. Bjorndal, H.R. Martins, T. Dellinger, M.J. Biscoito, S.E. Encalada and B.W. Bowen. 1998. Transatlantic developmental migrations of loggerhead sea turtles demonstrated by mtDNA sequence analysis. **Ecological Applications** 8(1): 1–7. DOI: 10.1890/1051-0761(1998)008[0001:TDMOLS]2.0.CO;2.

Bolten, A.B., P.L. Lutz, J.A. Musick and J. Wyneken. 2003. **Variation in sea turtle life history patterns: neritic vs. oceanic developmental stages.** In: The Biology of Sea Turtles, Volume 2. (eds. P. Lutz, J.A. Musick and J. Wyneken), pp. 243–257. CRC Press Boca Raton, London, New York, Washington, D.C., USA.

Boonrasi. 2020. Hot-melt adhesive from natural rubber. **Academic and Research Journal Rajamangala University of Technology Phra Nakhon** 14(1): 144–153.

Bowen, B.W., A.L. Bass, A. Garcia-Rodriguez, C.E. Diez, R. van Dam, A. Bolten, K.A. Bjorndal, M.M. Miyamoto and R.J. Ferl. 1996. Origin of hawksbill turtles in a Caribbean feeding area as indicated by genetic markers. **Ecological Applications** 6(2): 566–572. DOI: 10.2307/2269392.

Bugoni, L., L. Krause and M.V. Petry. 2001. Marine debris and human impacts on sea turtles in southern Brazil. **Marine Pollution Bulletin** 42(12): 1330–1334. DOI: 10.1016/S0025-326X(01)00147-3.

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. DOI: 10.1016/j.jembe.2015.12.003.

Casale, P., M. Affronte, D. Scaravelli, B. Lazar, C. Vallini and P. Luschi. 2012. Foraging grounds, movement patterns and habitat connectivity of juvenile loggerhead turtles (*Caretta caretta*) tracked from the Adriatic Sea. **Marine Biology** 159: 1527–1535. DOI: 10.1007/s00227-012-1937-2.

Chaloupka, M., D. Peter and H. Nakano. 2004. **Status of Sea Turtle Stocks in the Pacific.** FAO, Rome, Italy. 238 pp.

Chantrapornsyl, S. 1993. **Status of marine turtles in Thailand.** The Proceedings of Sea Turtle Conservation SymposiumWorkshop. Manila, Philippines 1993: 123–129.

Chantrapornsyl, S., M. Jarujinda, W. Sakamoto, N. Arai, W. Glom-In, K. Kittawattanawong and S. Munanansap. 2011. **Study of green turtle (*Chelonia mydas*) movement using satellite transmitters.** Marine and Coastal Resources Research and Development Institute. https://www.dmcr.go.th/detailLib/612. Cited 5 Dec 2023.

Godley, B.J., E.H.S.M. Lima, S. Åkesson, A.C. Broderick, F. Glen, M.H. Godfrey and G.C. Hays. 2003. Movement patterns of green turtles in Brazilian coastal waters described by satellite tracking and flipper tagging. **Marine Ecology Progress Series** 253: 279–288. DOI: 10.3354/meps253279.

Godley, B.J., J.M. Blumenthal, A.C. Broderick, M.S. Coyne, M.H. Godfrey, L.A. Hawkes and M.J. Witt. 2008. Satellite tracking of sea turtles: where have we been and where do we go next?. **Endangered Species Research** 4(1–2): 3–22. DOI: 10.3354/esr00060.

Hart, K.M., D.G. Zawada, I. Fujisaki and B.H. Lidz. 2010. Inter-nesting habitat-use patterns of loggerhead sea turtles: enhancing satellite tracking with benthic mapping. **Aquatic Biology** 11(1): 77–90. DOI: 10.3354/ab00296.

Hawkes, L.A., A.C. Broderick, M.H. Godfrey and B.J. Godley. 2009. Climate change and marine turtles. **Endangered Species Research** 7(2): 137–154. DOI: 10.3354/esr00198.

Hays, G.C., S. Fossette, K.A. Katselidis, P. Mariani and G. Schofield. 2010. Ontogenetic development of migration: Lagrangian drift trajectories suggest a new paradigm for sea turtles. **Journal of the Royal Society Interface** 7(50): 1319–1327. DOI: 10.1098/rsif.2010.0009.

Hays, G.C. and L.A. Hawkes. 2018. Satellite tracking sea turtles: Opportunities and challenges to address key questions. **Frontiers in Marine Science** 5: 432. DOI: 10.3389/fmars.2018.00432.

Hernández, A.L.M. and B.I. van Tussenbroek. 2014. Patch dynamics and species shifts in seagrass communities under moderate and high grazing pressure by green sea turtles. **Marine Ecology Progress Series** 517: 143–157. DOI: 10.3354/meps11068.

Keller, J.M. 2013. **Exposure to and effects of persistent organic pollutants.** In: The Biology of Sea Turtles, Volume 3. (eds. J. Wyneken, K.J. Lohmann and J.A. Musick), pp. 285–328. CRC Press Boca Raton, Florida, USA.

Kobayashi, D.R., J.J. Polovina, D.M. Parker, N. Kamezaki, I.J. Cheng, I. Uchida, P.H. Dutton. and G.H. Balazs. 2008. Pelagic habitat characterization of loggerhead sea turtles, *Caretta caretta*, in the North Pacific Ocean (1997–2006): insights from satellite tag tracking and remotely sensed data. **Journal of Experimental Marine Biology and Ecology** 356(1–2): 96–114. DOI: 10.1016/j.jembe.2007.12.019.

Lahanas, P.N., K.A. Bjorndal, A.B. Bolten, S.E. Encalada, M.M. Miyamoto, R.A. Valverde and B.W. Bowen. 1998. Genetic composition of a green turtle (*Chelonia mydas*) feeding ground population: evidence for multiple origins. **Marine Biology** 130: 345–352. DOI: 10.1007/s002270050254.

Lamont, M.M., I. Fujisaki, B.S. Stephens and C. Hackett. 2015. Home range and habitat use of juvenile green turtles (*Chelonia mydas*) in the northern Gulf of Mexico. **Animal Biotelemetry** 3: 1–12. DOI: 10.1186/s40317-015-0089-9.

Lewison, R.L., L.B. Crowder, A.J. Read and S.A. Freeman. 2004a. Understanding impacts of fisheries bycatch on marine megafauna. **Trends in Ecology and Evolution** 19(11): 598–604. DOI: 10.1016/j.tree.2004.09.004.

Lewison, R.L., S.A. Freeman and L.B. Crowder. 2004b. Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. **Ecology Letters** 7(3): 221–231. DOI: 10.1111/j.1461-0248.2004.00573.x.

Lewison, R.L. and L.B. Crowder. 2007. Putting longline bycatch of sea turtles into perspective. **Conservation Biology** 21(1): 79–86. DOI: 10.1111/j.1523-1739.2006.00592.x.

Limpus, C.J., J.D. Miller, C.J. Parmenter, D. Reimer, N. McLachlan and R.G. Webb. 1992. Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles to and from eastern Australian rookeries. **Wildlife Research** 19: 347–358. DOI: 10.1071/WR9920347.

Limpus, C.J., P. Eggler and J.D. Miller. 1994a. **Long interval remigration in eastern Australian Chelonia.** Proceedings of the thirteenth annual workshop on sea turtle biology and conservation 1994: 85–88.

Limpus, C.J., P.J. Couper and M.A. Read. 1994b. The green turtle, *Chelonia mydas*, in Queensland: population structure in a warm temperate feeding area. **Memoirs of the Queensland Museum** 35(1): 139–154.

Limpus, C.J. and N. Nicholls. 1994c. **Progress report on the study of the interaction of the El Nin˜o-Southern Oscillation on annual *Chelonia mydas* at the southern Great Barrier Reef rookeries.** Proceedings of the Marine Turtle Conservation Workshop 1994: 73–78.

Limpus, C. and M. Chaloupka. 1997. Nonparametric regression modelling of green sea turtle growth rates (southern Great Barrier Reef). **Marine Ecology Progress Series** 149: 23–34. DOI: 10.3354/meps149023.

Luschi, P., J.R.E. Lutjeharms, P. Lambardi, R. Mencacci, G.R. Hughes and G.C. Hays. 2006. A review of migratory behaviour of sea turtles off southeastern Africa. **South African Journal of Science** 102(1): 51–58. DOI: 10520/EJC96498.

Lutcavage, M.E., P. Plotkin and B. Witherington. 1997. **Human impacts on sea turtle survival.** In: The Biology of Sea Turtles (eds P. Lutz and J.A. Musick), pp. 387–404. CRC Press, Boca Raton, Florida, USA.

Makowski, C., J.A. Seminoff and M. Salmon. 2006. Home range and habitat use of juvenile Atlantic green turtles (*Chelonia mydas* L.) on shallow reef habitats in Palm Beach, Florida, USA. **Marine Biology** 148: 1167–1179. DOI: 10.1007/s00227-005-0150-y.

Mansfield, K.L., J. Wyneken, D. Rittschof, M. Walsh, C.W. Lim and P.M. Richards. 2012. Satellite tag attachment methods for tracking neonate sea turtles. **Marine Ecology Progress Series** 457: 181–192. DOI: 10.3354/meps09485.

Mansfield, K.L., J. Wyneken and J. Luo. 2021. **First Atlantic satellite tracks of 'lost years' green turtles support the importance of the Sargasso Sea as a sea turtle nursery.** Proceedings of the Royal Society B. 288 (1950): 1–10. DOI: 10.1098/rspb.2021.0057.

McDermid, K.J., B. Stuercke and G.H. Balazs. 2007. Nutritional composition of marine plants in the diet of the green sea turtle (*Chelonia mydas*) in the Hawaiian Islands. **Bulletin of Marine Science** 81(1): 55–71.

Miller, J.D. 1997. **Reproduction in sea turtles.** In: The Biology of Sea Turtles, Volume 1. (eds. P. Lutz and J.A. Musick), pp. 51–82. CRC Press, Boca Raton, Florida, USA.

Mitchell, S.V. 2000. **Use of epoxy in telemeter attachment.** Proceedings of the Eighteenth Annual Symposium on Sea Turtle Biology and Conservation. 2008: 254–255.

Morreale, S.J. 2009. **A Derivative of Encyclopedia of Ocean and Sciences: Sea Turtles,** 2nd ed. Academic Press is an imprint of Elsevier, London, UK. 617 pp.

Musick, J.A. and C.J. Limpus. 2017. **Habitat utilization and migration in juvenile sea turtles.** In: The Biology of Sea Turtles, Volume I. (eds. P. Lutz and J.A. Musick), pp. 137–163. CRC Press, Boca Raton, Florida, USA.

Papi, F., H.C. Liew, P. Luschi and E.H. Chan. 1995. Long-range migratory travel of a green turtle tracked by satellite: evidence for navigational ability in the open sea. **Marine Biology** 122: 171–175. DOI: 10.1007/BF00348929.

Rajagopalan, M., K. Vijayakumaran and A.B. Fernando. 1984. Some health problems observed in the hatchlings and juveniles of sea turtles in captivity. **CMFRI Bulletin** 35: 55–58.

Schofield, G., V.J. Hobson, S. Fossette, M.K. Lilley, K.A. Katselidis and G.C. Hays. 2010. Biodiversity Research: fidelity to foraging sites, consistency of migration routes and habitat modulation of home range by sea turtles. **Diversity and Distributions** 16(5): 840–853. DOI: 10.1111/j.1472-4642.2010.00694.x.

Seney, E.E., B.M. Higgins and A.M. Landry Jr. 2010. Satellite transmitter attachment techniques for small juvenile sea turtles. **Journal of Experimental Marine Biology and Ecology** 384(1–2): 61–67. DOI: 10.1016/j.jembe.2010.01.002.

Settle, S. 1995. Status of nesting populations of sea turtles in Thailand and their conservation. **Marine Turtle Newsletter** 68: 8–13.

Soykan, C.U., J.E. Moore, R. Zydelis, L.B. Crowder, C. Safina and R.L. Lewison. 2008. Why study bycatch? An introduction to the Theme Section on fisheries bycatch. **Endangered Species Research** 5(2–3): 91–102. DOI: 10.3354/esr00175.

Vander Zanden, H.B., A.D. Tucker, K.M. Hart, *et al*. 2015. Determining origin in a migratory marine vertebrate: a novel method to integrate stable isotopes and satellite tracking. **Ecological Applications** 25(2): 320–335. DOI: 10.1890/14-0581.1.

Wang, X., K. Kittiwattanawong, C. Junchompoo, W. Sakornwimon, M. Chen, F. Wu, S. Jutapruet and S.L. Huang. 2021. Mapping habitat protection priority over a marine ecoregion under information gaps. **Diversity and Distributions** 27(2): 233–248. DOI: 10.1890/14-0581.1.

Winton, M.V., G. Fay, H.L. Haas, M. Arendt, S. Barco, M.C. James and R. Smolowitz. 2018. Estimating the distribution and relative density of satellite-tagged loggerhead sea turtles using geostatistical mixed effects models. **Marine Ecology Progress Series** 586: 217–232. DOI: 10.3354/meps12396.

Witt, M.J., L.A. Hawkes, M.H. Godfrey, B.J. Godley and A.C. Broderick. 2010. Predicting the impacts of climate change on a globally distributed species: the case of the loggerhead turtle. **Journal of Experimental Biology** 213: 901–911. DOI: 10.1242/jeb.038133.

Yoksan, R. 2008. Epoxidized natural rubber for adhesive applications. **Agriculture and Natural Resources** 42(5): 325–332.