HERPETOLOGICAL JOURNAL, Vol. 4, pp. 11-14 (1994)

THE EFFECT OF SURGICALLY IMPLANTED TRANSMITTERS UPON THE LOCOMOTORY PERFORMANCE OF THE CHECKERED GARTER SNAKE, *THAMNOPHIS M. MARCIANUS*

WILLIAM I. LUTTERSCHMIDT*

Department of Biological Sciences, Southeastern Louisiana University, Hammond, Louisiana 70402, USA

**Present Address: Department of Zoology, University of Oklahoma, Norman, Oklahoma 73019 USA*

The effect of both surgery and implanted transmitters upon sprint time of *Thamnophis m. marcianus* from two populations was assessed under laboratory conditions using a circular racetrack. The mean sprint times of snakes before surgery were 7.52 s (SE = 0.393, n = 8) and 9.69 s (SE = 0.358, n = 5) for the Arizona and Texas populations, respectively. Mean sprint times of the same snakes following surgery were 7.55 s (SE = 0.387, n = 8) for the Arizona population and 9.83 s (SE = 0.408, n = 5) for the Texas population. A repeated measures ANOVA indicated that sprint time for both non-surgery and surgery treatments did not differ significantly. Transmitter treatments consisted of implanting transmitters equalling 10% or 15% of the snake's body mass. The mean sprint times for snakes receiving either 10% or 15% transmitter treatments were statistically compared to the mean sprint time of snakes receiving the surgery treatment. A two-way ANCOVA accounting for body mass indicated that the mean sprint time was significantly reduced for snakes carrying implanted transmitters equal to 15% of their body mass. These results suggest that surgical techniques have no effect upon locomotory performance and that implanted transmitters for radiotelemetry of snakes should probably not exceed 10% of the snake's body mass.

INTRODUCTION

Many studies of snake behaviour and ecology have used either ingested or surgically implanted transmitters (e.g. Osgood, 1970; Fitch & Shirer, 1971; Parker & Brown, 1972; Landreth, 1973; Brown & Parker, 1976; Nickerson *et al*., 1978; Jacob & Painter, 1980; Reinert & Kodrich, 1982; Reinert, 1984*a,b*; Reinert *et al*., 1984; Shine & Lambeck, 1985; Burger & Zappalorti, 1988; Reinert & Zappalorti, 1988*a,b*; Plummer, 1990). However, implanting transmitters surgically into the coelomic cavity of a snake may be the preferred method for radiotelemetry because it circumvents the many problems associated with ingested transmitters (Reinert & Cundall, 1982; Lutterschmidt & Reinert, 1990).

Although surgical implantation methods are commonly used, the effects of these methodologies upon snake behaviour and locomotory performance have never been experimentally evaluated. Transmitter packages having an approximate mass 10% of the snake's body mass have been assumed to have little or no effect upon snake behaviour (Pisani *et al*., 1987). However, Shine (1988) recently proposed that transmitters with a mass less than 5% of a snake's mass are more appropriate. Reinert (1992) has also suggested that transmitters implanted in the coelomic cavity should probably not exceed 5% of a snake's body mass.

Because data on how transmitter mass may reduce snake locomotor ability are unavailable, I have evaluated the effect of transmitter mass upon locomotory performance to determine a critical transmitter mass for surgical implantation.

MATERIALS AND METHODS

Thirty-six checkered garter snakes, *Thamnophis m. marcianus,* were collected from Graham County, Arizona and Lubbock County, Texas. Only male snakes were used for experimentation to eliminate possible variation due to sex. Snakes were housed in separate 3.78 l plastic cages and acclimated to laboratory conditions (24.0±2.0 C and a light and dark cycle of LD 12 hr:12 hr) for approximately 6 months. Snakes were maintained on a diet (30% of the snake's body mass weekly) of bullfrog tadpoles, *Rana catesbeiana*, and water *ad libitum.*

Each snake was randomly selected for one of three experimental groups: (1) non-surgery, and then surgery with no implanted model transmitter (i.e. repeated measures design); (2) surgical implantation of model transmitter equal to 10% of the snake's body mass; (3) surgical implantation of model transmitter equal to 15% of the snake's body mass. Surgical procedures were as described by Reinert & Cundall (1982). Experimental groups receiving surgery were allowed 24 hr before testing. Model transmitters consisted of a small steel rod coated with a 1:1 mixture of beeswax and paraffin. These models were designed to simulate actual size, shape, and mass of transmitter packages. The possible effects of an antenna, which would normally be placed longitudinally under the skin, was not used and therefore not evaluated.

Locomotory performance was assessed by determining burst or sprint speed (Garland & Arnold, 1983; Ford & Shuttlesworth, 1986). Sprint speed was determined by the time required to crawl a distance of 3.0 m around a circular racetrack similar to that described by Ford & Shuttlesworth (1986). Because distance (3.0 m) remained constant for all trials, the variable of time (not rate or speed) was used for treatment comparisons. Time (s) was measured to the nearest 0.01 s for each snake in three different trials to calculate an average sprint time.

Trials were conducted under standard conditions of light and temperature (25.0±2.0 C). Snake body temperatures ($\bar{x} = 24.7$, SE = 0.06, $n = 85$) were also kept constant and measured before all trials to avoid possible temperature effects upon metabolism and locomotory performance (e.g. Heckrotte, 1967; Stevenson *et al.*, 1985).

A model I, two-way ANOVA with repeated measures was used to first examine possible surgical effects upon sprint time in both populations by comparing non-surgery and surgery (with no implanted transmitter) treatments. The surgery group was then used as a control for a second comparison to determine if sprint time differed among the implanted transmitter groups (10% and 15% of body mass).

The experimental design consisted of preliminary tests (*t*-test) to first determine if transmitters of 15% body mass affected locomotory performance. Because sprint speeds of the 15% transmitter group were significantly reduced in comparison to the surgery group, the next experimental group (transmitters 10% of body mass) was investigated.

Final statistical comparisons consisted of a model I, two-way analysis of covariance with repeated measures to determine differences in sprint time among experimental groups for both the Arizona and Texas populations. The analysis of covariance eliminated possible effects of body size upon sprint speed (e.g. Heckrotte, 1967; Seigel *et al.*, 1987; Jayne & Bennett, 1990*a*). An *a posteriori* test (SAS, 1988) of adjusted means assessed differences among all experimental groups for each population. All data were analyzed using SAS (1988). The assumption of similar slopes among treatments and populations was met for the ANCOVA analysis (Figs. 1A and 1B).

RESULTS

Surgical methods described by Reinert & Cundall (1982) and the implantation of transmitters (10% of body mass) into the coelomic cavity had no effect upon sprint time in *Thamnophis m. marcianus*. The mean sprint times of snakes without surgery for both Arizona and Texas populations were 7.52 s (SE = 0.393, $n = 8$) and 9.69 s (SE = 0.358, $n = 5$), respectively. Mean sprint times for the same snakes following surgery were 7.55 s (SE = 0.387, $n = 8$) in the Arizona population and 9.83 s (SE = 0.408, $n = 5$) in the Texas population (Table 1). A repeated measures two-way ANOVA indicated that sprint times for non-surgery and surgery treatments did not differ significantly (Treatments: $F_{1,22} = 0.04$, $P > 0.05$; Population: $F_{1,22} = 29.08$, $P < 0.001$; Treatments x population: $F_{1,22} = 0.02$, $P > 0.05$).

Treatment	Arizona population	Texas population
Non-surgery	7.52 (0.393, 8)	9.69 (0.358, 5)
Surgery only	7.55 (0.387, 8)	9.83 (0.408, 5)
Surgery and 10% MT	6.87 (0.311, 7)	10.23 (0.644, 3)
Surgery and 15% MT	10.45 (0.776, 8)	12.47 (0.531, 5)

TABLE 1. Non-adjusted mean sprint times (s) with SE and *n* for each treatment of the two populations. The implantation of a model transmitter (MT) 10% and 15% of the snake's body mass is indicated by 10% MT and 15% MT.

Sprint time for the surgery treatment was then statistically compared to the sprint time of snakes receiving 10% and 15% transmitter treatments. A two-way ANCOVA accounting for body mass indicated that the mean sprint time differed significantly among treatments (Table 2). A multiple comparisons test for adjusted means indicated that sprint time was significantly reduced for snakes carrying implanted transmitters 15% of their body mass. Both the surgery and 10% transmitter treatments significantly differed from the 15% transmitter treatment but not from each other. In order to examine possible variation of the linear relationship due to the volumetric function of mass, the same analysis was conducted using the cube root of body mass (per. comm. G.D. Schnell). Because the same results were obtained, all results are reported in mass (not the cube roots of mass), for the sake of convenience.

The Arizona and Texas populations were analyzed as separate populations (and not grouped) due to preliminary tests indicating significantly different sprint times between the populations ($t = 3.76$, df = 11, $P < 0.01$). However, each population demonstrated similar responses to each of the experimental treatments (Figs. 1A and 1B).

Source	df	SS	MS	*F*	*P*
Treatment	2	48.26	24.13	19.13	0.0001
Population	1	72.57	72.57	57.53	0.0001
Treat. x Pop.	2	1.74	0.87	0.69	0.5085
Mass	1	21.04	21.04	16.68	0.0003
Error	29	36.58	1.26		
Total	35	180.17			

TABLE 2. A two-way ANCOVA table showing respective *F* and *P* values accounting for mean sprint time and mass as the covariate.

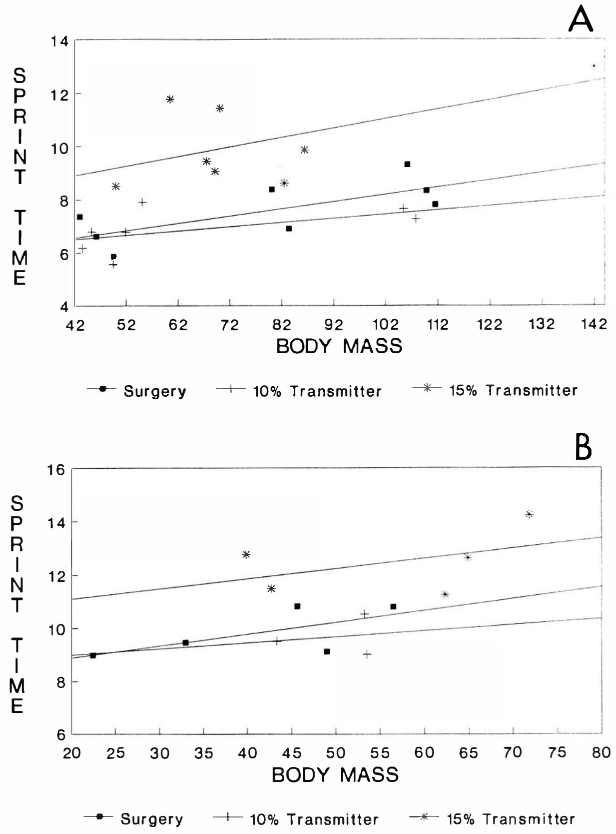

FIG. 1. Body mass (g) plotted against sprint time (s) showing similar slopes for the surgery, 10% transmitter, and 15% transmitter treatments. A, relationship between body mass and sprint time for all treatments in the Arizona population; B, relationships for the Texas population.

DISCUSSION

Snake ecologists have questioned the possible influences of transmitters upon behaviour. My own concerns and speculation of experimental bias have been: (1) a possible reduction in survivorship of individuals carrying transmitters due to an inability to successfully escape predators, (2) a lowered success rate in capturing prey for snakes that demonstrate an active foraging strategy, and (3) a reduction in home-range and movement patterns which may also affect other aspects of a snake's ecology (e.g. energetics and reproduction). In support of these concerns, Jayne & Bennett (1990b) and Garland *et al.* (1990) have shown that individual differences in locomotor performance of *Thamnophis* affect survival. Secondly, relationships between locomotor capacity and foraging behaviour have also been demonstrated (Huey *et al.*, 1984).

Although transmitters equal to 15% of a snake's body mass significantly reduced locomotory performance, neither surgical procedures nor implanted transmitters equal to 10% of a snake's body mass affected sprint time. These findings may help in addressing concerns of snake ecologists who use surgically implanted transmitters.

Until recently, a critical mass for transmitters (10% of the snake's body mass) has been assumed to have a limited effect upon locomotor ability (Pisani *et al.*, 1987; but also see Shine, 1988). Results of this study support Pisani *et al.* (1987) and indicate that critical mass (i.e. mass which will significantly reduce "sprint speed") of transmitter packages may be between 10% and 15% of a snake's body mass.

Ford & Shuttlesworth (1986) found similar results for juvenile garter snakes, *Thamnophis marcianus*. Sprint speed of snakes with a food bolus equal to 10% of their body mass did not significantly differ from snakes with no ingested food items. However, sprint speed was significantly reduced by the ingestion of a food bolus 30% and 50% of the snake's body mass. Garland & Arnold (1983) also showed that sprint speed of juvenile *Thamnophis elegans* was not affected by a "full stomach" (i.e. ingestion of food items between 17.6 - 26.9% of body mass). Unlike Ford & Shuttlesworth (1986) and Garland & Arnold (1983), my results indicate a significant reduction in sprint speed with a 15% increase in body mass. However, a direct comparison between my results and these studies may not be appropriate. The difference in results may simply suggest that snakes may be able to carry a greater mass within its stomach without a reduction in sprint speed. Therefore, surgically implanting a transmitter into the coelomic cavity may have a greater effect upon sprint speed than if the same transmitter mass was ingested. However, gravid garter snakes (*Thamnophis marcianus*) can carry a clutch mass 24% of their body mass before a significant reduction in locomotor ability occurs (Seigel *et al.*, 1987).

In summary, my results suggest that transmitter packages having a mass equal to and possibly less than 10% of the snake's mass do not reduce a snake's sprint speed. However, several other aspects of snake behaviour also should be considered when determining the mass and size of a transmitter. Although a certain size transmitter package may not affect sprint speed, it may alter endurance, the passage of material through the digestive tract, and possibly thermoregulatory behaviour. Such factors have not been evaluated by this study and should be of concern to investigators using surgically implanted transmitters. In order to circumvent possible influences upon snake behaviour, I suggest that the smallest transmitter package (that can meet the experimental needs) should be used for telemetric studies of snakes. Such practices may limit possible behavioural biases until the effects of surgical methods and implanted transmitters can be fully evaluated.

ACKNOWLEDGMENTS

I thank R. A. Seigel and N. B. Ford for the collection of snakes used in this study. I also thank the Arizona Fish and Game Commission for permits and the Roper State Park staff for their cooperation. I acknowledge the support of Louisiana Board of Regents LEQSF Grant (1987-89-RD-A-16) and a Southeastern Louisiana University Faculty Development Grant to R. A. Seigel. Lastly, I thank R. A. Seigel for his time and suggestions upon review of this manuscript.

REFERENCES

Brown, W. S. & Parker, W. S. (1976). Movement ecology of *Coluber constrictor* near communal hibernacula. *Copeia* **1976**, 225-242.

Burger, J. & Zappalorti, R. T. (1988). Habitat use in free-ranging pine snakes, *Pituophis melanoleucus*, in New Jersey Pine Barrens. *Herpetologica* **44**, 48-55.

Fitch, H. S. & Shirer, H. W. (1971). A radiotelemetric study of spatial relationships in some common snakes. *Copeia* **1971**, 118-128.

Ford, N. B. & Shuttlesworth, G. A. (1986). Effect of variation in food intake on locomotory performance of juvenile garter snakes. *Copeia* **1986**, 999-1001.

Garland, T. Jr. & Arnold, S. J. (1983). Effects of a full stomach on locomotory performance of juvenile garter snakes (*Thamnophis elegans*). *Copeia* **1983**, 1092-1096.

Garland, T. Jr., Bennett, A. F. & Daniels, C. B. (1990). Heritability of locomotor performance and its correlates in a natural population. *Experientia* **46**, 530-533.

Heckrotte, C. (1967). Relation of body temperature, size, and crawling speed of the common garter snake, *Thamnophis s. sirtalis*. *Copeia* **1967**, 759-763.

Huey, R. B., Bennett, A. F., John-Alder, H. & Nagy, K. A. (1984). Locomotor capacity and foraging behavior of Kalahari Lacertid lizards. *Anim. Behav.* **32**, 41-50.

Jacob, J. S. & Painter, C. W. (1980). Overwinter thermal ecology of *Crotalus viridis* in the north central plains of New Mexico. *Copeia* **1980**, 779-805.

Jayne, B. C. & Bennett, A. F. (1990*a*). Scaling of speed and endurance in garter snakes: a comparison of cross-sectional and longitudinal allometries. *J. Zool. Lond.* **220**, 257-277.

Jayne, B. C. & Bennett, A. F. (1990*b*). Selection on locomotor performance capacity in a natural population of garter snakes. *Evolution* **44**, 1204-1229.

Landreth, H. F. (1973). Orientation and behavior of the rattlesnake, *Crotalus atrox*. *Copeia* **1973**, 26-31.

Lutterschmidt, W. I. & Reinert, H. K. (1990). The effect of ingested transmitters upon the temperature preference of the Northern water snake, *Nerodia s. sipedon*. *Herpetologica* **46**, 39-42.

Nickerson, M. A., Sajdak, R. A., Henderson, R. W. & Ketcham, S. (1978). Notes on the movements of some neotropical snake (Reptilia, Serpentes). *J. Herpet.* **12**, 419-422.

Osgood, D. W. (1970). Thermoregulation in water snakes studied by telemetry. *Copeia* **1970**, 568-571.

Parker, W. S. & Brown, W. S. (1972). Telemetric study of movements and oviposition of two female *Masticophis t. taeniatus*. *Copeia* **1972**, 892-895.

Pisani, G. R., Busack, S. D., Dessauer, H. C., Hutchison, V. H. & Schnell, G. D. (1987). *Guidelines for use of live amphibians and reptiles in field research*, 1-14. ASIH, HL, and SSAR.

Plummer, M. V. (1990). Nesting movements, nesting behavior, and nest sites of green snakes (*Opheodrys aestivus*) revealed by radiotelemetry. *Herpetologica* **46**, 190-195.

Reinert, H. K. (1984*a*). Habitat variation within sympatric snake populations. *Ecology* **65**, 478-486.

Reinert, H.K. (1984*b*). Habitat variation between sympatric snake populations. *Ecology* **65**, 1673-1682.

Reinert, H. K. (1992). Radiotelemetric field studies of pitvipers: data acquistion and analysis. In *Biology of the pitviper: A symposium*, 185-198. Campbell, J. A. & E. D. Brodie Jr. (Eds.). Tyler, Texas: Selva Press.

Reinert, H. K. & Cundall, D. (1982). An improved surgical implantation method for radio-tracking snakes. *Copeia* **1982**, 702-705.

Reinert, H. K. & Kodrich, W. R. (1982). Movements and habitat utilization by the Massasauga, *Istrurus catenatus catenatus*. *J. Herpet.* **16**, 162-171.

Reinert, H. K. & Zappalorti, R. T. (1988*a*). Timber rattlesnakes (*Crotalus horridus*) of the Pine Barrens: Their movements and habitat preference. *Copeia* **1988**, 964-978.

Reinert, H. K. & Zappalorti, R. T. (1988*b*). Field observations of the association of adult and neonatal timber rattlesnakes, *Crotalus horridus*, with possible evidence for conspecific trailing. *Copeia* **1988**, 1057-1059.

Reinert, H. K., Cundall, D. & Bushar, L. M. (1984). Foraging behavior of the timber rattlesnake, *Crotalus horridus*. *Copeia* **1984**, 976-981.

SAS Institute. (1988). *SAS user's guide: statistics*. SAS Institute, Cary, North Carolina.

Seigel R. A., Huggins, M. M. & Ford, N. B. (1987). Reduction in locomotor ability as a cost of reproduction in gravid snakes. *Oecologia* **73**, 481-485.

Shine, R. (1988). Discussion: Radiotelemetry. In *Snake ecology group news letter*, 2-3. Gibson, A. R. & C. R. Peterson (Eds.). Cleveland State Univ., Dept. of Biology.

Shine, R. & Lambeck, R. (1985). A radiotelemetric study of movements, thermoregulation and habitat utilization of Arafura Filesnakes (Serpentes: Acrochordidae). *Herpetologica* **41**, 351-361.

Stevenson, R. D., Peterson, C. R. & Tsuji, J. S. (1985). The thermal dependence of locomotion, tongue flicking, digestion, and oxygen consumption in the wandering garter snake. *Physiol. Zool.* **58**, 46-57.

Accepted: 5.4.93