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Attachment of Radio Transmitters in a Rock Iguana, *Cyclura lewisi*

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Tracking with radio telemetry is an important tool for studying aspects of the behavior and ecology of animals, including movements and habitat use. In endangered lizards, such as iguanas of the genus *Cyclura*, radio tracking may yield valuable insights about habitat and area requirements that may aid in management and conservation. Radio tracking is a particularly important monitoring technique for *Cyclura* because they have large home ranges (up to 9 ha) that may shift seasonally (Rose 1982; Wiewandt 1977; Mitchell 1999). Unfortunately, no optimal method of attaching radio transmitters has been demonstrated for *Cyclura*, although many have been attempted.

Cycluran iguanas are found on islands throughout the West Indies, where they commonly live in habitats with rocky limestone substrates, using jagged rock sinkholes as retreats (Alberts 2000). This rocky substrate, and possibly the low-growing vegetation often found on these islands, contribute to the frequent detachment and loss of radio transmitters attached externally to these iguanas. The following methods of external attachment have been tried in different species of *Cyclura*, with varying levels of success: waist belts (Mitchell 1999), neck collars (with hatchlings, N. Perez, pers. comm.), vests worn over the anterior portion of the body (Hates et al. 2000), duct taping transmitters to tails (C. Knapp, pers. comm.), and suturing transmitters below dorsal crests (F. Burton, pers. comm.).

Two additional methods have been used to secure radio transmitters in *Cyclura*: feeding transmitters in food to iguanas (Christian et al. 1986, Goodyear and Lazell 1994) and surgically implanting transmitters into the body cavity (F. Burton, A. Alberts, pers. comm.). The former method is only useful for short-term data collection, as the transmitter is expelled during defecation after 4–7 days (Goodyear and Lazell 1994). The latter method, which has been used in several other lizards (Schauble and Grigg 1998; Sound and Veith 2000; Wikelski 1999), seems the best way to ensure long-term monitoring of an iguana because the transmitter is secured inside of the body. However, the implant procedure requires anesthesia and surgery, which increase risk to the animal and cost to the researcher due to the need for veterinary staff (desirable and often required for surgical implantation because all species of *Cyclura* are protected). Furthermore, no studies have been published on the long-term effects of transmitter implantation on lizards, so the risk of decreased fitness due to transmitter implantation is unknown. Because of the long life span in *Cyclura* (up to 60 years, Iverson et al. 2004), negative consequences of transmitter implantation could take years to manifest.

During a study on the spatial ecology of *Cyclura lewisi* (formerly *C. nubila lewisi*, see Burton 2004) on Grand Cayman in 2002, I used two methods to attach radio transmitters to iguanas. Transmitters were attached to five large males (36–49 cm SVL, 80–118 cm TL, 2.2–5.1 kg) in 11 instances by suturing below the posterior dorsal crest (Fig. 1). Transmitters were attached to seven females and one small male (27–38 cm SVL, 69–93 cm TL, 0.9–2.7 kg) in 17 instances by gluing to the posterior dorsum. Suturing was not used with these smaller iguanas because their smaller dorsal crests may be vulnerable to tearing if the transmitters became caught on rocks or vegetation. Suturing radio transmitters to animals has been previously described in fish (e.g., Erkinaro et al. 1999) and snakes (e.g., Ciofi and Chelazzi 1991). To my knowledge, however, no published study has reported suturing transmitters below the dorsal crest in lizards. Therefore, the purposes of this paper are to describe the technique of suturing transmitters to iguanas, to assess the impacts of this method on the lizards in this study, and to compare the short-term reliability of gluing and suturing methods.

Iguanas were not anesthetized for either method of attaching transmitters, but were fully restrained both manually and with large cloth straps secured with Velcro®. For method 1, radio transmitters (Holohil Systems, Ltd. model AI-2, cylinder 45 mm x 15 mm diameter with whip antennae 23 cm length, 6 month battery) that had a flat metal mounting plate (75 mm x 8 mm) on the bottom were encapsulated in liquid plastic. This unit was glued to the dorsum of the iguana just anterior to the base of the tail alongside the dorsal crest using cyanoacrylate gel. Other studies with lizards have used similar methods of attaching transmitters externally with glue or epoxy (Cuadrado 1998; Griffiths and Christian 1996; Sabo 2003).

In method 2, the posterior dorsum of the iguana was first cleaned with 70% isopropyl alcohol. Then the transmitter (same model as above) was sutured below the dorsal crest in the following manner, which is similar to a bead-tagging technique described by Rodda et al. (1988) that is currently used by many researchers working with *Cyclura*. The dorsal crest of the iguana was held firmly in hand while a 16-gauge needle was used to puncture the skin just below the origin of the dorsal scales. The needle was pushed through neoprene pads on each side of the crest, and nylon-coated steel leader wire (60 lb strength, 0.7 mm diam) was then threaded through the needle and pads. This was done in two places on the posterior dorsal crest, and the needle was subse-

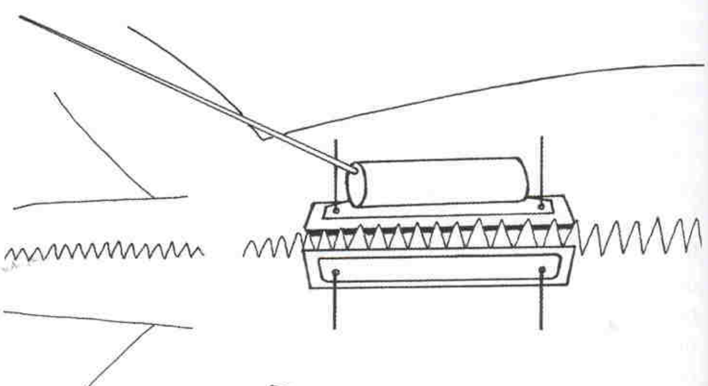

Fig. 1. Diagram of the method used to suture a radio transmitter below the dorsal crest of an iguana.

quently removed from the skin, leaving the leader wire in place below the dorsal crest. Next, the radio transmitter and backing plate were attached on opposite sides of the dorsal crest by leading the wire through the holes in each. Glass beads (ca. 4 mm diam with ca. 1.4 mm diam hole) were threaded onto the terminal portions of the wire, and the wire ends were secured with leader sleeves. The glass beads are not a necessary part of the design, but were added in this case because the holes in the radio transmitter mounts and backing plates were larger in diameter than the leader sleeves. The total mass of either type of transmitter package before gluing or suturing averaged 35–40 g, which was less than 5% of the body mass of iguanas and therefore acceptable within common standards (Macdonald and Amlaner 1980).

No adverse effects of gluing transmitters to iguanas were noticed. These transmitters were removed from iguanas by cutting them out of the plastic casing, leaving only a small patch of plastic on the dorsum which fell off before or during the next shedding. The effects of the suturing technique involved occasional slight bleeding immediately after puncturing the skin, and small puncture wounds evident upon removal of transmitters. No infection of the puncture sights was noted during or after radio tracking iguanas in this study. One year post-removal, these wounds had healed and were small when compared to scars resulting from intraspecific interactions. In some cases, puncture wounds were slightly expanded during wear (still < 2 mm diam), probably because the transmitter had become caught on vegetation and pulled away from the body in the animal's struggle to free itself. I witnessed such events wherein iguanas became temporarily entangled in vegetation because of radio transmitters, but in no case did this affect the movement of an iguana for more than one minute. Future use of the suturing method should modify this study's design to minimize the potential for transmitters to catch on rocks or vegetation. Transmitters should not have sharp edges or any places where vegetation could become caught, especially on the anterior side.

One major assumption in radio tracking studies is that animal movements are not affected by the techniques that researchers use (White and Garrott 1990). Although I could not verify this assumption for all individuals, the following observations lead me to believe that radio transmitters did not heavily influence the behavior of iguanas. No iguana was observed biting or excessively scratching or inspecting the radio transmitter and associated attachment site on the body. Iguanas were always more wary of researchers after capture and handling, but there was no evidence that this was more pronounced in cases where transmitters were attached (using either method). Iguanas did not appear to respond to the puncture sites after transmitters were sutured to them. In fact, one male was observed successfully copulating with a female less than fifteen minutes after having a transmitter sutured to him.

Only the short-term reliability of gluing and suturing methods was assessed because the number of radio transmitters was limited in this study and transmitters were periodically removed and reused on different iguanas. Eight of 17 (47%) transmitters that were glued to iguanas fell off within two weeks. Of the remaining glued-on transmitters, several were removed within one month for use on other iguanas, and four were removed after 30 days. One transmitter that could not be retrieved was still on an iguana when the study ended 45 days after attachment by gluing.

Only two of 11 (18 %) transmitters that where sutured to iguanas fell off within two weeks. These were the first two transmitters to be attached with this method, and loss resulted within two days from a failure to completely clamp the leader sleeves securing the apparatus. Once this problem was resolved, all sutured transmitters remained attached until removed intentionally by a researcher. Of these remaining nine transmitters, three were removed at 16–17 days, five were removed at 29–32 days, and one was left on as a long-term trial. Unfortunately, this iguana was run over by a vehicle 48 days after transmitter attachment. One of the sutures ripped through the dorsal crest of the iguana during the accident, and the transmitter was removed immediately afterward.

The two methods of transmitter attachment were used on different sized iguanas, and I could not investigate whether there was any relationship between body size and length of transmitter attachment. However, I believe that the low reliability of glued-on transmitters was because of the attachment method and not the body size of iguanas, inferred because of the way in which transmitter detached. Transmitters that had been glued-on detached at the site of gluing because of a failure of the adhesive or the sloughing or tearing off of old skin that was about to shed. Presumably these could occur in all sexes and sizes of iguanas. Additionally, if greater movement rates were responsible for increased snagging and detachment of transmitters, we would expect to see the opposite results of those presented here on reliability of methods, as male *C. n. lewisi* have greater or equal movement rates than females (Goodman 2004).

Burton (pers. comm.) used a similar suturing technique in 1993 to attach transmitters to two *C. n. lewisi*, except that design lacked the neoprene pads and backing plate incorporated in the current study. One of these transmitters remained attached for six months, while the other remained attached for at least two months, after which the iguana disappeared. Based on Burton's experience in 1993 and the results of radio tracking conducted in 2002, suturing transmitters to the dorsal crest seems more reliable than gluing transmitters to the dorsum with cyanoacrylate gel.

The main potential drawback to the suturing method, transmitters getting snagged on rocks or vegetation, was not a large problem in this study and can probably be further minimized with slight design improvements. Benefits of suturing transmitters to iguanas, compared to other attachment methods include cost efficiency, short-term attachment reliability, and less invasiveness than internal implantation. Although long-term safety and reliability of attachment need to be examined in more detail, this method of suturing radio transmitters to iguanas appears promising for researchers working with large lizards.

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Comet Assay Used to Detect Genotoxic Effects of Mining Sediments in Western Toad Tadpoles (*Bufo boreas*)

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Water contaminated by mining sediments can have lethal and sublethal effects on amphibians (e.g., Hopkins et al. 1997; Lefcort et al. 1998; Porter and Hakanson 1976; Rowe et al. 1998). However, not all mining sediments are alike. Depending on the parent-rock material, pH levels, and hydrological patterns, the heavy metal concentrations of sediment effluents can be highly variable (Robb and Robinson 1995) and, consequently, range from being highly toxic to relatively benign for amphibians. Thus, different management strategies ranging from intensive reclamation to no action may effectively reduce the threat from mining sediments (Robb and Robinson 1995).

Amphibian survivorship, development, and behavior studies can assess the toxicity of mining sediments (e.g., Lefcort et al. 1998; Porter and Hakanson 1976; Rowe et al. 1998). However, such studies could take weeks to months to complete reducing the number of sites examined in a field season. A more time efficient approach may utilize genotoxic assays of amphibian larvae *in situ* (or caged for short time periods) to assess the toxicity of sediment effluents. One promising technique is single-cell gel (SCG) electrophoresis.

Singh et al. (1988) first developed alkaline SCG electrophoresis for quantification of low levels of DNA damage in human lymphocytes. The technique is referred to as the "comet" assay because the DNA fragments from affected cells migrate further than intact DNA, resulting in a streaked appearance. The length to width ratio of the streak is an indication of the DNA damage (Singh et al. 1988). The comet assay has been modified for many plants and animals for genetic ecotoxicology research (Cotelle and Férard 1999). For amphibians, the comet assay has been used *in situ* and in field and laboratory studies to detect DNA fragmentation in nucleated erythrocytes resulting from exposure to organic toxicants such as herbicides, pesticides, and petrochemicals (Clements et al. 1997; Ralph et al. 1996; Ralph and Petras 1997, 1998a,b). However, it is not known whether this technique is effective for assessing the toxicity of heavy metals on amphibians (but see De Boeck et al. 2000 for effects of heavy metals on human lymphocyte DNA).

We examined the effectiveness of the comet assay to detect the toxic effects of mining sediments on Western Toad (*Bufo boreas*) larvae in Montana. We first used survival and growth studies, in the field and in the lab, to demonstrate the toxic effects of sediments from an abandoned gold/silver mine. We then used the comet assay to test for DNA fragmentation resulting from exposure to the same mining sediments.