Herpetological Review, 2011, 42(2), 187–191.

A Taping Method for External Transmitter Attachment on Aquatic Snakes

Radio telemetry is extremely useful for studying habitat use and movements of free ranging snakes. Surgically implanting radio transmitters into the body cavity of snakes is standard practice in most studies (e.g., Reinert and Cundall 1982; Weatherhead and Blouin-Demers 2004), but this implanting method has its drawbacks. Surgery itself is risky for individual snakes because of the potential for infection or incomplete healing of the incision site. Also, transmitters that are small enough to be carried by small or slender snakes have a relatively short battery life and need to be removed or replaced often, thus requiring frequent surgeries. In rare or endangered snake species, the risk of using invasive implantation surgery may not be merited. External attachment methods are relatively non-invasive and allow removal and replacement of radio transmitters on smaller snakes. The Giant Gartersnake (*Thamnophis gigas*) is a semi-aquatic snake endemic to wetlands of the Central Valley of California, USA, and is federally and state listed as threatened (U.S. Fish and Wildlife Service 1999). Telemetry studies of the habitat use and movements of this species typically used surgically implanted radio transmitters, but this method is limited to larger snakes, primarily females, because of size requirements for surgery (> 250 g). To

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Fig. 1. Radio transmitter attached to a *Thamnophis gigas* by the off-tail method using surgical tape.

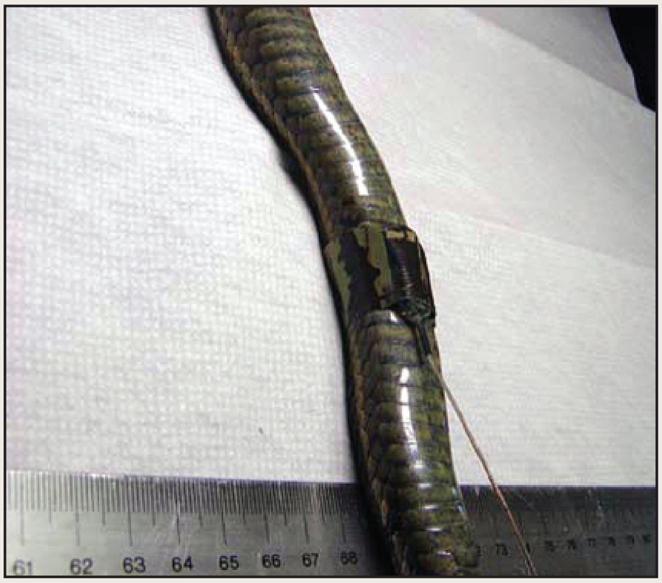

Fig. 2. Radio transmitter attached to a Thamnophis gigas by the body method using camouflage duct tape.

overcome difficulties and biases associated with radio telemetry of *T. gigas*, we developed and evaluated several alternative techniques to attach external radio transmitters using tape.

Materials and Methods.—We captured individual *T. gigas* by hand or in modified minnow traps (Casazza et al. 2000) at two sites in Colusa County (Colusa National Wildlife Refuge, 2003 and 2004, and Colusa Basin Drainage Canal, 2006). We measured, weighed, and marked each individual with a passive integrated transponder (PIT) tag in the field. In most cases, we attached transmitters to snakes while in the field and released them immediately after processing. However, if snakes appeared close to ecdysis, we held them in the laboratory until they shed. We taped transmitters to these snakes after shedding and released them at their capture locations as soon as possible.

We used 1.3 g radio transmitters (model R1620, Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA), measuring 8 × 19 × 4 mm with a 10 cm whip antenna. The flat, oblong shape of this transmitter has a low profile when attached to snakes (Fig. 1). Nominal battery life was 34 days, but many units exceeded this duration.

Initially, we used the method of Rathbun et al. (1993), which incorporated several strips of 3M™ Blenderm® clear plastic surgical tape. We also tried a type of cloth-backed gaff tape manufactured by Shurtape® that had been successfully used to mount transmitters onto penguins (C. Ribic, pers comm.). In 2004, we began using camouflage Duck® brand duct tape.

In addition to the various tape products we tried, we also modified the position of the transmitter on the snakes over the course of the study. Initially, we taped the antenna to the ventral surface of the snake and left the transmitter trailing off the end of the tail ("off-tail" method; Fig. 1), following Rathbun et al. (1993). In 2004, we changed the attachment site so that the transmitter was positioned on the ventral surface of the snake, about three-quarters of the distance from the snout to the vent, and the short antenna was directed caudally ("body" method; Fig. 2). We encircled the snake's body and the transmitter using one piece of tape (about 3 × 9 cm), which overlapped slightly on the dorsum of the snake. We secured the tape to the snake's ventral scutes anterior to the transmitter to prevent the transmitter's leading edge from snagging on obstacles in the environment. The reasoning for this ventral placement is that the radio transmitter would push into the body cavity by the weight of the snake thereby minimizing changes in the cross section of the snake as it moves through the environment. In removing transmitters from snakes, we carefully cut the tape with surgical scissors and cleaned any remaining adhesive on the skin with isopropyl alcohol.

We located snakes with transmitters 5–10 times per week from May through September, and 1–5 times per week thereafter until transmitters dropped off, were removed, or failed. Each time we located a snake, we attempted to confirm that the transmitter was still attached. We conservatively calculated retention time as the period from the snake's release to the last time the transmitter was known to be on the snake, either through visual contact or subsequent movement. Distances that individuals carried transmitters before dropping them were calculated as the sum of all movements from the release site to the final location. To determine if one attachment method or type of tape remained on snakes longer, we compared distances and durations by the type of tape and attachment technique. We used Kruskal-Wallis one-way analysis of variance to make these comparisons (JMP IN 5.1.2, SAS Institute, Inc., Cary, North Carolina, USA).

We attached radio transmitters to 62 *T. gigas* (39 females and 23 males) a total of 75 times in the course of three field seasons. Telemetered individuals averaged 76 cm (range: 60–98 cm) in snout-vent length and 271 g (range: 93–600 g) in mass.

For off-tail gaff tape attachment, snakes ranged from 69–72 cm and 138–600 g. For body gaff tape attachment, snakes ranged from 72–90 cm and 110–480 g. For body duct tape attachment, snakes ranged from 60–98 cm and 93–515 g.

Results.—Nine individuals dropped their transmitters prior to the first relocation. The remaining 66 transmitter attachments remained on the snakes for a mean of 14.3 days (range: 0.16–88 days), and were carried a mean distance of 391 m (range: 20–1700 m). All functioning transmitters were eventually recovered.

Table 1. Summary statistics for different locations and materials for externally attaching radio transmitters to snakes. N = number of attachments.

Method	Tape	Year	N	Duration (days) Mean	Duration (days) Range	Distance (m) Mean	Distance (m) Range
off-tail	surgical	2003	5	–	–	–	–
off-tail	gaff	2003, 2004	42	11.1	1.0–31.9	371	24–1700
body	gaff	2003, 2004	6	5.9	0.2–17.8	345	20–1505
body	duct	2004, 2006	22	22.9	0.2–88.0	440	35–1432

Our first attachments using the off-tail method with surgical tape (N = 5) failed almost immediately because of lack of adhesion of this tape, and we obtained no usable data from these individuals. Individuals with transmitters attached using the off-tail method with gaff Shurtape® tape (N = 42) traveled a mean distance of 371 m and retained their transmitters for a mean of 11.1 days (Table 1): however, radios in the off-tail position became entrapped in the environment in 13 individuals. Using gaff tape and the body method (N = 6), we were able to track snakes for a mean of 5.9 days (Table 1). We discontinued use of gaff tape after we discovered that its adhesive qualities were diminished after storage during the winter. With duct tape on the body (N = 22), individuals traveled a mean of 440 m and kept their transmitters for a mean of 23 days (Table 1).

We found no statistical differences ($p > 0.10$) in distance travelled ($\chi^2 = 0.907$, $p = 0.341$, df = 1) or duration of transmitter retention between transmitter attachment site ($\chi^2 = 0.254$, $p = 0.614$, df = 1) or tape type ($\chi^2 = 2.003$, $p = 0.157$, df = 1). We found no evidence of entrapment problems with radios attached by the body method. We found no discernable relationship between snake size and duration of radio attachment ($r = 0.13$, $p > 0.15$).

We recaptured 21 snakes that had external transmitters 95 times after their first attachment. Our overall recapture rate at both study sites from 2003 through 2006 was 2.0 captures per snake. We noted five snakes with scarring resulting from the off-tail attachment technique and four snakes with scarring from attaching the transmitter to the body. Several snakes could have carried transmitters longer and farther than we were able to measure. We were unable to recover nine transmitters before the batteries discharged or otherwise malfunctioned. On four occasions we removed attached, functional transmitters from snakes at the end of the field season. The longest duration for snakes retaining taped radio transmitters was in the late summer to early winter of 2006: three snakes were marked with the body taping method using Duck® tape from late summer into early fall. These radios remained on one snake for 42 days, and 87 and 88 days for the other two snakes.

Discussion.—Other investigators have used various techniques to attach transmitters to various snake species with mixed success. Ciofi and Chelazzi (1991) passed rubber tubing beneath the 22nd and 27th subcaudal scales of *Coluber viridiflavus*, providing an anchor through which they attached transmitters with nylon thread, which facilitated replacement of batteries without removing transmitters. Gent and Spellerberg (1993) studied movement rates for short periods (mean = 4.7 days) in *Coronella austrica* by mounting small transmitters on the dorsal side of the tail with surgical tape. Of 50 attachments, five were dropped on the first day and seven became snagged on vegetation and were removed by the researchers. Rathbun et al. (1993) taped transmitters onto the tail of nine *Thamnophis hammondii* using several strips of surgical tape. *Thamnophis hammondii*, another semi-aquatic gartersnake, retained their transmitters for a mean of 24.2 days. Cobb et al. (2005) and Figueroa (2006) glued small transmitters onto neonate *Crotalus horridus* and *C. oreganus helleri*, respectively, using cyanoacrylate glue, as did Jellen and Kowalski (2007) for neonate *Sistrurus catenatus*, with transmitters lasting 13–56 days. Although we did not evaluate a gluing method, it may not work well on the thin, smooth-scaled skin of *T. gigas* compared to the thick, rough scales of rattlesnakes.

More recently, Tozetti and Martins (2007) and Madrid-Sotelo and Garcia-Aguayo (2008) used duct style tape to externally attach radio transmitters to *Crotalus durissus* and *Oxybelis aeneus*, respectively, with an average monitoring time of 69.2 and 48.3 days, respectively. These attachments were dorsal compared to our ventral method. Madrid-Sotelo and Garcia-Aguayo (2008) also used cyanoacrylate glue in addition to the tape to affix the radio transmitters. Our monitoring time and that of Tozetti and Martins (2007) shows that duct tape alone can provide sufficient adhesion of radio transmitters to snakes. Again, our work shows that tape sufficiently adheres to these smooth-scaled snakes as well as the rough-scaled snakes in the study by Tozetti and Martins (2007). Also our work shows that ventral attachment of radio transmitters can work successfully in wetland habitats.

By attaching transmitters externally, we were able to obtain movement data on those *T. gigas* that were smaller than implantation procedures permit. We were also able to increase our sample size for snakes of all sizes. In addition, we were able to attach transmitters in the field immediately following snake captures, thereby reducing the interruption caused by captivity, anesthesia and surgery. An externally attached transmitter that fails prematurely will be lost by ecdysis, whereas implanted transmitters will remain in the body of the snake with unknown long-term consequences. During the active season, *T. gigas* shed their skin every 4–6 weeks, which invariably resulted in the loss of the transmitter. We found that *T. gigas* are often out of their burrows just prior to shedding, which permitted us to replace transmitters and continue tracking individuals.

We found the off-tail transmitter attachment technique was potentially more hazardous to the snakes than the body attachment. Four off-tail transmitters we recovered were snagged in vegetation, and the attached tape had distal pieces of tail that were pulled off by snakes. The shed radios we recovered that were attached with the body method showed no evidence of harming the snakes, but tape adhesive occasionally caused some superficial scarring. The small amount of tape used to affix transmitters with the body technique confers an additional advantage over the multiple pieces required to secure the antenna in the off-tail technique. When compared to the invasiveness of surgical implantation (Rudolph et al. 1998), the complications from taped transmitters are relatively minor. Taping did not cause any apparent mortality of the individuals in our study. The location of the radio attachment should be sufficiently posterior to allow for passage of gut contents at that location; we found no evidence of blockage of food items. We also did not detect any interference with shedding by taped radio transmitters.

We attribute our success of taping transmitters to *T. gigas* to several factors. The wetland habitat used by *T. gigas* has very little lignified vegetation and rocky outcroppings, and thus may be particularly forgiving to ventrally-mounted transmitters. Additionally, radio telemetry was conducted with concurrent, intensive snake trapping so we were able to recapture many animals, replace transmitters, and continue collecting data on the same individuals. A number of animals lost transmitters quickly and our dataset includes a long period of trial and error. In addition, our conservative calculations of distance and duration were designed to illustrate minimum expectations using our attachment method. Thus, our results may not reflect the full potential of this technique.

Taping radio transmitters to snakes is a simple, non-invasive and cost-effective way to collect movement data on individuals. This technique circumvents some of the limitations imposed by surgical implantation of transmitters, such as precluding studies of small snakes, poor recovery in cool weather (Rudolph et al 1998), and erratic behavior following periods of captivity while snakes recuperate from surgery. After surgically implanting transmitters in *T. gigas*, it is necessary to maintain them in captivity for up to two weeks to facilitate healing of the incision (Smith et al. 1988). Following this prolonged period of captivity, snakes often made unusually large movements immediately after release. Taping a transmitter to a newly captured snake and releasing it immediately rarely resulted in this response.

The period of time that a taped transmitter remains on a snake is not conducive to examine seasonal patterns in movement or annual home ranges. However, external transmitter attachment may facilitate research goals requiring one to monitor snake behavior over a within-season period (e.g., to measure rates of movement, Gent and Spellerberg 1993), or to monitor neonatal dispersal (Cobb et al. 2005; Figueroa 2006), reproductive behavior, habitat use, dispersal from hibernacula, and responses to landscape edges or features such as roads. The use of tape to attach radios in the fall facilitated location of winter hibernacula. Additionally, basking behavior associated with ecdysis facilitated transmitter replacement and continued long-term monitoring of individuals in spring and summer. Thus, our taping technique for the external attachment of radio transmitters to snakes, in addition to the variations tried by Tozetti and Martins (2007) and Madrid-Sotelo and Garcia-Aguayo (2008), demonstrates the potential for diverse applications of this technique in snake ecology and conservation. We recommend the use and further evaluation of the duct tape "body" method for use in future studies of snake movements.

Acknowledgments.—We thank Galen Rathbun for showing us his taping technique and helping us start this study. We also thank the many field technicians who participated in this study. B. J. Halstead and E. M. Nowak provided helpful reviews of earlier drafts of this manuscript. Snakes were handled in accordance with the University of California, Davis, Animal Care and Use Protocol 9699 and as stipulated in our U.S. Fish and Wildlife Service Recovery Permit TE-020548-5.

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