an ideal way to observe and quantitatively record movement patterns and microhabitat locations without disturbing animal behavior.

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A New Method for Immobilizing Fossorial Frogs After Radiotransmitter Implantation and Notes on Movement Patterns of the Pig-nosed Frog, *Hemisus marmoratus*

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Little is known about the activity patterns and habitat use of fossorial anurans. Radiotelemetry provides a solution to tracking such individuals over longer periods of time (Richards et al. 1994). However, transmitters need to be implanted for anurans that spend a substantial proportion of their time buried underground. In anurans, the healing of cuts after transmitter implantation, is made extremely difficult especially in small species that inflate their lungs in response to disturbance or as a means to enlarge underground burrows.

In this study we describe a method of immobilizing frogs that prevents sutures from rupturing and thus shortens the healing process after implantation of transmitters. This method was used in a study of the population biology of the pig-nosed frog *Hemisus marmoratus*. Our study was conducted in the Comoé National Park, Ivory Coast, West Africa at the beginning of the rainy season in 1997. Previous work in West Africa has shown that female pig-nosed frogs provide parental care in terrestrial breeding chambers (Rödel et al. 1995) and release tadpoles by either opening flooded chambers or leading tadpoles to open water over a slide (Kaminsky et al. 1999). Our objective in transplanting transmitters in females was to obtain information on migration patterns and habitat use during the breeding season.

Materials and Methods. —To determine movement patterns of pig-nosed frogs we implanted radiotransmitters (1.15 ± 0.04 g) into the body cavity of five females. We used a PLL synthesized tracking receiver (TRX-1000S, Wildlife Materials Inc.) and senders with individual frequencies (Holohil Systems Ltd.) that had a maximal range of 50 m, a life-span of two to four weeks, and were equipped with magnetic reed switches to activate or deactivate the sender.

Females were captured at a drift fence as part of a long-term study of the population biology of *H. marmoratus*. We picked only females whose mass was at least 10 times that of the sender (12.7 ± 1.08 g, range 11.8–14.5 g). Males were too light to be included in the study (range 2.5–5.6 g). Females were anesthetized by placing them in a 0.001 % solution of MS-222 Sandoz (Sigma). After 30 min females were turned on their backs and a small incision made through the ventral skin and abdominal wall. The activated sender was then placed in the abdominal cavity and the peritoneum and epidermis sown together with linen thread.

To prevent the fresh suture from rupturing when females inflated their lungs, a common occurrence in many anuran species, individuals were placed in customized plastic restrainers (Fig. 1). Restrainers were molded from an alginate (Alginoplast, Bayer Dental) imprint of a large female museum specimen. The alginate was diluted to a watery solution to lengthen processing time. After the alginate had hardened and the preserved specimen had been removed, we poured a fast-binding dental plaster (Dento-Stone Klassik, Dentona) into the mold. The ventral side of the female mold was then covered with translucent foil (Omnidur 2 mm, Omnident) to form the bottom of the restrainer. The foil was heated with a Bunsen burner to make it workable. The dorsal side of the mold was fitted with light hardening plastic (Individo Lux, Voco) to form the top of the restrainer. Caudal and cranial holes of 3–5 mm were left open to allow water to pass through the restrainer.

Females who had been implanted with radiotransmitters were placed into the restrainer and both halves held together with rubber bands. To prolong battery life, a magnet was placed on the restrainer to activate the switch and interrupt the current in the transmitter. To reduce the duration of anesthesia, water was repeatedly poured through the restrainer until we could clearly see females breathing through the translucent bottom. Restrainers were then packed into a wet towel to prevent females from desiccating and the healing process observed through the opaque half of the restrainer. After three days females were removed from the restrainers and placed into plastic terraria (23 x 15 x 24 cm) with a wet sponge for several days. After new epidermis had formed, the

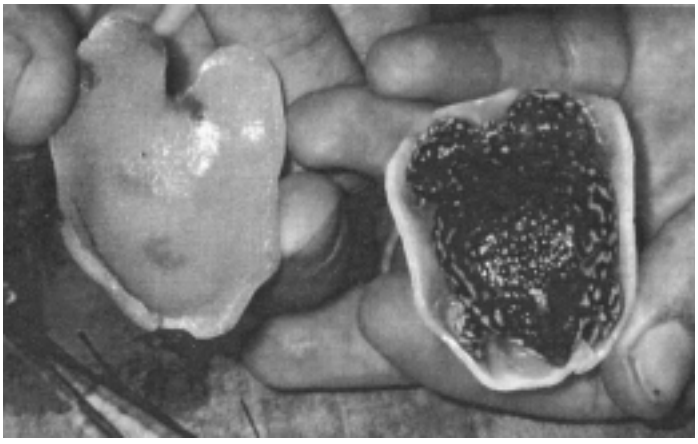

FIG. 1. Restrainer used to immobilize females after surgical implantation of a radiotransmitter.

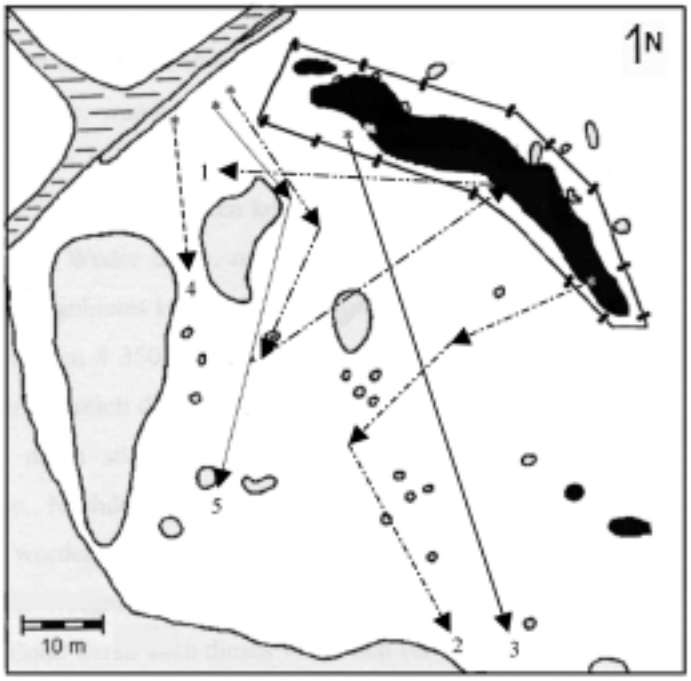

FIG. 2. Patterns of movement of five *Hemisus marmoratus* females implanted with transmitters. Black surfaces indicate ephemeral ponds, white areas grass savanna, gray areas bush savanna and the hatched area is a dirt road. The black lines with circles show the location of a drift fence with pit traps. Stars indicate where females (1–5) were found and released after transmitter implantation. Arrows show the direction of movement and numbers indicate the location at which females were last found. Last sites of females 2 and 3 were outside the area of the map.

suture fell off together with the voided skin. Since females spent most of their time underneath the sponge it was possible to place a magnet underneath the terraria to continue interrupting the circuit in the transmitter. Females were released with the next rains at the study site after wounds had completely healed. Their position was determined telemetrically at regular intervals two to three times a day.

Results and Discussion.—We followed five females and determined their activity pattern over a time period between 8 and 32 days. No adverse effects of surgery were seen in females recovered in the field. Fig. 2 shows the movement patterns of females. FEMALE 1: We followed Female 1 for 32 days. She remained for eight days at the release site, migrated 40 m south on a night after it rained and spent 11 days submerged under a clump of grass. Two days later Female 1 was found in amplexus at the fence; we placed her over the fence and two hours later she was still in amplexus trying to leave the fenced area. We again lifted her over the fence; she traveled west for 40 m where she was located underground, presumably attending eggs in her nest. Female 1 remained at this site for the following 11 days until a downpour flooded the area and the signal was lost. Most probably the female opened the nest cavity that night, released her tadpoles and left the study area. FEMALE 2: Female 2 burrowed 5 cm into the ground after being released inside the fenced area. She did not move for 15 days at which time battery power was low and she was excavated. This female was again implanted with a transmitter and released at the same site; upon release she migrated over 185 m south on three nights when it rained. Six days after being released her signal was lost. FEMALE 3: Female 3 moved 150 m into the bush savanna during one night and spent nine days buried under a grass clump 5 cm beneath the surface until reduced battery power led us to excavate her and remove the transmitter. FEMALE 4: Female 4 spent four days buried underground at the release site until it rained; she then moved 25 m in a southerly direction, burrowed into the substrate again and remained there for the next eight days. Despite an intensive search, no signal was detected the next day. FEMALE 5: Female 5 also spent four days buried underground. During the next rain she migrated 60 m southeast, then to the southwest. After five days underground, we lost contact with Female 5.

The loss of signals can be attributed to females leaving the study area, to predation, or to transmitter failure (although we think transmitter failure unlikely). All females that were fitted with transmitters were active above ground after rains. Dry periods between rains were spent underground where they were apparently inactive. This activity pattern is consistent with earlier studies that suggest the pig-nosed frog spends most of its time below ground and emerges mainly for reproduction and possibly to feed (Passmore and Carruthers 1979; Rödel 2000; Stewart 1967; Wager 1986).

The telemetry data did not reveal use of distinct home ranges. Instead individual females seemed to roam widely throughout the area. Additional pig-nosed frogs need to be followed to determine whether they use distinct home ranges or not. It seems likely that we followed females during their excursions to and from breeding sites and that their home ranges lie elsewhere (see Spieler and Linsenmair 1998).

None of the females recovered showed any infections, inflammations, or other negative effects of the implants. Implanted transmitters have the great advantage of not hampering frogs searching for retreat sites or in amplexus and are an absolute necessity in tracking fossorial species such as *H. marmoratus*. The restrainer described in this study prevents sutures from rupturing due to lung inflation in response to disturbance and thus considerably shortens the healing process. It is recommended for all small anurans in which transmitters are implanted.

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A Comparison of Aquatic Drift Fences with Traditional Funnel Trapping as a Quantitative Method for Sampling Amphibians

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Recent reports of amphibian declines have sparked increased efforts to inventory and monitor amphibian populations worldwide (Keisecker et al. 2001; Pechmann and Wilbur 1994). Standard techniques for the quantitative inventory and monitoring of amphibian populations include systematic observations, automated recording of calling anurans, drift fences with pitfall traps, and aquatic funnel trapping of amphibian larvae (Heyer et al. 1994). Terrestrial drift fence arrays with pitfall traps are an effective way to sample general species richness of amphibians and can be especially effective at detecting rare or cryptic species (Corn 1994; Gibbons and Semlitsch 1982). Drift fences intercept the movements of animals and guide them into traps, generally increasing capture rates (Corn 1994). Aquatic drift fences, or net leads, have been effectively used to increase trap capture rates for fish (Hubert 1983) and turtles (Vogt 1980); however, they have seldom been used to sample aquatic amphibian species and life stages (but see Beuch and Egeland 2002; Enge 1997a).

One preferred method for sampling aquatic amphibians and amphibian larvae is funnel trapping of aquatic environments (Heyer et al. 1994; Olson et al. 1997). A variety of funnel traps have been used, including cylindrical wire or plastic minnow traps, collapsible rectangular traps, and plastic soda bottles with the top inverted (Adams et al. 1997; Beuch and Egeland 2002; Willson and Dorcas 2003). Beuch and Egeland (2002) tested the efficiency of several different types of aquatic funnel traps for capturing amphibian larvae in seasonal forested wetlands in Minnesota. They applied the drift fence principle to aquatic funnel trapping by staking a 3.0-m section of minnow seine between two cylindrical minnow traps. They concluded that the seine did not increase trapping efficiency.

We compared the effectiveness of aquatic drift fences to traditional funnel trapping for capturing amphibians within a large ephemeral wetland in the western Piedmont of North Carolina. We used a paired-sample design, with five pairs of trap arrays, to account for spatial variation in amphibian abundance within the wetland. Each pair consisted of one experimental and one control array, set 1 m apart in a straight line (Fig. 1). The relative position (right or left) of the experimental and control arrays was determined randomly and locations for the five pairs of trap arrays within the wetland were chosen based on comparability of water depth (approximately 0.5 m) and uniformity of habitat.

Each experimental array consisted of four collapsible rectangular mesh minnow traps [model RN10; Memphis Net and Twine Co. Inc., Memphis, Tennessee; US $10.99] placed at each end and along the middle of a 3.0-m long section of silt fencing (Enge 1997) supported by three wooden stakes (Fig. 1). To ensure that trapped animals had access to air we placed an air-filled 0.6-L soda bottle inside each trap to serve as a float and tied traps loosely to 1-m bamboo garden stakes, allowing the trap to slide up and down with fluctuations in water level. Each control array consisted of four traps, positioned identically to the first array, but without silt fencing (Fig. 1). To examine the efficiency of this technique, we recorded the time required to set up and monitor both experimental and control arrays.

We checked traps every other day between 17 March and 3 April 2002 and identified to species, counted, and released all amphibians captured. MANOVA (SAS 2000; alpha = 0.05) was used to assess the effects of fencing on amphibian captures and to make univariate comparisons for individual species, life stages, and number of species captured between experimental and control traps.

Over the 18-day trapping period we captured a total of 998 amphibians representing 8 species (Fig. 2). Traps with drift fencing

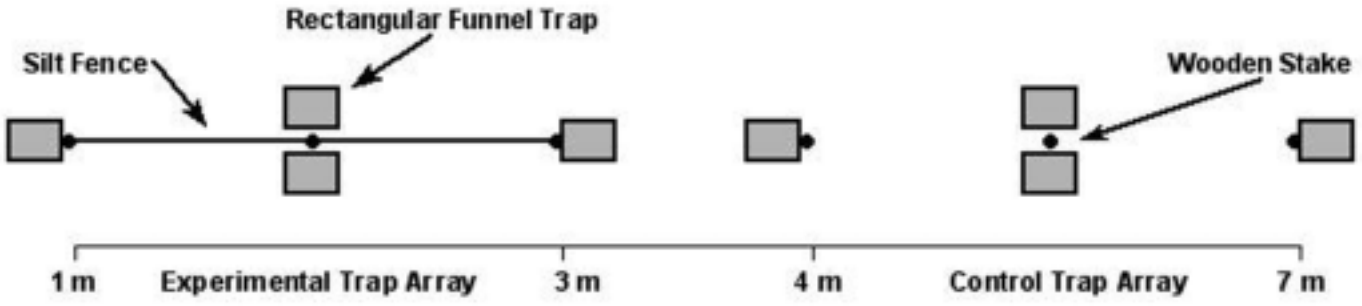

FIG. 1. Design for control and experimental trap arrays. Each array consisted of a set of four rectangular funnel traps. One array of funnel traps was placed along a section of silt fencing and one was not. Five pairs of trap arrays were set within the wetland.