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THE EFFICACY OF NAPHTHALENE AND SULFUR REPELLENTS TO CAUSE AVOIDANCE BEHAVIOR IN THE PLAINS GARTER SNAKE

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Abstract: The efficacy of naphthalene, sulfur, and a commercial combination of these chemicals as a repellent against the plains garter snake (*Thamnophis radix*) was investigated. Behavioral tests were conducted using 96 recently captured snakes to determine whether significant avoidance results from the presence of these chemicals. Field tests were performed at 24 locations in the snakes' home range and in unfamiliar habitats. In both home ranges and unfamiliar habitats application of potential repellents did not result in significant avoidance behavior. The snakes may be able to sense these volatile chemicals, but the stimuli were unable to alter their behavior. Based on this study, tendency to seek cover, refuge, familiar habitat, or to investigate unfamiliar areas was stronger than deterrence of the chemicals. Because the substances tested did not elicit avoidance behavior in the plains garter snake, usage of these repellents should be discouraged. Habitat modification for snake management is discussed as an alternative to the application of chemical repellents.

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Key Words: avoidance behavior, naphthalene, plains garter snake, repellent, sulfur, *Thamnophis radix.*

The plains garter snake *(Thamnophis radix)* is common throughout North America (Conant and Collins 1991:167) and is the most common snake found in urbanized areas in Nebraska (Lynch 1985). Retaining walls, as well as decorative gardens containing rocks or wooden components are a popular part of landscapes in residential locations; garter snakes favor these objects, as well as debris piles, as refugia (Gregory 1977). Human-snake encounters become very common during spring and summer when snakes move about searching for mates or food, and when people utilize the outdoors (Ferraro 1991). A nonlethal method of snake management that would decrease human interactions and yet allow the snakes to remain part of the food web would be extremely beneficial. An effective repellent that could be easily applied by the public would accomplish this goal. In recent years a number of commercially available "snake repellents" containing naphthalene and sulfur have been widely advertised. The purpose of this investigation was to determine the efficacy of the popular Environmental Protection Agency (EPA) registered chemicals naphthalene and sulfur as snake repellents toward the most commonly encountered species, the plains garter snake. The objectives were: (1) to test these substances in field situations where human-snake interaction occurs, (2) to establish whether these chemicals create a significant avoidance behavior resulting in a change in snake movements, and (3) to determine the ability of the chemicals to act as a deterrent to snakes seeking cover in an unfamiliar location. The results of this investigation should be of benefit and use to the concerned public and wildlife damage control professionals when considering usage of a snake repellent.

STUDY SITES AND METHODS

The study sites were located within urbanized areas of eastern Douglas and Sarpy counties Nebraska. Twenty-four trial sites were selected from within this 54 km^2 area. To qualify as a trial site the following criteria were utilized:

(1) no chemical repellents or insecticides had been applied on the property within the last year;

(2) snake habitats or potential snake habitats had not been disrupted within the previous 6 months;

(3) the willingness of property owners to refrain persons or pets from entering the specific study site just prior to and during the scheduled trials; and

(4) for Experiment 1 trial sites, 5 or more garter snakes had been sighted at the location within the past month and for Experiment 2 trial sites, no snakes had been sighted at the location within the past 3 months.

All residential trial sites were located in well-established neighborhoods from 20-70 years of age. The study was conducted during June and July of 1992 and 1993. This was after the mating period (mid-April to mid-May) (Lesch 1977, personal observation) but before parturition (August to early September) and the autumnal migration toward possible hibernation locations (Seibert and Hagen 1947, Lesch 1977). All test trials were scheduled on sunny or partly sunny days between 1000 hrs and 1700 hours Central Daylight Time.. These conditions correspond to the garter snake's optimal activity times (Heckrotte 1961, Dalrymple and Reichenbach 1984). At the onset of each test trial, air temperature, relative humidity, wind speed, and wind direction were recorded. Garter snakes were hand captured and immediately examined. Snakes undergoing shedding (ecdysis) with gross physical abnormalities such as any scars or defects in the facial region were not used.

Three substances were tested: (1) naphthalene crystals (99%), (2) sulfur, and (3) a commercially available product consisting of 7.05% (wt/vol) naphthalene, 28.00% sulfur, and 65.05% (wt/vol) "inert ingredients." Two controls were used. One consisted of 2.5-10.0 mm particles of limestone. The other control was a strip of soil devoid of vegetation and other substrate objects.

Experiment 1: Familiar Habitat Test

Suitable garter snake habitats (such as rock walls, garden debris piles, and weed fence lines) were carefully searched with minimal disturbance. The search area did not exceed 20 m^2. A strip 15 cm by 4 m was cleared 2 m from the snake's core habitat use area (Fig.1). The strip ran parallel to habitat where the snakes were captured. Midpoint of the 4 m chemical strip was in line with the midpoint of the search/capture area. Only fresh, new chemicals were used each time a test strip was formed. When applied to the strip area, test chemicals completely covered the strip (15 cm x 4 m) at a depth of 1-2 cm (Fig.1) A 1-hour time lapse took place to allow the test substances to emit odors. Snakes were released 1 at a time, 2 m from the test strip. The snakes were observed from a distance of 6-9 m. Care was taken to insure that no shadows from the observer fell onto the test site. The direction of the snake's movement was recorded. The trial concluded when the snake either took cover in the habitat, moved more than 10 m from the release point, or if no movement occurred during a 15 min period. These trials were repeated at 11 similar locations. Two trials using naphthalene, 2 trials with sulfur, and 4 trials using a commercial product containing 7.0% naphthalene and 28.0% sulfur were conducted. The control trials consisted of 2 sessions using ground limestone and 2 sessions with no substance placed on cleared strips.

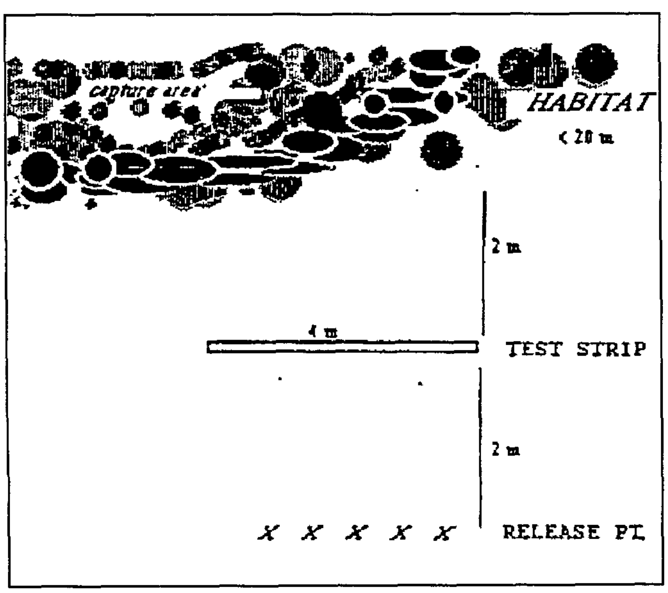

Figure 1. Diagram of home range (Experiment 1) trial set-up, showing capture area, placement of test strip, and snake release points.

Experiment 2: Unfamiliar Habitat Tests.

Garter snakes were hand captured from 13 locations and randomly grouped into lots of 3 for each trial. Trial sites were a minimum of 5 km from locations where the snakes were collected. No snakes were held for more than 6 hours. Trials were located in areas that had cover, yet where no snakes had been sighted previously. In most trials these areas consisted of normal residential landscaping next to a building. A strip 15 cm x 4 m was cleared 2 m from the snakes' potential habitat. This consisted of typical residential landscaping usually next to a building with shrubs and groundcover. Substances to be tested were applied to the strip to a depth of 1-2 cm and a 1 hour time lapse occurred. Subjects were released 1 at a time 4 m from the test strip (Fig. 2). These trials used 3 snakes each and were repeated at 11 similar locations: 2 trials using naphthalene, 2 using sulfur, 4 trials using the commercial combination, 2 using no substances, and 2 with ground limestone.

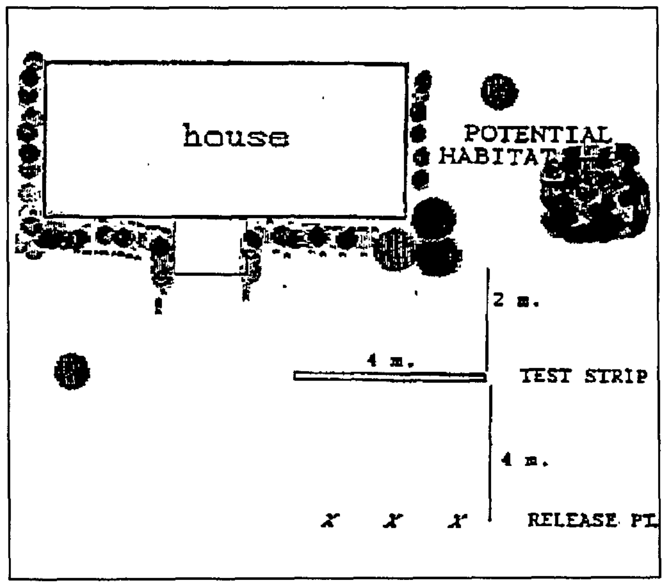

Figure 2. Diagram of unfamiliar habitat (Experiment 2) trial set-up, showing placement of test strip and release points.

RESULTS

Experiment 1: Familiar Habitat

Sixty individuals were used in the study. Thirty-two were males with a mean snout-to-vent length (SVL) of 33 ± 10.9 cm (range 20-49 cm), and 28 were females with a mean SVL of 41 ± 11.9 cm (range 22-53 cm). Each snake was placed in a holding bag, where it usually remained motionless until released. Climatic conditions for substance and control trials are compared in Table 1. There was no significant variance within test trials or between the substance and control trials.

When snakes were released, they first aligned themselves against the substrate in a coiled or semi-coiled position. Tongue-flicking was observed within the initial 25 seconds in all subjects. Two individuals (3%) exhibited no movement within the 15-minute time limit and this negative result was recorded as avoidance behavior. Both individuals were involved at different locations in substance trials with the commercially

Table 1. Mean temperature, humidity, and barometric pressure at investigation sites for chemical test and control trials conducted at the garter snakes' home range location in Experiment 1.

Treatment	n	Climatological conditions[a]		
		Temperature (°C)	Humidity[b] (%)	Barometric pressure (inches)
Substance	40	26.0 ± 1.3	62.4 ± 8.9	28.507 ± 0.112
Controls	20	27.3 ± 1.4	65.4 ± 8.5	28.508 ± 0.120
Probability	-	0.658	0.951	0.708

[a] Mean ± standard deviation
[b] Reading as dew point

prepared repellent. Only 11 (18.3%) snakes displayed constant movement, while others were observed pausing 1 or more times. Non-avoidance behavior was exhibited by 47 (78.3%) of the 60 snakes. Non-avoidance was highest (90%) in the sulphur trials and lowest (70%) in the limestone control (Table 2). There were no significant differences between any of the trials, substance, or controls ($P = 0.849$). It was noted that of the snakes that moved and avoided crossing the strips, 7 (11.6%) traveled in the direction of the test strip and passed within 5 m of the strip's end. Only 4 (6.6%) moved in such a manner that indicated complete avoidance. There was no significant difference in trial time between the substance and control experiments ($P = 0.424$).

Experiment 2: Unfamiliar Habitat Tests.

Thirty-six individuals were used in trials at 12 sites. The snakes typically were motionless while in the holding bag. Climatic conditions were not different, either within tests or between tests and control trials (Table 3). All but one subject began to move within 50 seconds of the release. Typically the snakes would slowly move from their coiled position and move 1-2 m, then elevate their heads. Generally, movements were of a meandering pattern for the first 1-3 m and then became more directional.

In an unfamiliar habitat, 77.8% of the garter snakes demonstrated non-avoidance behavior by crossing the test strip in response to the control and potential repellents (Table 4). Six of the 8 (75%) snakes that exhibited avoidance behavior traveled away from the test strip. No significant difference ($P = 0.459$) between the duration of control trials (522 ± 193.0 sec) and potential repellent trials (592.2 ± 161.9 sec) was found.

DISCUSSION

Garter snakes often reach a large population size in relatively small areas. This snake thrives in man-made habitats, where other native snake species are greatly reduced or eliminated by urban sprawl. Many aspects of the garter snake's life history allow it to exploit the urban environment. Mulch and ground covers used in association with residential gardens increase the surface earthworm population. Hence, food resources for garter snakes may be optimal in these residential locations. Garter snake predators include hawks, striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*) and these animals usually have low populations within urbanized areas.

Basking is important for thermal regulation and food digestion. Garter snakes frequently bask on concrete slabs such as stoops, sidewalks, or patios, and this increases the chance for human-snake encounters. Many people want a clear-cut easy answer to avoiding encounters with snakes. Many people fear snakes so intensely that they are willing to try any product that offers remedy. A method that would reduce the presence of snakes in the urban landscape could be very financially suc-

Table 2. Experiment 1 test trial results of potential repellents in the plains garter snakes' familiar habitat to elicit avoidance behavior.

Treatment	No. of snakes	No. of locations	Behavioral patterns	
			Non-avoidance	Avoidance
Naphthalene	10	2	8	2
Sulfur	10	2	9	1
Mixture[a]	20	4	15	5
Limestone control	10	2	7	3
Blank control	10	2	8	2
Trial totals	60	12	47	13

[a]Dr. T's Snake-A-Way™.

Table 3. Mean temperature, humidity and barometric pressure at investigation sites for chemical and control trials conducted at unfamiliar habitats of *Thamnophis radix* during Experiment 2.

		Climatological conditions[a]		
Treatment	***n***	**Temperature (°C)**	**Humidity[b] (%)**	**Barometric pressure (inches)**
Substances	24	26.6 ± 3.9	62.2 ± 6.4	28.515 ± 0.141
Controls	12	27.0 ± 3.3	64.5 ± 5.7	28.477 ± 0.162
Probability	-	0.732	0.787	0.571

[a]Mean ± standard deviation.
[b]Reading as dew point.

cessful. This is why snake repellent products appear in the retail market. The questionable effectiveness of such repellent applications have fueled an ongoing controversy. However, manufacturer's and proponents of repellents insist certain substances will deter animals and reduce problem encounters.

Several investigators have studied the effect of potential snake repellents. Secoy (1979) tested 10 chemicals including paradichlorobenzene and sulfur on *T. radix*. Tactile and odorant products were tested by San Julian and Woodward (1984). They determined that none of the 12 substances tested altered normal behavior of the black rat snake (*Elaphe obsoleta*).

All these studies have 1 important common factor; they were confinement studies. Confinement studies remove the snake from its natural environment and allow only 2 choices: either cross the substance or use an alternative path. In these tests the snake's escape behavior is foremost. Field test trials of potential repellent substances that approximate intended use will give the most reliable results. This investigation was designed to conform with application methods stated on the chemical repellent labels. Hence, results of this study convey an accurate evaluation of the tested products in regards to the plains garter snake.

These results demonstrate that naphthalene, sulfur, or a combination of these chemicals did not elicit avoidance behavior. The application of these substances in either the snake's home range or unfamiliar habitat failed to alter the snake's normal locomotory or escape behavior. For the most part subjects traveled into their original refuge area, either crossing or passing close by the strips. Snakes did not hesitate when chemical strips were crossed, and snakes did not expend any additional investigatory behavior when chemicals were applied. Unfamiliar habitat trial results were similar to those performed in core habitat use areas, supporting the conclusion that the snakes ignored the tested repellents. Some investigatory behavior may occur in unfamiliar habitats.

The use of these chemicals as a snake repellent should not be recommended. Newborn and unfed garter snakes have been taught to respond to prey extract when associated with food. This learning is retained as the snake matures (Fuchs and Burghardt 1971, Burghardt 1975). This capability of discrimination related to chemical cues may be used by newborn snakes to locate a suitable home range. When born, they are surrounded by fluids from the mother and birthing remnants. These will dry and leave lasting chemical cues the newborn may use to orientate to a home range. The presence of any foreign chemical odorant in the home range during birthing or when snakes are seeking replacement cover can be used as a

Table 4. Test trial results of potential repellents to elicit avoidance behavior in *Thamnophis radix* in unfamiliar habitats.

			Behavioral patterns	
Treatment	**No. of snakes**	**No. of locations**	**Non-avoidance**	**Avoidance**
Naphthalene	6	2	5	1
Sulfur	6	2	4	2
Mixture[a]	12	4	10	2
Limestone control	6	2	5	1
Blank control	6	2	4	2
Total trials	36	12	28	8

[a]Dr. T's Snake-A-Way™

cue. In this case, normally adverse odorants or repellents may act as an attractant. Begun et al. (1988) demonstrated in a laboratory study that *T. sirtalis* could be trained to move toward the unnatural odor of amyl acetate to obtain food.

Homeowners applying a chemical repellent both in the snake's home range and nearby non-familiar area such as next to a patio in hopes of curtailing snake encounters, may create the opposite effect. Chemicals placed in the home range may be ignored, since odor cues and related resources are already present. Over time, the snakes habituate to the chemical repellents and associate the odor of the repellents with their home range. Hence, when migrating or searching for food, these snakes may be temporarily drawn to the non-familiar location where the chemical was applied. In this study the chemicals were only applied 1 hour before the trial began. The odor of the chemicals was strongest immediately after exposing them to air. The repellent label instructs the user to "retreat with enough of the product to restore the original odor intensity". In this study, the "intensity" of the chemicals tested was extremely high when tests were conducted.

It may be argued that if a repellent evokes avoidance behavior, it should be made available because the use of a "pseudo-repellent" may prevent people from illegally using poison to kill snakes in an area. This proposes an ethical question - is it rational to place chemicals in the environment to act as a placebo and give an uninformed person temporary "peace of mind"? Education to appease the public's fears, linked with habitat modification, is the most intelligent solution to the problem. Snakes in this investigation did seek the less optimal habitat when placed in the vicinity. Yet it is unknown whether these individuals remained at the location. Using rock or lumber walls that are tight fitting with few areas where snakes could find refuge may decrease snake numbers. Trimming plants, shrubs, and bushes, and eliminating low branches lessen habitat suitability. Also, removing debris and high vegetation may increase predation pressure on the snakes.

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