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A TECHNIQUE FOR EXTERNAL RADIO-TRANSMITTER ATTACHMENT AND THE USE OF THREAD-BOBBINS FOR STUDYING SNAKE MOVEMENTS

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Abstract. Radio-tracking is a widely used method in studies of snake movement and habitat use. However, radio-tracking has some inconveniences, such as the invasiveness of surgical transmitter implantation and the high costs of receivers and transmitters. Here we describe a technique for external radio-transmitter attachment in snakes and the use of thread-bobbins (quilt-cocoons or spool-and-line device) as an alternative for tracking snakes. Both methods allow the animals to resume their natural behavior just after handling and to be monitored until the detachment of the device, usually upon shedding. These characteristics seemed to be particularly useful when the survey must be done within short periods of time with a high number of snakes. The use of thread-bobbins greatly facilitates the gathering of data on movement, habitat use, effective distance moved, and substrate use of snakes in the wild.

Keywords: radio-transmitter attachment, spool-and-line method, snake, movement.

Introduction

Studies on spatial ecology of reptiles have become more frequent in the last decades. The possibility of repeatedly locating the same animals provides valuable information on movements as migrations, home range, habitat use, dispersion of juveniles, and even physiological aspects of certain species (Weatherhead and Anderka, 1984; Boarman *et al.,* 1998). Some of these information can be obtained by using methods such as mark-recapture, or radio-tracking (White and Garrott, 1990). Radio-tracking yields high probabilities of re-locating each marked individual and the use of this method in studies of snakes have become more common with the development of smaller and lighter radio-transmitters (Mech, 1986; White and Garrott, 1990). Despite this technological advance, some negative aspects are still associated with this method, such as: (1) difficulty in attaching the transmitter to some animals like snakes which, have cylindrical bodies and usually small body size, and also (2) high cost of equipments. Some studies used force-feeding transmitters to animals in order to solve the problem of attaching them (Fitch and Shirer, 1971; Kroll *et al.,* 1973). However, the presence of this object in the digestive tract may affect feeding (Fitch and Shirer, 1971) or the thermoregulatory behavior (Lutterschmidt and Reinert, 1990). Some authors proposed attaching the device by using subcutaneous sutures (Ciofi and Chelazzi, 1991), which potentially may expose animals to infections. Currently, the most widely used technique is the surgical implantation of transmitters in the intraperitoneal cavity (Reinert and Cundall, 1982). Despite the efficiency of this method, the need for a surgical intervention results in stress and risk of death to individual snakes (Rudolph *et al.,* 1998). Furthermore, in some cases, the implantation of a transmitter may have undesirable physiological consequences in the implanted animals, such as reabsorption of ovarian follicles (Graves and Duvall, 1993), thus negatively interfering in the reproductive process.

Here we provide a detailed description of a practical and efficient technique for externally attaching radio-transmitters as well as the use of thread-bobbins or spool-and-line devices (Dole, 1965; Duellman and Lizana, 1994) as an alternative to radio-tracking. Thread-bobbins have been used for monitoring amphibians (Toledo *et al.,* 2005; Tozetti and Toledo, 2005), chelonians (Wilson, 1994), and small mammals (Vieira and Cunha, 2002), but its use in snakes has not been reported. Herein we present a technique to attach thread-bobbins, an inexpensive and easy-to-use alternative that can provide information hardly obtainable by radio-tracking.

Material and Methods

The technique for external radio-transmitter attachment was applied to 15 individuals of *Crotalus durissus* (Serpentes, Viperidae), whereas thread-bobbins were attached to five of them. All animals were captured and monitored in the Itirapina Ecological Station (IES) located in the municipalities of Itirapina and Brotas, State of São Paulo (from 22°11'25" to 22°14'55"S and from 47°51'41" to 47°55'48"W; 720-750 m of altitude), southeastern Brazil. Animals were captured during searches conducted by car and during occasional encounters inside IES. After capture, snakes were immobilized using a transparent plastic tube in order to take measurements (*e.g.* length and body mass) and for sex determination. Only snakes with body mass above 250 g were selected so that radio-transmitters and thread-bobbins would not represent more than 5% of their body mass (Hardy and Greene, 1999). Animals suitable for the study were subcutaneously implanted with pit-tags (Trovan® model ID 100).

Procedure for external radio-transmitter attachment

We used radio-transmitters SI-2 with an external antenna (9 g, 33 x 11 mm; Holohil Systems Ltd., Ontario, Canada). In order to attach the transmitter, the snake was immobilized inside a transparent tube and a portion of the animal's body surface was cleaned with a cotton ball embedded in alcohol. The transmitter was then attached to the dorsal region, at the posterior third of the snake's body using three strips (four centimeters wide) of duct tape, long enough to encircle half of its girth. The transmitter was longitudinally positioned on the animal's body, with the antenna facing the tail. The transmitter was then attached by laying the strips one at a time, perpendicular to the transmitter and parallel to each other, with an overlap of about 1 cm between them. The strips completely covered the transmitter (Figure 1) and were tightly attached to the body in order to prevent twigs and leaves from attaching during animal movements. After attaching the transmitter, strips were gently pressed against the snake's body surface to remove any air bubbles and to increase adhesion between strips and scales. The

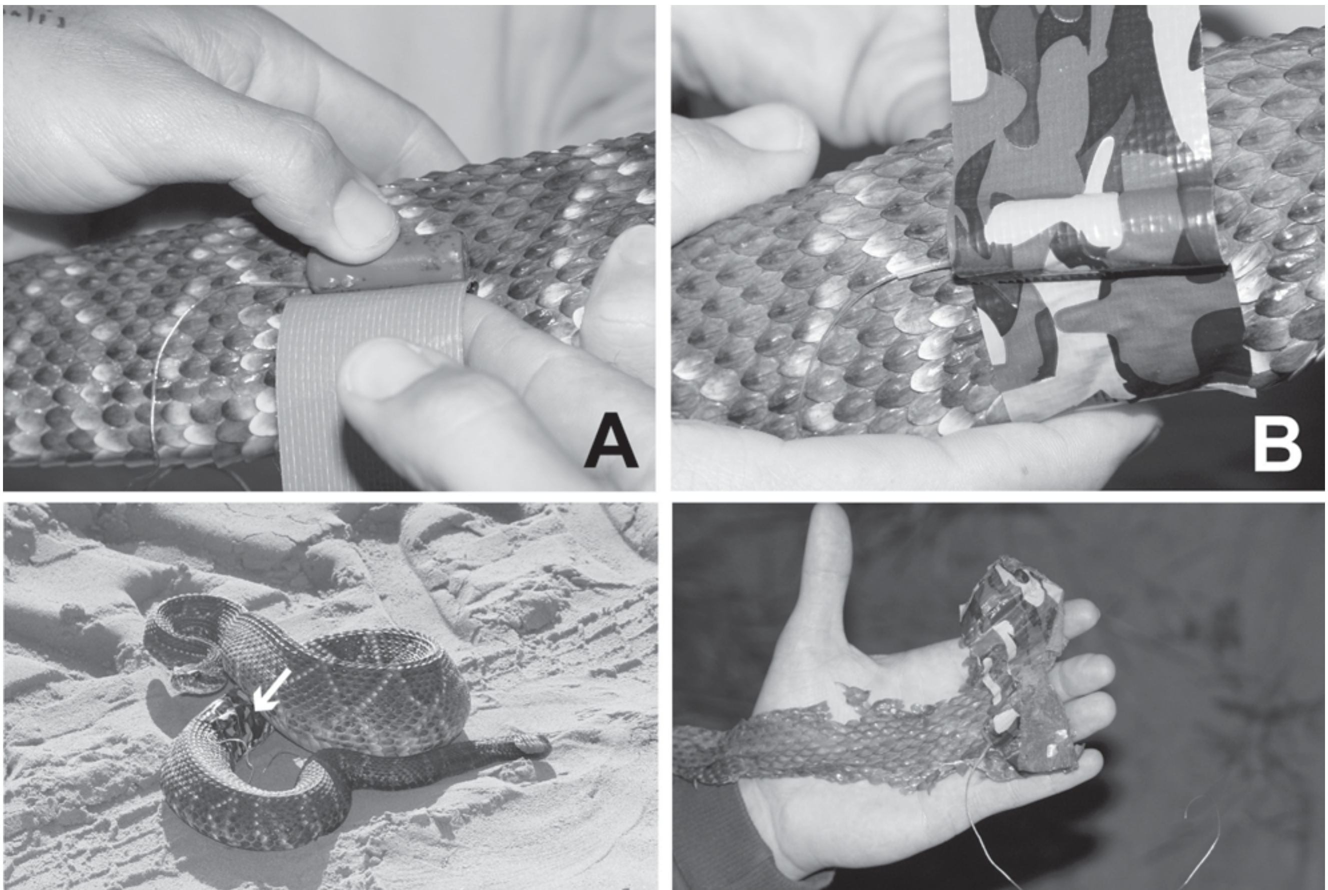

Figure 1. Steps for externally attaching radio-transmitters to a rattlesnake (A, B) and final appearance after attachment (C). Detail of a radio-transmitter found attached to the skin after shedding (D).

detachment of transmitters occurred during shedding (Figure 1). We encourage researchers to test different colors of adhesive tapes in order to match the one that most closely resembles the snake coloration, thus preventing predators from detecting contrasting colors.

Procedure to attach and use thread-bobbins

The bobbin is a small spool of thread wound in such a way that it unwinds from inside out, being originally produced for the textile industry and may be obtained in Brazil at the Hiltex Indústria e Comércio de Fios Ltda. (Av. Vicente Catalani, 1325, Bairro das Brotas, Itatiba, SP, phone number 55-11-4524 0029). We used bobbins 37 mm long, 14 mm wide, weighting approximately 6 g, and containing 300 m of thread. Before attachment, the thread-bobbin was encased in plastic wrap and a puncture was made to allow the thread to unwind. This device was attached to the dorsal-posterior region of the animal's body (Figure 2), following the same procedures described for the attachment of transmitters (the total mass of the device is approximately 12 g and can be used for snakes with body mass above 250 g. The loose end of the thread was tied to a static object in the environment (a branch or stake directed into the ground). As the animal moves, the spool leaves a trail of thread that describes the trajectory of its movement. It is important to point out that, despite the wind, the thread trail remains stationary in the environment, attached to the vegetation (even in sparse vegetation). When the bobbin is completely empty, the animal is freed from it, carrying only the adhesive tape that will be detached with the next shedding. The examination of the trajectory of the thread trail provides very precise data on the distance covered during a certain time interval, direction of movement, and types of substrate used

Evaluation of movements

Each animal was re-located in intervals of at least 12 hours after the device attachment to minimize the effects of temporal dependence (auto-correlation)

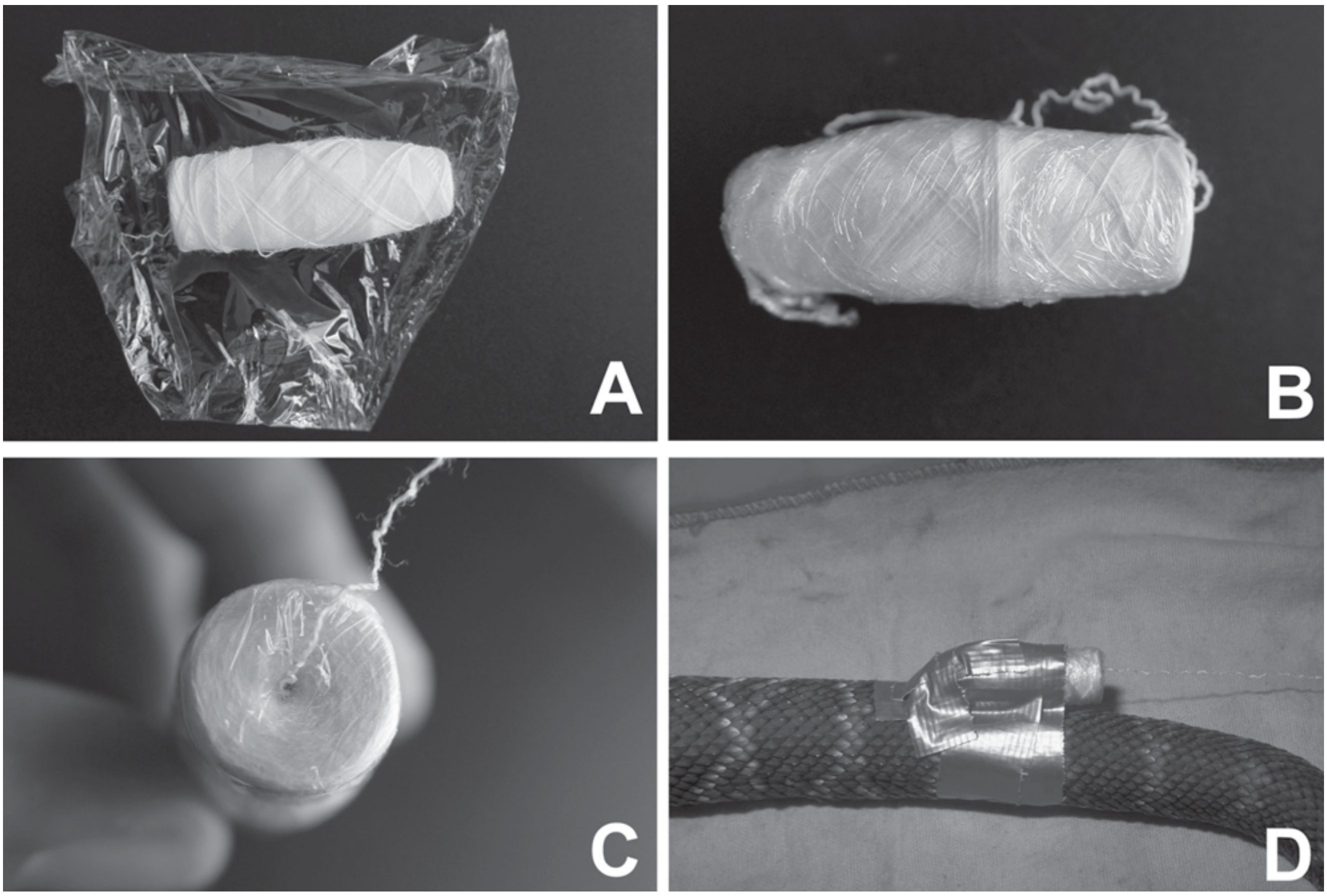

Figure 2. Bobbin being encased in plastic wrap (A-B), details of the perforation to allow the thread to unwind (C) and the device attached to a rattlesnake (D).

among points (White and Garrott, 1990). Animals equipped with thread-bobbins were re-located by tracking the thread trail. The location in which the animal was observed was termed "point" and was marked by colored flagging. Re-locations provided visual contact with individuals, except when animals were sheltered in burrows. Signals of radio-transmitters were tracked with a portable receptor (Telonics TR-4) and a four-element Yagi antenna.

In both tracking methods, for each re-location, the distance in a straight line between consecutive points was measured with the aid of a measuring tape. Such measure was termed "straight line distance between consecutive re-locations" (SLD in m/day). For animals equipped with thread-bobbins, in addition to SLD, the thread left between re-locations was recovered and measured. The length of the thread left between two consecutive points was termed "effective distance moved" (EDM; Figure 3). SLD values obtained from the monitoring using radio-transmitters and thread bobbins were compared using a Mann-Whitney test (U-test). EDM and SDL values obtained from the monitoring using bobbins were compared using a Wilcoxon matched pairs test. Differences were considered significant at $p < 0{,}05$ (Zar, 1999).

Results

Animals equipped with transmitters or thread-bobbins were observed moving through dense vegetation or sheltered in deep and narrow burrows. Animals were also observed basking, foraging, and even capturing and ingesting a prey offered by us. This indicates that the presence of adhesive tapes apparently does not interfere on the distention of the body during the passage of food.

The mean monitoring time using radio-transmitters was 69.2 days (range: 1-195 days; Table 1). Radio tracking was interrupted due to shedding (46.7% of animals) or detachment of adhesive tapes (53.3% of animals; Table 1). Thread-bobbins were efficient short-term tracking devices for *Crotalus durissus.* Of five animals monitored, four moved until the bobbin was empty, which took on average 3.4 days (range: 1-9 days). The monitoring of the remaining specimen was interrupted by the detachment of adhesive tapes (Table 2).

We observed no significant differences between SLD values obtained with radio-transmitters and thread-bobbins ($U = 31$; $P = 0.57$; $N = 20$; Figure 4). On the other hand, EDM was significantly higher than SLD (Wilcoxon Matched Pairs Test, $t = 0.0$; $P = 0.04$; $N = 5$; Table 2; Figure 4). On average, EDM values were 1.76 higher compared to those of SLD (Table 2; Figure 4).

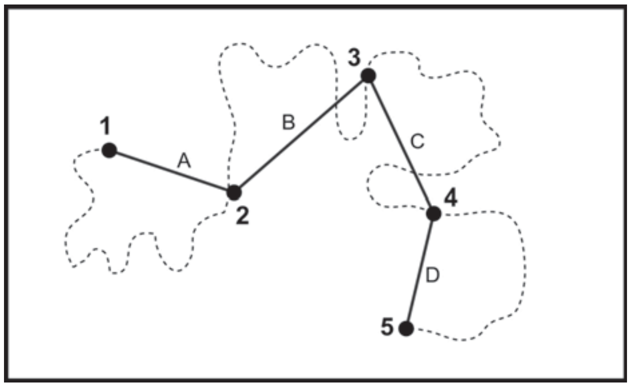

Figure 3. Diagram of measurements taken from hypothetical re-locations of a snake tracked with thread-bobbin. The numbers indicate re-locations in chronological order from 1 to 5. Letters (a, b, c, and d) represent the strait line distances between consecutive re-locations (= SLD). The dashed line represents the thread trail from which the effective distance moved is obtained (= EDM).

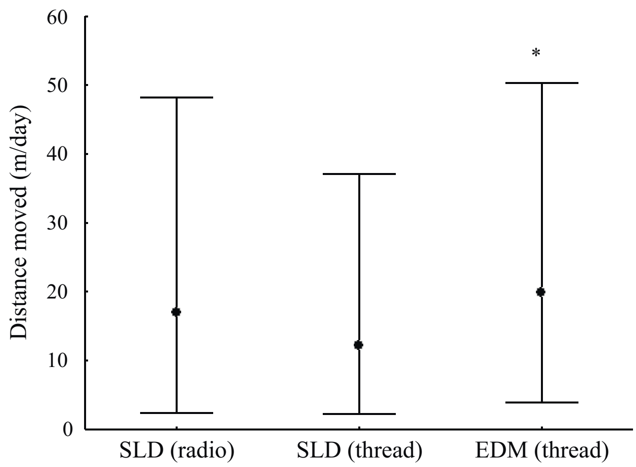

Figure 4. Variation in the distances moved by snakes monitored by radio-transmitters or bobbins. Points represent means and bars, the maximum and minimum values. DDM = daily distance moved; EDM = effective distance moved. See text for details. * = significant difference.

Discussion

The proposed method for external radio-transmitter attachment was feasible to track snakes in short to medium-term studies. Despite the mean monitoring time for radio-transmitters of 69.2, one individual was monitored for 195 days, which corresponds to approximately 50% of the life span of the battery of the transmitters used. Monitoring events with less

Table 1. Individual monitoring results for *Crotalus durissus* equipped with externally attached radio-transmitters. The number for each animal corresponds to transponder number. S = shedding; DS = detachment of strips.

Animal	Size (mm)	Sex	Days	Points	SLD (m/day)	Cause of detachment
61BE8EA	970	f	195	21	12.94	S
61BED1A	771	f	36	6	2.43	S
61C0023	735	f	183	28	8.64	S
61C0BEO	1085	f	59	12	28.17	DS
1C94997	1196	m	44	8	32.16	S
610B167	1190	m	191	18	18.48	DS
610D9DC	1010	m	14	5	18.47	S
618A8A9	1035	m	5	2	38.72	DS
61BCD61	785	m	45	8	15.54	DS
61C0025	1055	m	39	4	13.92	DS
61C007D	775	m	37	12	6.67	DS
61C0686	637	m	21	3	3.42	S
61C360B	708	m	57	9	10.00	S
61C4308	1168	m	1	1	48.21	DS
61COB5F	1256	m	111	14	8.08	DS
	Mean (± standard deviation)		69.2 (± 67.6)	10.07 (± 7.6)	17.7 (± 13.4)	

Table 2. Straight line distances between consecutive re-locations (SLD) and effective distances moved (EDM) with their corresponding maximum and minimum values; SLD – EDM ratio calculated based on specimens of *Crotalus durissus* monitored with thread-bobbins; and means and standard deviations (in parenthesis). The number for each animal corresponds to transponder number. See details for obtaining SLD and EDM in Methods. ET = end of thread; DS = detachment of strips.

Animal	Size (mm)	Sex	SLD (m/day)	Days	Points	EDM (m/day)	EDM/SLD	Cause of detachment
618D311	537	F	21.6	1	1	33.4	1.5	ET
61BF70C	840	F	5.8	1	1	15.4	2.6	DS
610D05F	1335	F	14.1 (37.1/5.0)	4	4	21.5 (37.1/5.0)	1.7	ET
61C013B	655	M	5.5 (7.1/4.0)	2	3	7.1 (10.3/4.0)	1.3	ET
124BCE4	1240	M	14.9 (29.1/2.2)	9	4	22.8 (43.8/5.4)	1.7	ET
		Mean (± standard deviation)	12.38 (± 6.8)	3.4 (± 3.4)	2.6 (± 1.5)	20.04 (± 9.7)	1.76 (± 0.5)	

than 10 days of duration and which were interrupted due to detachment of adhesive tapes occurred only during the initial phase of the study. Thus, the ability of the researcher to attach the device and the absence of shedding may both considerably increase the monitoring time.

The rough skin of *C. durissus,* with hard and keeled scales, may have facilitated the attachment of the device and its persistence on the snake skin. The effectiveness of this method in smooth-scaled snakes like colubrids and boids remains to be tested.

No animals died during monitoring, suggesting that the presence of the device did not compromised the survival of the snakes due to being preyed on by predators and caused no injuries to the specimens monitored, despite signs of strong predation pressure on snakes in the study area (Tozetti *et al.,* 2004).

Since recovered detached transmitters were used in new animals, the number of monitored animals was higher than the number of transmitters available. This possibility may lessen the effects of individual variations in the population, maximizing the detection of general behavioral patterns. External radio-transmitter attachment is recommended in situations when data collection is conducted within a short time interval and involves a high number of snakes (*i.e.* studies during specific events such as mating, male combat, gestation, aestivation) or sites of difficult access and/or limitations regarding the time of stay of researchers during long periods (as in remote islands). We believe that one of the main advantages of external radio-transmitter attachment is avoidance of anesthesia, which is inherent to surgery. In addition, unlike what is observed in surgical implants (see Hardy and Greene, 1999), with external radio-transmitter attachment the animals resume their normal behavior immediately after manipulation.

Regarding thread-bobbins, the limiting factor was the end of the thread and not the detachment of adhesive tapes or shedding. Despite the short monitoring time, this method has the advantage of providing data on substrate use, as the thread remains attached to the vegetation and static in relation to the substrate. In two occasions, juveniles of *C. durissus* moved on shrubs located at 40-50 cm above ground, a behavior not expected for predominantly terrestrial animals (with body mass above 250 g). We suggest the use of thread-bobbins of different colors in case of simultaneous monitoring of animals located a few meters from each other.

The low cost, associated with the ease of attachment and monitoring make the use of thread-bobbins suitable for studies in which data collection must be done in a short time interval involving a high number of snakes. Such characteristics allow a fast assessment of movements and habitat use, as well as provide complementary data to those obtained by radio-tracking, especially regarding distance covered and substrate use. The effective distance covered was significantly higher than that of point-to-point measurements, suggesting that if only the linear distance between the initial and final points of a trajectory is considered (as in studies using radio-transmitters), covered distances may be greatly underestimated.

Resumo

O uso de rádios-transmissores é comumente aplicado em estudos de movimentos e de uso do ambiente por serpentes. Entretanto, a rádio-telemetria apresenta alguns inconvenientes tais como a necessidade de um procedimento traumático para fixação dos transmissores nos animais (implante cirúrgico) além do alto custo do equipamento. Neste estudo apresentamos uma técnica para fixação externa de rádio-transmissores em serpentes e também o uso de carretéis (novelos de linha, “thread-bobbins”) como método alternativo para o registro dos movimentos de serpentes. Ambos os métodos permitem que o animal retome seu comportamento natural logo após a manipulação podendo ser monitorado até que o equipamento se desprenda, geralmente quando houver uma muda de pele. Tais características conferem vantagens aos métodos, especialmente quando a amostragem é feita em um curto intervalo de tempo envolvendo o maior número possível de serpentes. O uso de carretéis se mostrou eficiente para a obtenção de dados a respeito dos locais de repouso e abrigo, do modo de forrageio, uso do ambiente, registro da distância efetivamente percorrida e uso do substrato pelas serpentes na natureza.

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