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Repetitive Data-Logger Attachments to Sea Turtles Using a New Quick-Release Method

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Classic studies involving visual observation of larger vertebrates are difficult when animals frequent obscuring environments, and observations of flying, nocturnal, or diving species become discontinuous or even impossible. However, attached transmitters and data-loggers which monitor animals continuously provide a solution to this, so that periods of monitoring may be greatly extended, even to years, if attachment systems are sufficiently robust and appropriate while minimally affecting the animal concerned.

Our specific aim was to develop an attachment method that fully meets the requirements of repeated deployments of replaceable data-loggers on sea turtles.

Methods. — Field work was carried out during the peak nesting season of hawksbill turtles (*Eretmochelys imbricata*) (July to September) 1998 and 1999 at Buck Island Reef National Monument (64°N, 17°W), St. Croix, U.S. Virgin Islands. Data-loggers were attached to the anterior of the carapace (2nd vertebral scute) of female hawksbill turtles during nesting, after the nest-hole was completed and the egg-laying process had already commenced. The general attachment method described below was used in both field seasons to attach different metal base plates to the carapaces of the turtles.

The carapace of nesting hawksbill turtles is usually relatively dry by the time the first eggs are laid (average time after emergence from water is ca. 40 min, Z. Hillis-Starr, *pers. comm.*). However, we scrubbed the carapace with a brush and freshwater to remove the film of algae and salt crystals, as well as loose sand and to prepare the surface of the scutes for the adhesive. All barnacles on, or near, the attachment area on the first and second vertebral scutes were removed using pliers. The attachment area was dried with a towel and roughened with sandpaper.

Following Mitchell (2000) we used a combination of a fast setting epoxy putty (Repair stick ST115 steel, Weicon® worldwide GmbH & Co. KG, Münster, Germany, info@weicon.de), which cures within ca. 5 min at 20°C, together with a slower-setting viscous epoxy from a cartridge (R-Kex®, synonym Foil-Fast®, Rawl, Glasgow, UK, info@rawlplug.co.uk), that cures within ca. 30 min. Like all epoxy resins, these materials consist of two components that react when mixed and cure within a temperature-dependent predictable time. Since under tropical conditions the fast-reacting epoxy cures too fast to be handled properly, we stored the putty in an insulated bag with ice-packs. Just prior to use, two pieces of the epoxy putty (ca. 25 g each) were taken from the bag and simultaneously kneaded to allow the two components of each piece to mix evenly and be warmed. We then rolled two pieces of the putty into a cylindrical shape and attached them beneath the edges of a metal plate, one being placed on each side (Fig. 1). While the ends of the pieces met in the tip, we left a gap (ca. 0.5 cm) in the middle of the trailing edge. The area between the rolls of putty was filled with R-Kex (ca. 85 g), that is readily mixed while being manually pumped from the cartridge through the nozzle onto

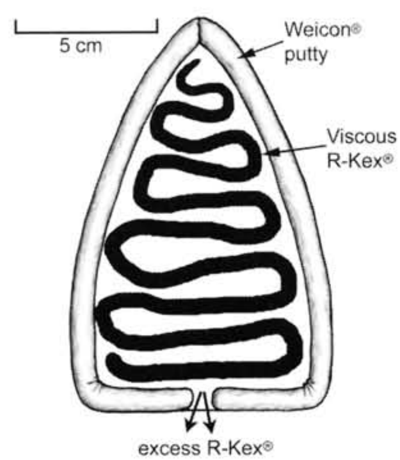

Figure 1. Epoxy adhesives applied to the base plate (see also Mitchell, 2000).

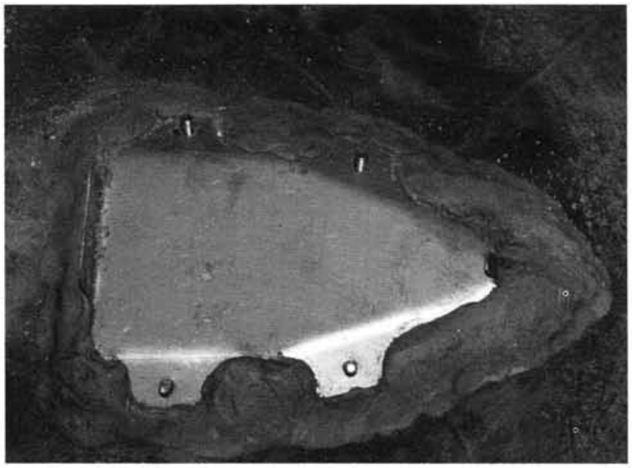

Figure 2. Base plate attached to the carapace of a nesting hawksbill turtle.

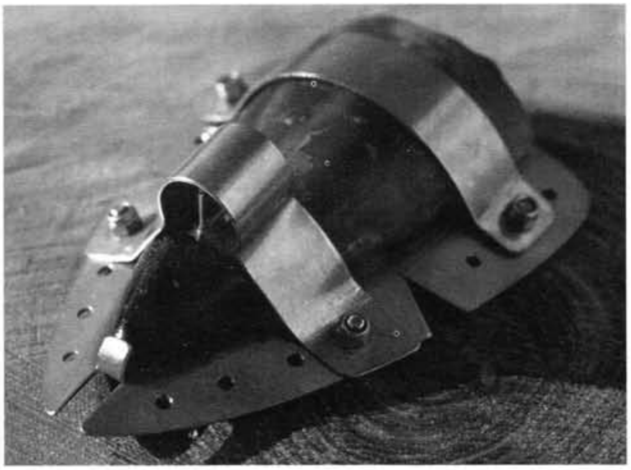

Figure 3. Base plate (1 mm stainless steel) and device used in 1999 field season.

the bottom of the base plate. The covered bottom of the base plate was pressed onto the prepared attachment area of the carapace. Any excess R-Kex discharged through the gap at the posterior end (Fig. 1) was wiped away with a cloth. The putty coils were firmly pushed onto the carapace and the protruding edges of the plate were covered with additional (ca. 25 g) Weicon® putty (Fig. 2). To ensure a firm bond between the fast-setting epoxy and the carapace it was important to avoid any slow-setting R-Kex seeping between the two layers, as this resulted in slipping of the plate. Approximately 5 min after kneading, the putty started to cure, the reaction being moderately exothermic.

After first trials with 0.5 mm strong stainless steel we developed a plate made from 1 mm stainless steel. This material was chosen because of its resistance to UV rays and saltwater and to avoid magnetic interference of the base plate with the compass of the device to be attached. The shape of the plate enabled the device to be secured by four self-securing nuts and bolts onto the plate (Fig. 3). The logger was held in place by two stainless steel bands. The anterior band served for device retention and protected the speed valve of the logger against impact. Numerous holes drilled into the edges of the plate allowed the epoxy to perfuse when the plate was pressed onto the carapace. The base plate was completely flat at the device attachment site, but the protruding edges were bent down to match the domed shape of the anterior part of the carapace. This detail reduced the maximum thickness of the epoxy layer between carapace and plate by ca. 5 mm. Upon return of the equipped turtle the device was easily and quickly exchanged by loosening the four retaining nuts. The device was taken out of the plate and a new logger was secured by tightening the nuts. The exchange could be completed within 2 min.

After completion of the study the plate was easily removed by using a hacksaw to cut a slit into the epoxy at one of the corners of the plate. A screwdriver was placed into the slit and hit with a hammer until the plate and the epoxy layer were detached from the carapace. In most cases the plate and epoxy were removed in one piece. Otherwise the remaining epoxy was removed with the screwdriver and hammer.

The thermal characteristics of the epoxy during the bonding reaction were examined under laboratory conditions. A sea turtle carapace was equipped with two probes to measure the temperature within the epoxy mass and underneath the bony carapace during the attachment procedure (Fig. 4). A balloon filled with ca. 1 liter of water was pressed against the lower probe during the experiment to simulate the insulating effect of the body flesh of the turtle. The temperature of the air in the laboratory and the water in the balloon was 27°C to approximate typical night temperatures under field conditions. Measurements were taken until the

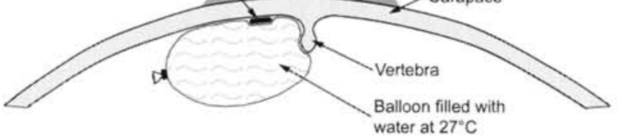

Figure 4. Experimental set-up for temperature measurement during exothermic epoxy curing process (cross section showing placement of temperature probes).

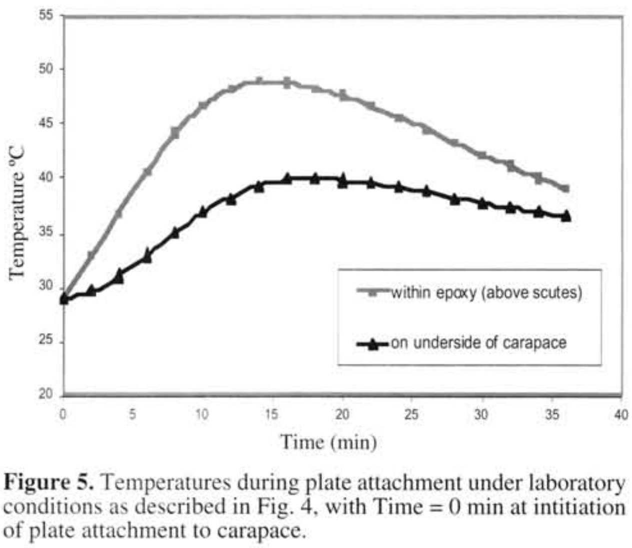

Figure 5. Temperatures during plate attachment under laboratory conditions as described in Fig. 4, with Time = 0 min at intitiation of plate attachment to carapace.

temperature within the epoxy mass fell below 40°C and the R-Kex epoxy was cured.

The weight of all materials attached to a turtle in the field (device, plate, and epoxy) was measured in air and in salt water (35 ppm, 28°C) using a spring balance. The body masses of nesting turtles were measured once per season during routine monitoring activities at Buck Island.

Results. — While the first trials showed that 0.5 mm stainless steel was not strong enough, the final version of the plate made of 1 mm steel enabled us to deploy successfully and retrieve devices using the base plate for quick release. The steel strips and the nuts held the devices in place over the desired monitoring periods of up to 16 days (mean 12 days, $n = 13$) before being exchanged or removed, but the protruding tab of the anterior band was deformed in several cases (7 of 15 deployments), leading to damage to the speed sensor in 5 cases. In two of these cases it was observed that the damage occurred during the nesting process on land while the turtle was crawling under logs in the vegetated area. The attached plates were used for up to three successive deployments so that they remained in place for up to 31 days without apparent reduced stability.

Although the initial attachment was completed in ca. 15 min, each successive exchange took ca. 2 min. The exchange could be executed during egg-laying or even during crawling. We were thus able even to consider device exchange on turtles performing a false-crawl, i.e., coming ashore without actually completing a nest.

The final removal of the base plate took ca. 5 min. When the removal was conducted during the egg-laying process or by crawling behind the turtle, no apparent reaction to the procedure was observed. No materials stayed on the carapace after the removal procedure and there was no sign of damage to the carapace scutes.

The masses of loads attached to the turtles including device, battery, base plate, and adhesive materials were 300 g in air (140 g in saltwater) in 1998 and 430 g in air (230 g in saltwater) in 1999. The mean body mass of the 9 animals equipped during this study was 70 kg (range 49 to 95 kg), so that the maximum mass of the complete attachment was 0.6% of the mean body mass.

During the simulated attachment under laboratory conditions the measured temperatures varied between 29 and 49°C (Fig. 5). The highest temperature, measured 14 min after initiation of attachment, occurred within the epoxy mass itself and thus affected only the turtle's non-innervated scutes. The maximum temperature measured below the bony carapace was 40°C (16 min after the onset of the experiment). The epoxy was cured and the measurements ceased 36 min after the plate was placed onto the carapace.

Discussion. — During deployment of telemetry devices the habits and demands of the equipped animal as well as the data-logger functions have to be given careful consideration. Hawksbill turtles typically inhabit littoral waters of tropical shelves with coral reefs (Márquez, 1990). Their habit of wedging themselves into crevices (Vaughan et al., 1992) not only leaves obvious marks and scratches on the scutes of their carapace, but also often damages attached biotelemetry devices (Vaughan et al., 1992; *pers. obs.*).

The present quick-release attachment method was optimized in several aspects to meet the requirements of a state-of-the-art behavioral study. These aspects concern the duration and intensity of the handling of the animal, the toxicity and local effects of adhesive to the attachment area, as well as the secure fixation of the device.

The handling times involved in our method are much shorter than in techniques using epoxy and fiberglass (e.g., Papi et al., 1997; Polovina et al. 2000; Renaud and Carpenter, 1994). The materials used are easy to handle at night under field conditions and inaccuracies in mixing ratios, leading to variation in curing time or instability of the attachment, are unlikely due to automatic mixing or predetermined ratios. Therefore attachments can proceed without delaying the animal's stay on the beach, as described by Cheng (2000).

According to the manufacturer's data sheet the epoxy putty does not contain any solvents. The epoxy putty can be kneaded by hand and no skin irritation was observed during contact with bare skin. However, use of gloves during application is recommended by the manufacturer and vapor should not be inhaled. Once cured, epoxy resin is inert and therefore non-irritating (Weicon® safety data sheet No. 91/155 EEC).

The rise in temperature caused by the curing process of the epoxy may be sensed by the turtle but we do not consider it harmful. Since the carapace scutes (ca. 4–5 mm thick in an adult hawksbill) are not innervated, the maximum temperatures that reach the nerves within the bony carapace are below 49°C. The setup of our laboratory experiment represents a worst-case scenario, as the volume of water in the balloon was small compared to the volume of the tissue of the turtle that would absorb the heat of the epoxy. In our experiment the scutes did not detach from the bone, as has been observed at high temperatures (Carr, 1952). The duration of maximum heating is short under laboratory conditions and is probably reduced further when the turtle enters the water within 10 to 15 min after the plate has been pressed onto the carapace.

The thermal reaction of any epoxy material is dependant on its volume and on the surface area:volume ratio. The thickness of the epoxy layer between the plate and the carapace should therefore be kept to a minimum. To achieve this the plate should suit the average curve of the attachment site. In this study a layer of ca. 1 cm was not found to be harmful.

We found that a material thickness of 1 mm stainless steel is necessary for the base plate. However, tabs protruding from the plate should be made of 1.5 mm steel. The base plate and the pattern of epoxy application combined in this study were designed to optimize hydrodynamics and protruding elements were avoided except for the metal arch protecting the speed sensor. The overall size of the attached load resembled the dimensions of the barnacles that are frequently found in groups on the shells of hawksbill turtles nesting at Buck Island (*pers. obs.*). To estimate the drag associated with our attachment assembly further studies of the hydrodynamic features should be done within a flume channel (Watson and Granger, 1998).

Our results show that the use of base plates and epoxy is a suitable technique for repetitive data-logger deployments to study internesting female sea turtles.

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Preliminary Observations on Reproductive Parameters of the Sulawesi Forest Turtle (*Leucocephalon yuwonoi*) in Captivity

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The Sulawesi forest turtle was described as *Geoemyda yuwonoi* (McCord et al., 1995), and later assigned to the new genus *Leucocephalon* (McCord et al., 2000). The species has featured in the pet trade and Southeast Asian food markets for a number of years, but very few natural history data have been reported. Platt (1998), Platt et al. (2001), and Hagen and Ching (in press) made some field observations, but no reproductive data have been presented. Because of its restricted geographic range and ongoing exploitation, *Leucocephalon yuwonoi* has been listed as Critically Endangered by the IUCN Red List of Threatened Species (IUCN, 2002) and assigned to CITES Appendix II. It has been targeted as a priority species by the recently formed IUCN/SSC Turtle Survival Alliance, and a Taxon Management Group for the species has been established.

Small numbers of *Leucocephalon* have been imported into the United States, and approximately 60 live specimens are known to exist in several zoological institutions and private collections. Successful captive breeding has not previously been reported.

Data for eggs from 15 clutches laid by 7 captive female *Leucocephalon* are presented in Table 1. Based on these data, it appears that the typical clutch for this species consists of one, relatively large egg (mean egg mass = 45.4 g , s.d. = 6.02 g, $n = 16$; mean egg length = 60.8 mm, s.d. = 6.9 mm, $n = 18$; mean egg width = 32.4 mm, s.d. = 2.5 mm, $n = 18$). Three of 15 clutches included 2 eggs. The eggshell is hard and calcareous.

Female 1, captive since August 1998, is the only individual to have produced more than one clutch. Eggs were laid in August 1998, January 1999, May, October, and December 2001, April and July 2002, and February and May 2003. The December 2001 and May 2003 clutches each included 2 eggs. Most of the other females described herein have been in captivity for less than one year, and more data are needed before accurate statements can be made about clutch frequency.

All clutches produced by female 1 since Ocotber 2001 have been buried 4 cm deep in a nest box containing 10 cm of sphagnum peat. Nest construction has not been observed. All other eggs were laid openly in the enclosures. Induction of oviposition with oxytocin was successful in some, but not all cases, possibly due to environmental stressors or pathology. One debilitated female required surgical removal of the egg.