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HABITAT USE IN FREE-RANGING PINE SNAKES, *PITUOPHIS MELANOLEUCUS*, IN NEW JERSEY PINE BARRENS

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ABSTRACT: Five male and five female pine snakes (*Pituophis melanoleucus*) were fitted with radio transmitters for 1 yr in the New Jersey Pine Barrens. Habitat selection by radio-tracked snakes was compared with that of 51 hand-captured snakes located by searching the same study area in the previous 8 yr. Habitat selection of radio-tracked snakes (but not activity patterns) differed from that of the hand-captured snakes, and from that of points distributed randomly in the available habitat. Radio-tracked pine snakes selected pine-oak forests and spent equal time in undisturbed and disturbed habitats. Non-radio-tracked snakes were found over 90% of the time in disturbed habitats. Snakes were found in dense vegetation that provided shade and moist, cool ground cover. Snakes were inactive 41% of the time, basked 36% of the time, moved 20% of the time, and nested 3% of the time.

Key words: Pine snakes; *Pituophis melanoleucus*; Habitat; Pine barrens; Radio-tracking

HABITAT selection is the choice of a particular environment from a variety of available choices. Macrohabitat choice (selection of a major biome or plant community) should involve characteristics that are partially independent of daily changes (Heatwole, 1977). Rapidly fluctuating factors are unsatisfactory as cues to habitat selection, because they could result in selection of a habitat that is suitable for only a short time.

In reptiles, habitat selection has not been examined extensively. Habitats have usually been described without regard to availability. Thus, choice of habitats generally has not been clearly demonstrated for reptiles. Although habitat descriptions are numerous for snakes (Wright and Wright, 1957), they usually have been obtained from sightings or capture-recapture techniques (e.g., Blaesing, 1979; Fitch and Fleet, 1970; Plummer, 1981). More recently authors have described the habitats used by snakes equipped with radio transmitters (Brown and Parker 1982; Brown et al., 1982; Fitch and Shirer, 1971; Nickerson et al., 1978; Reinert and Kodrich, 1982). These studies have been valuable in providing descriptive information of use but not of habitat selection. Only Weatherhead and Charland's (1985) study of the black rat snake (*Elaphe o. obsoleta*) compared snake location with available habitat. Further, most studies have not compared the behavior of snakes observed by chance with those located by radio telemetry. An assumption is that reptiles are equally visible in all habitats at all times, thus chance encounters accurately reflect habitat use (Heatwole, 1977).

In this paper, we test whether habitat use is reflected accurately by chance encounters to evaluate habitat selection. We describe habitat use in pine snakes (*Pituophis m. melanoleucus*) equipped with radio transmitters to determine if selection of particular habitat features by radio-tracked snakes differs from (1) that of snakes located by chance and (2) that of random points distributed in the available habitat. Selection requires habitat use that differs from random use of the available habitat. We tested a null hypothesis of no differences in habitat and behavior between radio-tracked snakes and snakes located by chance. Because snakes with radios could be located when not visible, we predicted alternatively that there would

be differences in habitat selection between them and hand-captured snakes.

In the New Jersey Pine Barrens, pine snakes occur in pitch pine (*Pinus rigida*) and scrub oak (*Quercus marylandica*) habitats and avoid white cedar (*Thuja occidentalis*) swamps and lowland pine areas, and there are no sexual differences in habitat use (Zappalorti and Burger, 1986). Pine snakes occur in a variety of habitats in North America, but they are not common anywhere (Wright and Wright, 1957). The Pine Barrens is exposed to continuous pressures from developers, habitat is disappearing, and pine snakes are listed as threatened in New Jersey. It is critical to ascertain habitat requirements before important decisions concerning development are made.

Methods and Study Area

We studied pine snakes near Tom's River, Ocean County, New Jersey in 1981–1982. The study area contained residential communities and forested sections of pitch pine, scrub oak, and white cedar. Five males and five females were located just following emergence from hibernation in early spring (March, April) or while nesting (June to early July) in 1981. We determined the sex of each snake following Gregory's (1983) technique, and we measured (snout–vent length = SVL) and weighed them. All snakes were adults (>1 m SVL). Prior to implantation in the study animals, transmitters were surgically implanted in other pine snakes which were observed for 2 wk to be sure that snakes moved, ate, and behaved normally. Radio transmitters (3 g, 2.5 cm long × 2 cm wide) were inserted surgically in the body cavity on the side of the body (Reinert and Cundall, 1982). All snakes in the study were held in large aquaria for 2–3 days prior to their release where captured.

The study area was searched every 1–3 days for snakes from 1 June 1981 through December 1982. Searching consisted of driving and walking slowly with a receiver and then determining the exact location of the snake. Because snakes were not always visible, searching often included turning over logs or other debris when the radio signal indicated that a snake was present. All logs and debris were replaced in the same position.

When a snake was located visually or tracked to a log or hole, the following data were collected: snake identity, forest type, elevation, soil type, disturbance type (disturbed or undisturbed), nearest vegetation, ground cover, distance to water, and activity. We distinguished four forest types on the basis of percent pine (after Forman, 1979): oak–pine (*Quercus marylandica, Pinus rigida*, <50% pine, >50% oak), pine–oak (50–80% pine), pine lowland (>80% pine), and cedar bog (no pine). Vegetation referred to the herb species that the snake was closest to, and ground cover referred to substrate, fallen leaves, lichens, or mosses. Most of the herb species and ground cover types occurred in all forest types (except for the cedar bog). Four soil types were recognized (USDA, 1980) and recorded, because we suspected that females might be found on a particular soil type that was suitable for excavating nests. Soil types were Atsion, Berryland, Lakehurst, Lakewood (from soil maps: USDA, 1980). Soil type did not correspond completely to either forest type or vegetation. A site was considered disturbed if it showed evidence of past human activity such as clearing for agriculture, hunting lodges, railroads, or logging roads. The study area did not include sites currently used by people (except for sand or paved roads).

Snake activity was recorded as inactive (in the shade or hidden), basking in the sun, basking in the shade, and moving. We defined basking as a snake thermoregulating on a clear day with 50% or more of its body exposed to direct sun (basking in sun), or with <50% exposed to direct sun (basking in shade, after Parker and Brown, 1980). We compared the habitats used by the radio-tracked snakes with available habitat (determined by taking the characteristics of random points) and with the habitats used by 51 snakes located by chance (Zappalorti and Burger, 1986). Data on characteristics of the available habitat were taken at 200 random points distributed throughout the study site. Random points were selected by using random

TABLE 1.—Sightings of pine snakes (five male, five female) by month (April–September 1982) for each sex in New Jersey Pine Barrens. Proportion of sightings by month was calculated for each sex separately. Number of individuals in parentheses.

	Female		Male	
Number of sightings	131	(5)	67	(5)
Proportion of total sightings	66		34	
Proportion of sightings by month				
April	0.10	(4)	0.06	(4)
May	0.39	(5)	0.49	(5)
June	0.21	(5)	0.03	(2)
July	0.16	(5)	0.16	(5)
August	0.13	(4)	0.24	(5)
September	0.01	(1)	0.02	(2)

numbers to generate X and Y coordinates for the points.

RESULTS

Temporal Patterns

We radio-tracked 10 (five male and five female) pine snakes initially located within the study area. We compared snake activity (proportion of sightings) from April–September in 1982 (Table 1). All males were first located in April or June (1982) and females were located in June and July (1981) and May (1982). Two-thirds of the records from radio-tracked snakes were from females whereas only one-third were from males ($\chi^2 = 22.9$, df = 1, $P < 0.001$). Females were relocated on an average of 26 days whereas males were located on an average of 13 days. Both sexes were observed more in May than in any other month. Females were located most often in June, males in August.

TABLE 2.—Statistical comparison (χ^2 Contingency Tables, NS = not significant at $\alpha = 0.05$) of habitats selected by radio-tracked pine snakes with 200 random points and with those selected by 51 other (non-radio-tracked) pine snakes.

Habitat characteristic	Comparison of radio-tracked snakes					
	With random points			With other snakes		
	χ^2	df	P	χ^2	df	P
Forest type	23.1	1	0.0001	4.1	1	0.03
Disturbance type	56.7	1	0.0001	10.4	1	0.001
Soil type	16.4	3	0.002	10.7	3	0.01
Vegetation species	41.8	9	0.0001	24.9	9	0.003
Ground cover	54.4	6	0.0001	27.3	6	0.0001
Distance to water	0.2	3	NS	0.2	3	NS
Elevation	0.6	1	NS	4.1	1	0.04

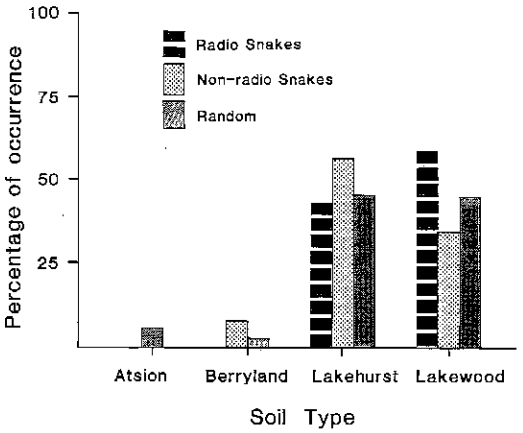

FIG. 1.—Major soil types where radio-tracked and hand caught snakes were located compared to available soil (random) types.

Habitat Selection

Radio-tracked pine snakes spent significantly more time (93%) in pitch pine–oak habitats than non-radio-tracked snakes (79%) and than the availability of this habitat (80%, Table 2). All snakes avoided the lowland pine and cedar swamps located within the pine–oak habitats even though these forest types accounted for 18% of the random points. Although 87% of the random points were in undisturbed habitats, radio-tracked snakes were observed 42% of the time in undisturbed habitats, but non-radio-tracked snakes were observed only 2% of the time in undisturbed habitats (Table 2). Thus, hand-caught snakes were found significantly more often, while radio-tracked snakes were found significantly less often in disturbed habitats.

Soil types, plant species, and ground cover selected by radio-tracked pine snakes also differed from the available habitat and from those used by non-radio-tracked snakes (Table 2). Radio-tracked pine snakes spent most of their time in Lakewood soils, whereas hand-captured pine snakes occurred mostly in Lakehurst soils, and most of the random points were in Lakehurst

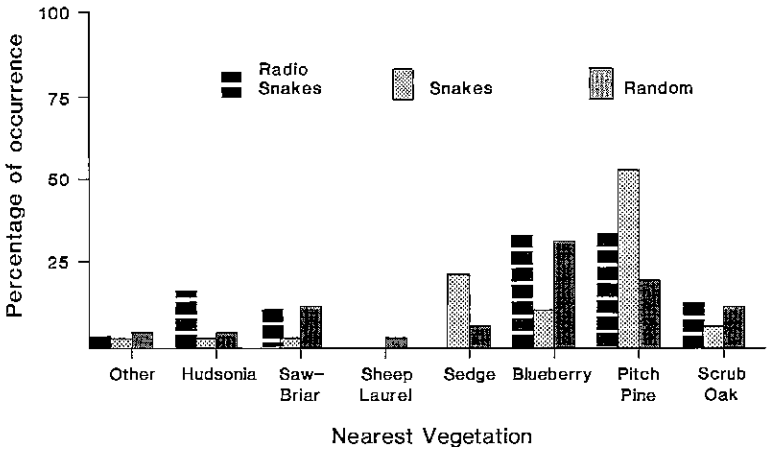

FIG. 2.—Species of vegetation that radio- and non-radio-tracked pine snakes were closest to when located, compared to available vegetation (random).

soils (Fig. 1). All snakes were found near a wide variety of vegetation species and on numerous types of ground cover (Figs. 2, 3). However, radio-tracked snakes were most frequently found near blueberry and pitch pine, whereas non-radio-tracked snakes were most often near pitch pine and Pennsylvania sedge. Radio-tracked snakes were found more often under or on oak leaves and non-radio-tracked snakes were located more often on pavement (Fig. 3). Distance to water did not vary significantly among the two groups of snakes and random points.

Thermal Relationships

Cloacal temperatures of non-basking snakes were greater than that of the surrounding substrate (Fig. 4). Substrate temperature was lower for radio-tracked ($\bar{x}$ = 23 C) than for non-radio-tracked snakes ($\bar{x}$ = 27.7 C, Wilcoxon test $\chi^2 = 6.36$, df = 1, $P < 0.01$). This difference is not due to ambient air temperatures ($\chi^2 = 3.40$, df = 1), indicating that radio-tracked snakes were more often located in shady spots under or within logs or leaves than non-radio-tracked snakes. Otherwise there were

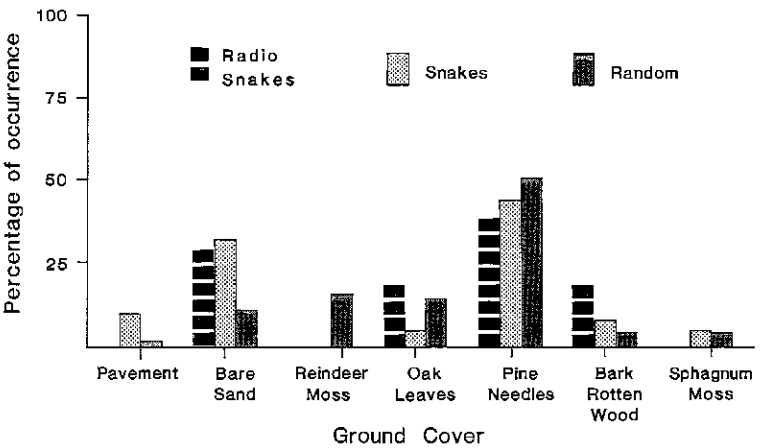

FIG. 3.—Ground cover type that radio- and non-radio-tracked pine snakes were closest to when located, compared to available cover types (random). Pavement includes sand road.

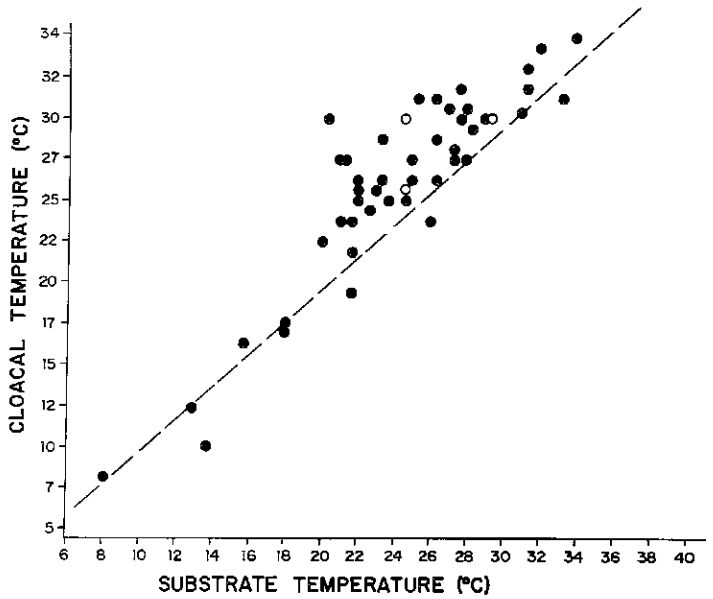

FIG. 4.—Relationship of cloacal temperature to substrate temperature for all radio-tracked pine snakes each time that a snake was located. Each dot equals one (closed dot) or two (open dot) observations. Dashed line indicates where cloacal temperature and substrate temperature are equal.

no differences between the two groups of snakes with respect to other weather variables and time of day.

Activities

Overall, 41% of the radio-tracked snakes were inactive, 36% were basking, 20% were moving, and 3% were nesting, whereas of the hand-captured snakes, 15% were inactive, 35% were basking, and 50% were moving. Thus >50% of the hand-captured snakes were moving whereas >40% of the radio-tracked snakes were inactive.

DISCUSSION

Activity

Both sexes were located more often in May than in any other month. Females were located more in June than were males, and males were located more in August than were females. Frequent occurrence of both sexes in May probably reflects increased movement to increase mating opportunities. All our observations of matings occurred in May. Females lay eggs in June and spend 1–2 days digging nests in open areas (Burger and Zappalorti, 1986). This activity probably accounts for their frequent occurrence in June. Males may be observed more in August because they are moving back to the hibernacula areas. Males in this study moved farther from the capture site than females (Burger and Zappalorti, 1986) and thus had farther to return in the early fall.

Habitat Selection

Radio-tracked pine snakes selected habitats in pine–oak forests of the Pine Barrens, and they occurred equally in disturbed and undisturbed areas of the forest despite the low availability of disturbed sections. In contrast, non-radio-tracked snakes were located in disturbed habitats >90% of the time. These observations indicate that (1) pine snakes use both disturbed and pristine, undisturbed forests and (2) determining forest and disturbance type preferences solely on the basis of chance encounters does not accurately reflect habitat selection of pine snakes.

Disturbed areas of the forest examined in this study had been disturbed in the

recent past and were now abandoned (e.g., bog iron villages, hunting lodges, abandoned railroad beds). They were characterized by low tree density, openness, and low levels of human activity. Disturbed sites may have higher rodent populations than dense, wet, lowland pine sections. Feeding primarily on rodents (Wright and Wright, 1957), pine snakes may prefer these habitats as foraging grounds. Areas of high human use (e.g., retirement villages, township maintenance facilities) were avoided completely by pine snakes. Within forests, pine snakes used the open areas created by past human activities for nesting habitat and basking sites. Abandoned, disturbed sites probably were present even before European settlement, because the North American Indians periodically burned patches of forest to increase deer production (Russell, 1981).

Disturbed sites were used by females for nesting sites (Burger and Zappalorti, 1986). Open sites provided suitable digging conditions while allowing adequate light penetration for incubating the eggs located in subterranean nests. As the sandy Lakehurst soil type is devoid of roots and high levels of decaying material, digging may be easier for nesting females.

Radio-tracked pine snakes were often located buried beneath leaves or hidden inside logs or boards where they could not be found by merely lifting the log. Data from pine snakes encountered by chance (albeit searching for them) indicated that natural, undisturbed pitch pine and oak forests were relatively unused. However, this was not the case for radio-tracked snakes.

A diversity of habitat use has been noted for black rat snakes *Elaphe obsoleta* (Stickel et al., 1980), crowned snake *Tantilla coronata* (Semlitsch et al., 1981), and massasauga *Sistrurus catenatus* (Reinert and Kodrich, 1982). Weatherhead and Charland (1985) reported that radio-tracked *E. obsoleta* preferred habitat interfaces between field and deciduous forest. This preference reflected the snakes' foraging behavior toward birds. In contrast, pine snakes in this study showed no clear preference for ecotones, perhaps because they feed on small mammals not limited to ecotones. The sparse vegetation of most areas of the Pine Barrens provided places with dense cover (directly under a pine tree) or sparse cover (under blueberry or other low ground cover), so the snakes could hunt in different cover types without shifting habitats. Even within major habitat types (pine–oak or pitch pine lowlands), pine snakes selected characteristics that were different from random points. Snakes used particular vegetation types, ground cover, and elevation. Further, use of ground cover and vegetation type differed between radio-tracked and non-radio-tracked snakes.

Of the available vegetation, blueberry, scrub oak and pitch pine provide the densest cover from the sun. Air temperatures just above the sand in the Pine Barrens frequently exceed 40 C, and shade may be an essential habitat requirement. Because snakes were often in places with low tree density (with sun penetration to the ground), snakes could easily and quickly move back and forth between sun-drenched and shaded spots. Pine snakes spent as much time basking in the partial shade as in the full sun, suggesting the importance of heavy shade. We believe some vegetation (sheep laurel, saw briar) was avoided because it provided little shade (its sparseness allowed sun to filter through) or it was too short for snakes to bask under. By basking near, or partially under, dense shrubs, the snakes could regulate their temperature with a minimum of movement, and move quickly into full shade if temperatures rose too quickly. Seasonal habitat shifts (Reinert and Kodrich, 1982) were not noted except for the major shifts that occurred at nesting and hibernating.

The importance of cover for thermoregulation has been noted for snakes (Blaesing, 1979), where physiognomic characteristics of the vegetation (e.g., perch angle, size, or position) may be more important than the species of vegetation (Plummer, 1981). Cover allows snakes to thermoregulate (*Thamnophis sirtalis;* Blaesing, 1979), avoid heavy rain (*Leptophis depressirstris*), or direct sunlight (*Spilotes pullatus:* Nickerson et al., 1978),

or to move into sunlight (Stickel et al., 1980).

Methodological Problems and Assumptions

The pattern of habitat use observed in any study depends on limitations of the methods and assumptions of the study design. Monetary and manpower constraints in any study using radio telemetry limit the number of animals that can be followed. Most studies with radio-tracked snakes have used only one or two snakes or have followed snakes for only a few days. However, Weatherhead and Charland (1985) followed a reasonable sample ($n = 7$) of average-sized black rat snakes for several months, noting their habitat requirements. Our 10 pine snakes represented average-sized snakes, minimizing individual variation due to size.

We assumed that habitat data from radio-tracked snakes would more accurately reflect habitat preferences than data from other snakes encountered by chance. We made this assumption because snakes that are moving or are in the open are easier to see than stationary snakes under logs or leaves (cf. Weatherhead and Charland, 1985). Thus pine snakes encountered by searching might bias the results toward more open habitats and higher activity levels. Data from radio-tracked snakes representing repeated sampling of the same individuals should reflect whatever habitats these individuals prefer. If a particular habitat or microhabitat were used very infrequently, it might not be noted in a study of non-radio-tracked snakes. However, by using radio transmitters, it is possible to record such little-used habitats which could be critical for a particular life history stage such as nesting or hibernating.

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Literature Cited

Blaesing, M. E. 1979. Some apsects of the ecology of the eastern garter snake (*Thamnophis sirtalis sirtalis*) in a semi-disturbed habitat in West-Central Illinois. J. Herpetol. 13:177–181.

Brown, W. S., and W. S. Parker. 1982. Niche dimensions and resource partitioning in a Great Basin desert snake community. Pp. 59–82. *In* N. J. Scott (Ed.), Herpetological Communities. USFWS, Dept. of Interior Wildlife Research Report 13.

Brown, W. S., D. W. Pyle, K. R. Greene, and J. B. Friedlaender. 1982. Movements and temperature relationships of timber rattlesnakes (*Crotalus horridus*) in Northeastern New York. J. Herpetol. 16:151–161.

Burger, J., and R. T. Zappalorti. 1986. Nest site selection by pine snakes, *Pituophus melanoleucus*, in the New Jersey Pine Barrens. Copeia 1986:116–121.

Fitch, H. S., and R. R. Fleet. 1970. Natural history of the milk snake (*Lampropeltis triangulum*) in Northeastern Kansas. Herpetologica 26:387–396.

Fitch, H. S., and H. W. Shirer. 1971. A radiotelemetric study of spatial relationships in some common snakes. Copeia 1971:118–128.

Forman, R. T. T. 1979. Pine Barrens: Ecosystem and Landscape. Academic Press, New York.

Gregory, P. T. 1983. Identification of sex of small snakes in the field. Herpetol. Rev. 14:42–43.

Heatwole, H. 1977. Habitat selection in reptiles. Pp. 137–155. *In* C. Gans (Ed.), Biology of the Reptilia, Vol. 7. Academic Press, New York.

Nickerson, M. A., R. A. Sajdak, and R. W. Henderson. 1978. Notes on the movements of some neotropical snakes (Reptilia, Serpentes). J. Herpetol. 12:419–422.

Parker, W. S., and W. S. Brown. 1980. Comparative ecology of the two colubrid snakes, *Masticophis t. taeniatus* and *Pituophis melanoleucus deserticola*, in northern Utah. Milwaukee Public Mus. Publ. Biol. Geol. 7:1–104.

Plummer, M. W. 1981. Habitat utilization, diet, and movements of a temperate arboreal snake (*Opheodrys aestivus*). J. Herpetol. 15:425–432.

Reinert, H. K., and D. Cundall. 1982. An improved surgical implantation method for radiotracking snakes. Copeia 1982:702–705.

Reinert, H. K., and W. R. Kodrick. 1982. Movements and habitat utilization by the massasauga, *Sistrurus catenatus catenatus*. J. Herpetol. 16:162–171.

Russell, E. W. B. 1981. Vegetation of northern New Jersey before European settlement. Am. Midl. Nat. 105:1–12.

Semlitsch, R. D., K. L. Brown, and J. P. Caldwell. 1981. Habitat utilization, seasonal activity, and population size structure of the southeastern crowned snake *Tantilla coronata*. Herpetologica 37:40–46.

STICKEL, L. F., W. H. STICKEL, AND F. C. SCHMID. 1980. Ecology of a Maryland population of black rat snakes (*Elaphe o. obsoleta*). Am. Midl. Nat. 103: 1–14.

USDA. 1980. A Soil Survey of Ocean County, New Jersey. U.S. Department of Agriculture, Somerville, New Jersey.

WEATHERHEAD, P. J., AND M. B. CHARLAND. 1985. Habitat selection in an Ontario population of the snake, *Elaphe obsoleta*. J. Herpetol. 19:12–19.

WRIGHT, A. H., AND A. A. WRIGHT. 1957. Handbook of Snakes of the United States and Canada. Cornell University Press, Ithaca, New York.

ZAPPALORTI, R. T., AND J. BURGER. 1986. The importance of man-made habitats to pine snakes. Environ. Cons. 12:358–361.

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