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# ARTIFICIAL REFUGIA AS A HABITAT-IMPROVEMENT STRATEGY FOR SNAKE CONSERVATION

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## *Introduction*

WILDLIFE MANAGEMENT OFTEN INVOLVES HABItat manipulation to create improved living conditions for species of particular interest (Yoakum and Dasmann 1969; Yoakum 1971). For many years, such efforts have been commonly and successfully used in game and sport fish management (White 1971). With the exception of nest boxes for songbirds, however, such procedures have only recently been applied to non-game and endangered animal species.

Programs for the management of snake species have traditionally fallen under the category of "pest control," and have usually been aimed at reducing the population size or limiting the occurrence of snakes in the vicinity of human habitations (Allen 1961; Klauber 1972; Knight 1986; Brown 1993). The increasingly evident decline of amphibian and reptilian populations (Ashton 1976; Dodd 1987; Corbett 1989) has begun to emphasize the need for management techniques that can be successfully implemented to improve environmental conditions for these unpopular, but important, members of natural communities.

Although human population growth and its resultant destruction of habitat is considered a major factor in the decline of many wildlife species, several species of amphibians and reptiles are commonly associated with artificial structures or disturbed areas (Wilson and Porras 1983; Schwartz and Henderson 1991). The propensity of certain species to be associated with human-altered habitats led Ashton and Ashton (1981) to include such areas as a habitat category for the Florida herpetofauna. In particular, some snakes seem to have little aversion to disturbed areas (Blaesing 1979; Zappalorti and Burger 1985), and several species are commonly found in the vicinity of human habitation. Human-induced habitat changes may inadvertently provide suitable microclimatic conditions, increased or concentrated food supplies, or accessible overwintering sites (Owens 1949; Gillingham 1974).

During 1981–1982, several shed skins of Corn Snakes (*Elaphe guttata*) and Pine Snakes (*Pituophis melanoleucus*) were found at what appeared to be a natural underground refugium in southern New Jersey. Excavation of the site in July 1982 revealed that it was not natural, but synthetic. The refugium consisted of construction debris, such as lumber, metal, and rubber mats, that had been buried approximately 2 m deep in a 2.5 × 3.5 m trench. The excavation of the site yielded one Pine Snake, one Milk Snake (*Lampropeltis triangulum*), three Corn Snakes, two freshly laid clutches of Corn Snake eggs (25 eggs), and 22 shells of hatched egg from the previous years. It was apparent from these findings that a successful snake refugium had been inadvertently constructed. This led Zappalorti to purposely design and build similar structures for use by snakes. Since 1982, a total of 43 such artificial refugia have been constructed in the Pine Bar-

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*Acronyms used in this chapter:*

ANOVA Analysis of variance
PVC Polyvinyl chloride
SE Standard error of mean

rens of southern New Jersey. This chapter summarizes our continuing monitoring program of the use of these artificial structures by snakes.

### *Study Area*

This research was conducted in a 2,833-ha area in Ocean County, New Jersey. Approximately 37% (1,043 ha) of the land had been developed as residential communities. The remaining 1,790 ha were typical coastal plain forest, dominated by Pitch Pine (*Pinus rigida*) and various oaks (*Quercus marilandica*, *Q. ilicifolia*, and *Q. velutina*). A more detailed vegetational description of the study area is given by Zappalorti and Burger (1985). General descriptions of coastal plain forests in New Jersey can be found in Forman (1979). Elevations ranged from 3 to 38 m above sea level. Approximately 20 km of sand, gravel, or paved roads traversed the area, and a 30-m wide, common right-of-way for public sewer and electric transmission lines bisected the area from east to west.

### *Artificial Refugia*

A total of 25 refugia was constructed on the study area during 1985–1986. These were positioned from 53 m to 589 m apart (mean distance between refugia 188 m, SE 29.5 m) along 5 km of the sewer and electric right-of-way.

Each refugium (Figure 1) was constructed using 22 pressure-treated railroad ties, 14 m of 7.5-cm-diameter, perforated, plastic (PVC) pipe, 4.5 $m^2$ of plastic sheeting or tar paper, and several stumps, logs, and branches. After removal of surface vegetation, a 2-m-wide, 4.5-m-long, 1.8-m-deep trench was excavated. Two full-length (2.6 m) railroad ties

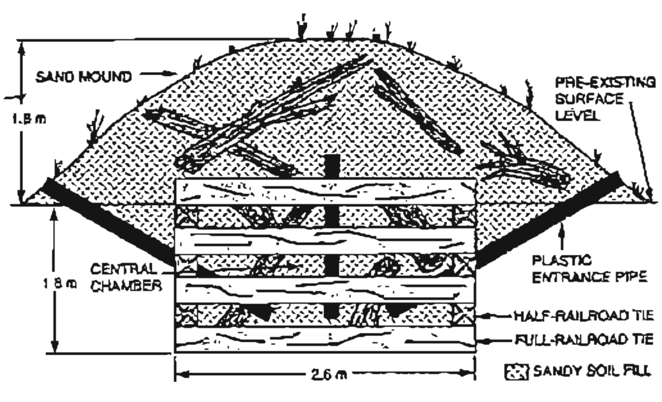


FIGURE 1. Structural design of underground refugia. Refer to adjacent text for construction details.

FIGURE 2. A completed refugium with surface shelters for snakes provided by old railroad ties.

were laid on the floor of the trench along each side, and two half-ties (1.3 m) were placed on top of the full-ties at each end to form a rectangle. The ties were secured to one another with large nails to prevent separation over time. This alternate stacking procedure of full-ties and half-ties was repeated four times to form a rectangular box. Four 3.5-m-long sections of plastic, perforated pipe (7.5 cm in diameter) were placed on each side of the structure to serve as entrances to the central chamber (Figure 1). These entrance pipes extended from the ground surface to the bottom of the chamber at an angle of approximately 35 degrees from the horizontal, and were staked in place to prevent movement. The central chamber was then filled with stumps, logs, branches, and sandy soil. The top of the structure was formed using eight ties nailed side by side and covered with plastic sheeting or tar paper to prevent water from filling the chamber during heavy rains. Finally, logs, stumps, and branches were piled on top of the structure to a height of 1 m, and the entire structure was covered with sandy soil until a mound approximately 1.8-m high was formed. Vegetation that was originally removed from the ground surface was replanted on the mound, and several logs or old railroad ties were scattered about the mound (Figure 2).

### *Sampling Period and Procedures*

Between the spring of 1987 and the fall of 1989, the 25 refugia were subjected to 1,679 hours of observation. Systematic searches were performed at refugia during each visit. One or two observers walked slowly toward a refugium until it was clearly visible. Entrance pipes and non-vegetated areas in the vicinity were scanned with binoculars for the presence of exposed snakes. If no snakes were observed from several vantage points, the structure was slowly approached, and the area within a 10-m radius was surveyed for up to 15 minutes. The entrance pipes were checked with a flashlight.

Observations of snake activity at refugia were placed in one of the following seven categories:

(1) Ingress or egress—snakes with some portion of their body in direct contact with a refugium entrance pipe;

(2) Exposed—snakes observed in a coiled or sedentary position on the ground surface;

(3) Concealed—snakes found hidden under shelter objects, such as logs, stumps, or railroad ties;

(4) Mating—snakes of the same species and different sex found coiled together either copulating or in some phase of courtship behavior;

(5) Ovipositing—female snakes found in the process of excavating a nest burrow (Burger and Zappalorti 1991) or laying eggs;

(6) Shedding—snakes found in premolt condition (opaque), in the process of ecdysis, or observation of a shed skin; and

(7) Active—snakes observed actively crawling.

It is obvious that several of these categories are not mutually exclusive. For simplicity, each observed snake was placed in the one activity category that best represented its behavior and required the least subjectivity on the part of the observer. For example, any snake having opaque eyes or skin was placed in the "shedding" category regardless of other behavior exhibited. Repeated observations of the same specimen were not included in the following analyses.

Chi-square comparisons of behavior frequencies between species were performed in accordance with the methods of Zar (1984). Analysis of variance (ANOVA) and unplanned comparisons of mean monthly observation frequencies were performed following the methods of Sokal and Rohlf (1981).

## *Results*

A total of 139 snakes of nine different species were observed at 17 of the 25 artificial refugia during the three-year period (Table 1). Pine Snakes comprised the greatest percentage (52.5%) of snakes observed during both overwintering (November 1 to April 30)

TABLE 1. Number of individual snakes of nine species observed at artificial refugia from 1987 through 1989.

| Species | Overwintering (November 1 to April 30) | Active period (May 1 to October 31) | Total |
|---|---|---|---|
| Pine Snake (*Pituophis melanoleucus*) | 40 | 33 | 73 |
| Corn Snake (*Elaphe guttata*) | 15 | 32 | 47 |
| Racer (*Coluber constrictor*) | 1 | 6 | 7 |
| Eastern Hognose Snake (*Heterodon platirhinos*) | 1 | 3 | 4 |
| Common Garter Snake (*Thamnophis sirtalis*) | 1 | 2 | 3 |
| Milk Snake (*Lampropeltis triangulum*) | 0 | 2 | 2 |
| Common Kingsnake (*Lampropeltis getula*) | 0 | 1 | 1 |
| Eastern Ribbon Snake (*Thamnophis sauritus*) | 0 | 1 | 1 |
| Rough Green Snake (*Opheodrys aestivus*) | 0 | 1 | 1 |
| Totals: | 58 | 81 | 139 individuals |

and active-season periods (May 1 to October 31). Corn Snakes were the next most frequently observed species at refugia (33.8% of observed snakes). Combined, these two species accounted for 94.8% of the snakes observed to use these structures as overwintering sites, and 80.2% of the snakes observed during the active season.

Snakes were observed utilizing the structures for a broad variety of behaviors during the active season. Figure 3 illustrates the relative frequency of various behaviors exhibited by the two most commonly observed species, Corn Snakes and Pine Snakes. A Chi-square analysis (2 × 7 contingency table) indicated that the relative frequency of observed behaviors differed significantly between these two species ($\chi^2_{(6)} = 49.15, P < 0.01$). Pine snakes were most frequently observed lying exposed on the ground surface, often basking on the mound itself (Figure 4). In comparison, Corn Snakes were most frequently found under the shelter objects, such as logs, stumps, or railroad ties, that had been placed around each refugium. Both species were commonly observed entering or exiting refugia, indicating the use of these structures as active season shelters (Figure 5). In addition, ecdysis, courtship, mating, and ovipositing were observed for both species at refugia. Six clutches of Pine Snake eggs and ten clutches of Corn Snake eggs were known to be laid in refugia during the three-year study period. It is suspected, however, that nesting at refugia was more frequent than these fortuitous observations indicate. To avoid excessive disturbance, extensive

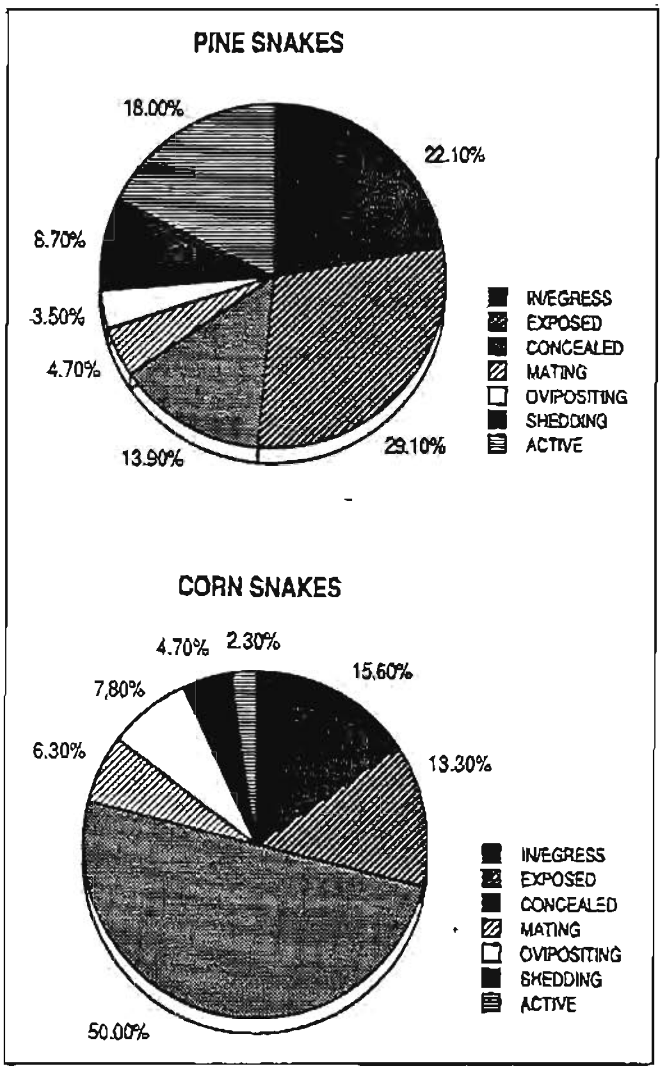


FIGURE 3. Comparison of the relative frequency of behaviors of Pine Snakes (*Pituophis melanoleucus*) and Corn Snakes (*Elaphe guttata*) observed at artificial refugia.

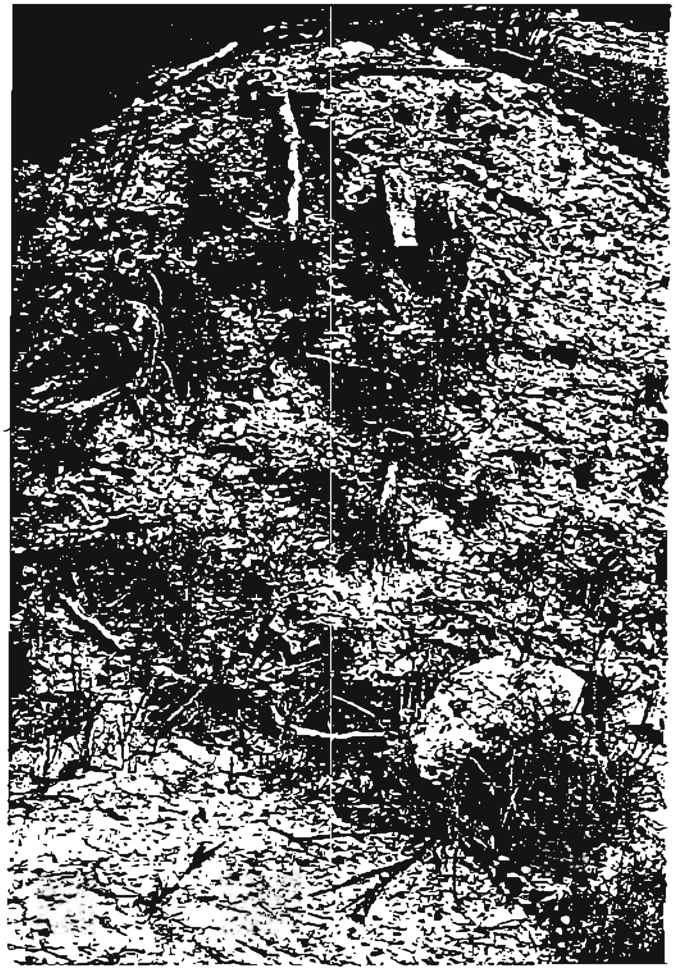

FIGURE 4. Two Pine Snakes (*Pituophis melanoleucus*) observed utilizing a refugium as a basking and/or foraging location.

excavations in search of eggs were not routinely performed at refugia. Egg clutches were usually discovered when neonatal snakes were observed emerging from the refugia after hatching.

Because of unequal sampling efforts during the three years, the data were transformed into "snakes observed per hour of sampling" to facilitate comparisons. A one-way ANOVA (model I) indicated that the mean monthly frequencies of observation of snakes per hour at artificial refugia differed significantly ($F_{s(7,16)} = 3.70$, $P < 0.05$). This suggests the occurrence of seasonal trends in the use of refugia. Snakes were observed with the highest frequency during the spring and fall months, as they entered or emerged from hibernation at the structures (Figure 6). Unplanned comparisons of mean monthly frequencies using the T-Method (Sokal and Rohlf 1981) indicated that, in July and August, significantly lower numbers of snakes were observed per hour than in October ($P < 0.05$). The low observation frequencies in July and August possibly resulted from either nocturnal behavior patterns or an increase in the use of surrounding woodland by snakes.

Figure 7 illustrates the frequency of observation of snakes (in snakes observed per hour of sampling) at each refugium over the three-year-study period. The number of structures exhibiting snake activity increased from five in 1987, to seven in 1988, and finally to 17 in 1989.

In addition to the snakes reported, several other species of reptiles and amphibians were observed in the vicinity (less than 10 m radius) of refugia. The most frequently observed species were Eastern Box Turtles (*Terrapene carolina*), Fence Lizards (*Sceloporus undulatus*), Ground Skinks (*Scincella lateralis*), and Woodhouse's Toads (*Bufo woodhousii*).

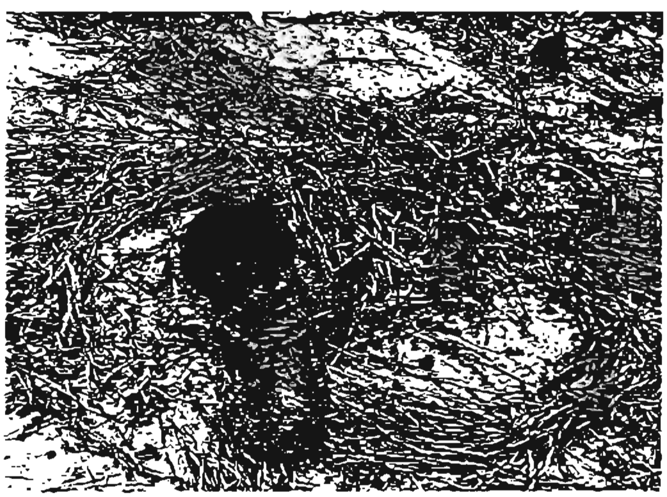

FIGURE 5. A Corn Snake (*Elaphe guttata*) emerging from a refugium entrance pipe following hibernation.

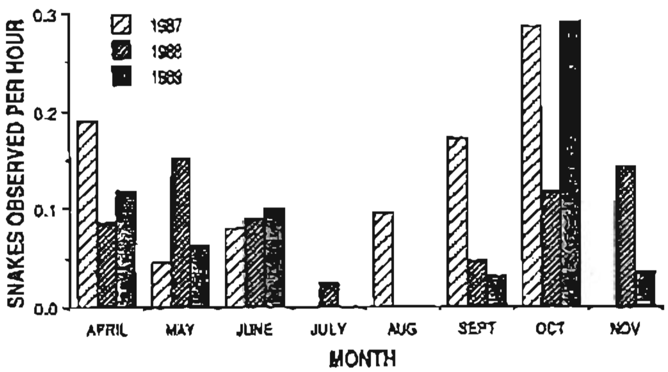


FIGURE 6. Monthly frequency of observation of snakes at artificial refugia.

*Discussion*

Previous investigators have constructed artificial hibernacula for a variety of experimental purposes (Goris 1971; Gillingham and Carpenter 1978). We are unaware, however, of any prior effort to design and construct refugia for use by free-ranging snakes in natural habitats. Our observations suggest that such structures may be useful as a habitat-improvement technique for snake conservation. It is clear that a large number of snakes, representing a diverse array of species, located and used our refugia within three years of their construction. The refugia have been particularly successful at attracting Pine Snakes and Corn Snakes for use as overwintering and nesting sites. Both of these species have demonstrated declining populations in New Jersey, and are officially listed as threatened (Pine Snake) or endangered (Corn Snake) by the New Jersey Department of Environmental Protection and Energy.

Natural hibernacula of Pine Snakes and Corn Snakes are usually associated with the decaying root systems of tree stumps or mammal burrows (Burger et al. 1988). Suitable hibernation sites may be a limited resource for certain snake species (Graves et al. 1986; Burger et al. 1988), and high mortality may occur during the first winter, due to the inability of hatchling snakes to locate safe refugia (Fukada 1978). Although it is presently unknown whether our artificial refugia have resulted in any increases in the population sizes through increased survival or reproductive success, they do provide suitable habitat for a wide variety of ecologically significant activities for these and other snake species.

Although a majority of the refugia have exhibited snake activity over time, it appears that the placement of a refugium may greatly influence its attractiveness to snakes and its frequency of use. Surrounding habitat and topography may play an important role in determining the activity at any particular structure. Upland habitat used by Pine Snakes as nesting areas (Burger and Zappalorti 1986) is located near several of the refugia that exhibited frequent snake activity (for example, refugia numbers 3, 5, 6, 12, 20, and 24 [Figure 7]). Refugia exhibiting little or no snake activity since their construction (for example, refugia numbers 7, 8, 17, and 18 [Figure 7]) are in the vicinity of streams and wetlands which are dominated by White Cedar (*Chamaecyparis thyoides*).

Along the right-of-way, high frequencies of snake observations occurred at approximately 1.5- to 2-km intervals. This could represent a natural spacing distance for hibernacula that may result from the relative distance to suitable nesting and foraging sites and the maximum activity ranges of members of subpopulations or kin-groups. However, detailed information on the spacing of natural refugia, or the movements and genetic relationships of snakes in the vicinity of either artificial or natural refugia, is currently unavailable. If low use continues at intermediate structures, construction efforts could be substantially reduced by building fewer refugia at greater intervals.

### *Summary*

In an effort to improve snake habitat by providing artificial shelters, we constructed 25 subterranean refugia along a 5-km section of a sewer and electric line right-of-way in southern New Jersey. By the end of the three-year study period, snake activity had been observed at 17 (68%) of the structures. The bulk of the observations were of Corn Snakes (*Elaphe guttata*) and Pine Snakes (*Pituophis melanoleucus*). These two species utilized the refugia with high frequency for winter hibernation and for shelter, ovipositing, courtship, shedding, and basking during the active season. Seven other species of snakes (Table 1) also were observed at the structures during the study. Our observations indicate that snakes will locate and use artificial refugia which are placed in suitable habitat. Such structures may improve existing snake habitat by creating favorable sites for biologically important behaviors.

In the years since their construction, an increasing number of these structures have served as hibernacula, active-season shelters, nesting sites, and basking habitat for snakes. This suggests that the construction of artificial refugia may be an effective method for improving snake habitat. Long-term studies are currently underway in an effort to determine if the presence of artificial refugia results in an increase in snake population levels, and to compare the use of artificial refugia with that of natural refugia.

### *Acknowledgments*

The Ocean County Utilities Authority constructed the 25 refugia as part of a mitigation plan. Jersey Central Power and Light Company (General Public Utilities) provided substantial funding for the intensive monitoring of the refugia. Authorization and necessary permits were supplied by the New Jersey Department of Environmental Protection and Energy,

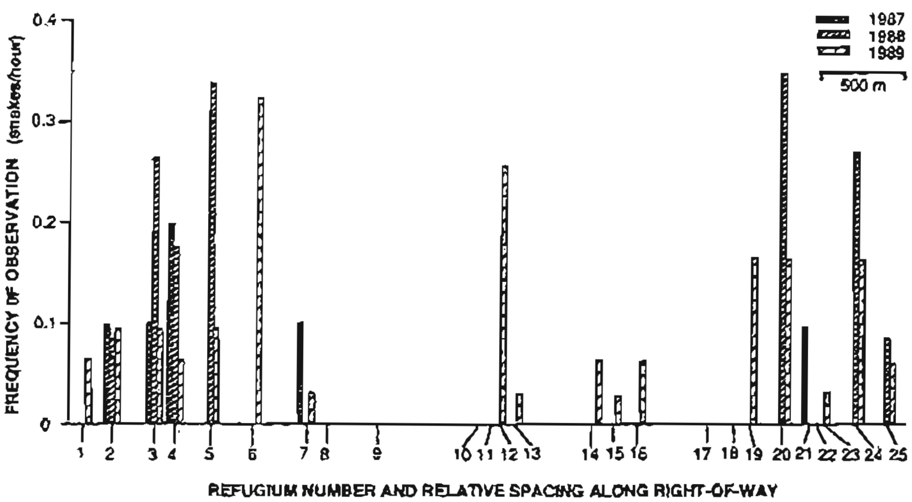


FIGURE 7. Frequency of observation of snakes at 25 artificial refugia along a 5 km public utility right-of-way. These data suggest that an increasing number of the structures were used by snakes over the three-year study period.

Division of Fish, Game and Wildlife (Endangered and Nongame Species Program). Herpetological Associates, Inc., provided additional support, necessary supplies, and long-term funding for this project. The use of a field research station was provided by the Ocean County Planning Board and Engineering Department.

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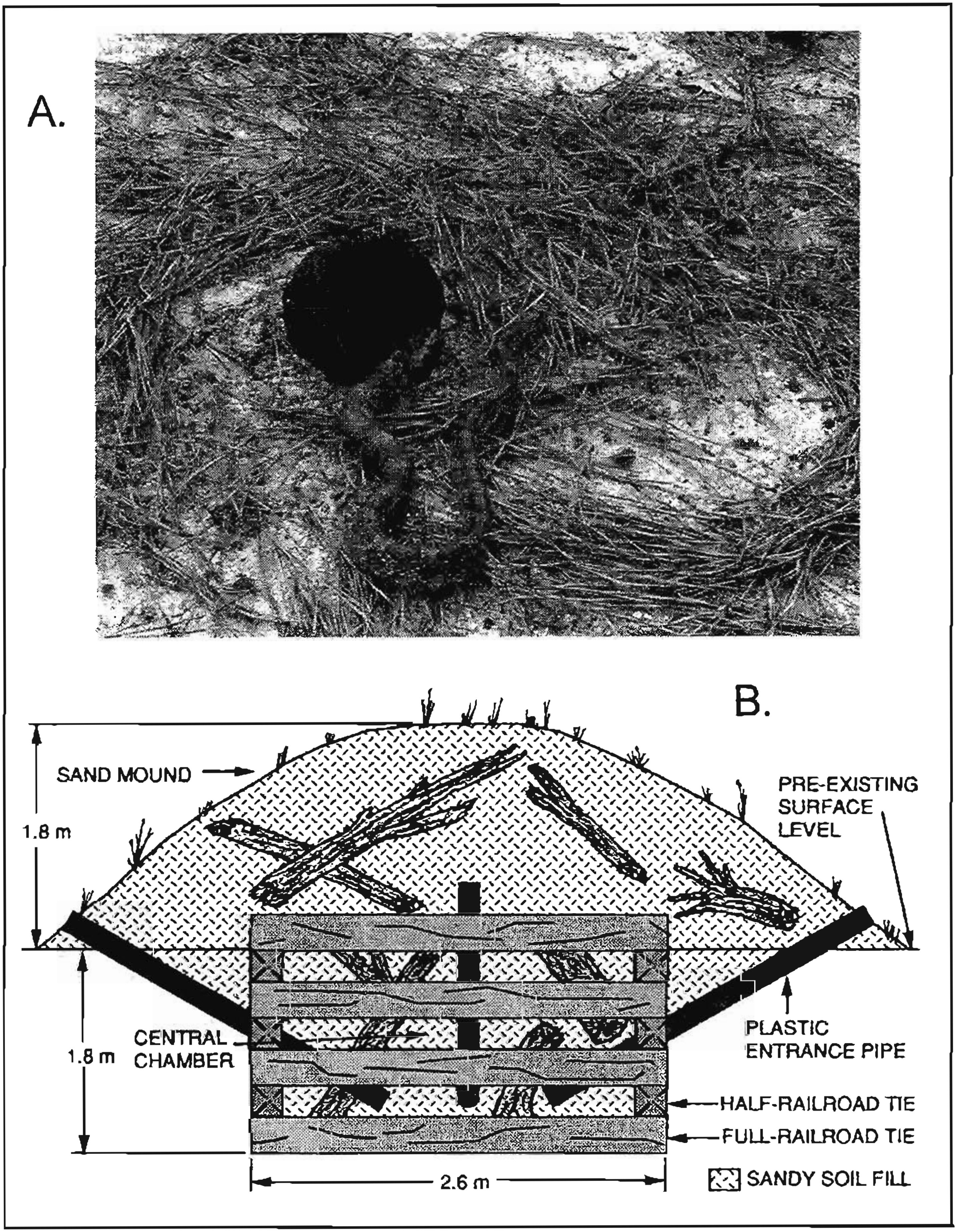
# *APPENDIX ONE*

***Artificial Refugia as a Habitat-Improvement Strategy for Snake Conservation***

***by***

***Robert T. Zappalorti and Howard K. Reinert***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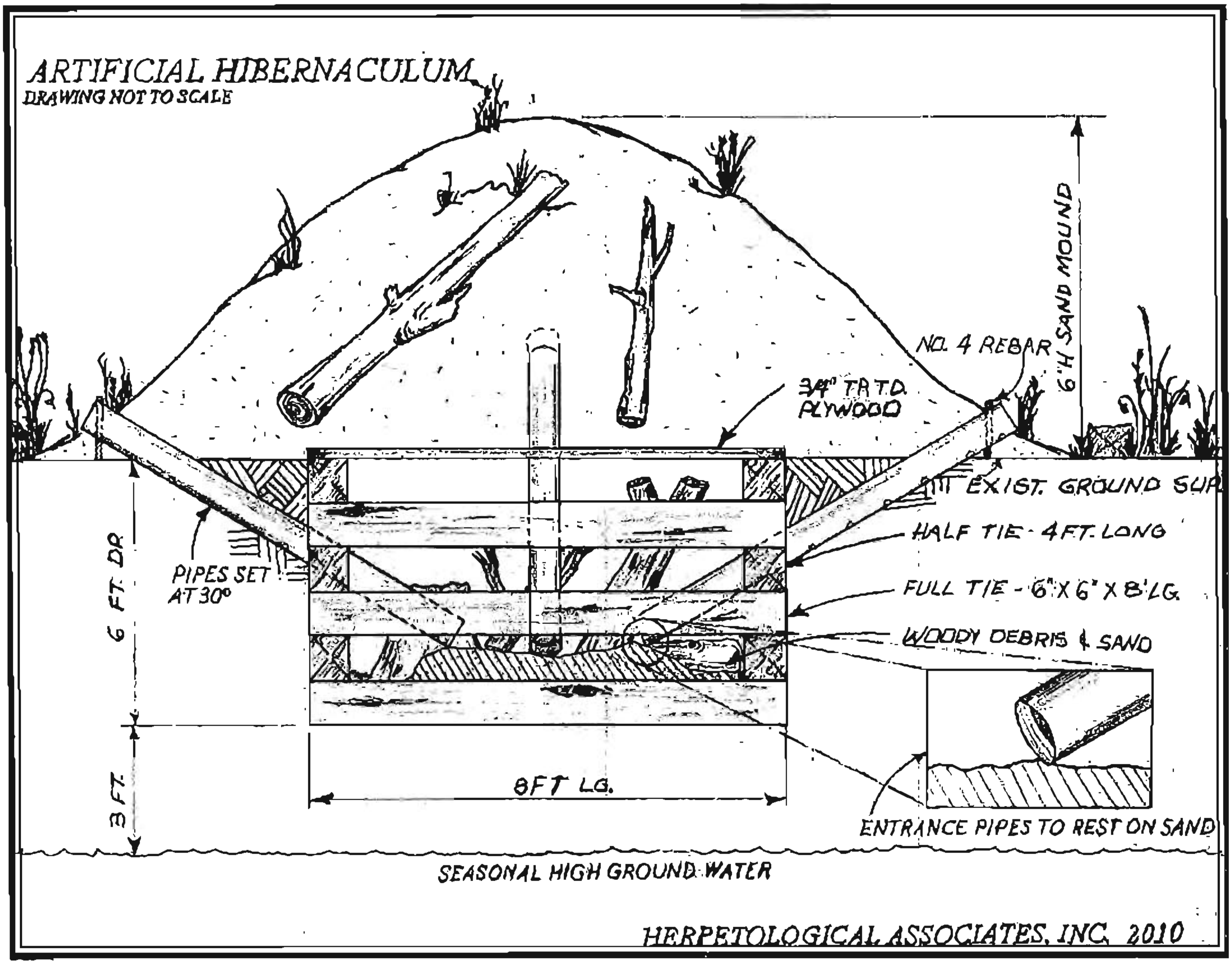


Diagrammatic drawing of an artificial snake hibernaculum, which serves as a winter den and/ or a summer shelter and shedding station. Use of these human-made dens has been documented for up to 30-years by R.T. Zappalorti.