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A Captive Breeding Program of the Corn Snake (Elaphe guttata), with Notes on Survivorship of Released Hatchlings in the Pine Barrens of New Jersey

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A CAPTIVE BREEDING PROGRAM OF THE CORN SNAKE, ELAPHE GUTTATA, WITH NOTES ON A SAMPLING PROGRAM OF RELEASED HATCHLINGS

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ABSTRACT

A total of 16 adult *Elaphe guttata* (4 males and 12 females) were kept in the laboratory as part of a captive breeding program initiated in 1982. Snakes were artificially hibernated in "cold rooms" (8 at Trenton State College and 8 at Herpetological Associates' laboratory) at temperatures from 10°C to 15°C between November 1984 and March 1985. Of the 12 females, 10 were successfully mated in the spring of 1986 and subsequently deposited 76 eggs. These were incubated and 48 successfully hatched (64%). A total of 135 *E. guttata* were successfully captive bred between 1982-1986 (Table 1). All hatchlings were sexed and permanently marked. The sex ratio of the 135 snakes was 71 males and 64 females (53% males and 47% females). Marked hatchlings were released in Burlington and Ocean Counties (27 from Burlington and 108 from Ocean). An intensive sampling regime was initiated in the Ocean County study area to recapture captive-bred *Elaphe guttata*. Information on movements and growth rate from 6 (7.4%) of the original 81 snakes was obtained (3 from 1983 and 3 from 1984). During 1985, 14 *Elaphe guttata* were found in Ocean County of which 6 (43% of the total caught) were captive-bred snakes. Population size was estimated at 189 snakes by use of the Lincoln Index. Range limits of the population size (95%) were 72-306 individuals. Herptiles and mammals were also investigated by use of a six month drift fence trapping program near the release site. We captured 13 species of mammals of which seven were shown to be prey species of *Elaphe guttata* through laboratory tests. *Sorex cinereus* (32%) and *Permyscus leucopus* (25%) were the most common mammalian resources at the study site. *Sceloporus undulatus hyacinthinus* were the most abundant reptile trapped in the drift fence (49%). There is a correlation between the known food items in the diet of *Elaphe guttata* and the prey species abundance in the drift fence. Feeding tests suggest prey items are consumed in similar proportion to their abundance at the Ocean County study site.

INTRODUCTION:

In 1976, the Endangered and Nongame Species Program, Division of Fish, Game and Wildlife, New Jersey Department of Environmental Protection (NJDEP) classified the corn snake, Elaphe guttata, as a "threatened" species in New Jersey. In the spring of 1977, Herpetological Associates, Inc. (HA) was commissioned by NJDEP, under a research contract to study the ecology and distribution of E. guttata in southern New Jersey (Figures 1 and 2). HA carried out distributional studies throughout the historic range in an attempt to reconfirm museum locations in Atlantic, Burlington, Cumberland and Ocean Counties (Figure 1). Field surveys in these 4 counties throughout the duration of the study (1977 through 1987) failed to reveal corn snakes in Atlantic and Cumberland Counties (Zappalorti and Johnson 1980, pp. 55-68 and Zappalorti and Barber, 1987). We did, however, confirm breeding populations in both Burlington and Ocean Counties during our intensive sampling regime. The historic location, in Burlington County, is the largest population based on personal experience and available locality records (Zappalorti and Johnson, 1982-B). Although the land is relatively protected because it is within a State forest area, in recent years, the population has been reduced from its former numbers by illegal collecting. In contrast, the historic population in Ocean County has been further perturbated by serious loss of habitat from housing developments and illegal collecting by hobbyists and commercial animal dealers. HA initiated life history and mark-recapture studies at both of these areas in the spring of 1977 and continued the investigation to the present date. Observations were made on mating, nesting, clutch size, incubation period, hatchling size, sex ratio, age class sizes, activity range, habitat utilization and behavior in the wild (Zappalorti and Johnson 1978; Zappalorti 1979; Zappalorti and Merli 1980; Zappalorti and Johnson 1982-B and Heck and Zappalorti, 1985). However, recapture of marked individuals was rare because of their fossorial habits and their ophidian tendency to remain hidden. Based on data gathered by HA between 1977 and 1982 (Zappalorti and Johnson 1982-C), the NJDEP officially changed the status of the corn snake from "threatened" to "endangered" on January 17, 1984. Subsequently, HA under contract from NJDEP initiated a captive breeding program in 1982 to produce hatchlings, which

were marked and released to help mitigate losses from the population (Dodd, pgs. 503-504, 1987). Commencing with 1985, both growth rates and ecological studies to ascertain population sizes and trends became possible with the recapture of marked snakes in Burlington and Ocean Counties. (Heck and Zappalorti, 1985). This report conveys information on behavior, population estimates, longevity of captive bred snakes in the wild and growth rates in both study populations. Based on current information, the "endangered" status for the corn snake is well justified since it is known only from two southern New Jersey counties (Zappalorti and Johnson, 1982-A).

PERSPECTIVE AND SCOPE:

Among herpetologists, both amateur and professional alike, the corn snake's popularity in captivity as a "pet" is well acknowledged. It is sometimes referred to as the "red rat snake" because of its bright red, orange or coral-red blotched pattern. This beautifully colored snake adapts well to captivity and has been known to live up to 21 years in zoos. Since they are able to adjust so well in the laboratory, and with proper care, have been known to breed in captivity, HA recommended that an experimental captive breeding program be initiated in the spring of 1982, Zappalorti and Johnson (1981, pp. 12-15).

The main objective of our two-part breeding program was:

1. To breed corn snakes in the laboratory and release the marked hatchlings on NJDEP wildlife sanctuaries that are managed and protected (Dodd, 1987).

2. To capture gravid females in the wild, maintain the female in the laboratory until her eggs are deposited, mark and release the female at her exact point of capture, hatch the eggs in the laboratory, sex and mark the hatchlings, and release them at protected sanctuaries.

The success of a breeding program depends on the healthy condition of the snakes, and more important, the knowledge of the keeper implementing the program. One needs an understanding of the annual activity cycles in order to provide the conditions which will help with the inducement of courtship, mating and deposition of fertile eggs. It is important to select healthy specimens for the breeding stock. Additionally, one must have the knowledge to accurately sex the adults. We used two techniques for sexing snakes, namely, adults were sexed by probing, Schaffer (1934), Fitch (1960), and hatchlings were sexed by the hemipenis-popping method, Gregory (1983).

SPECIFIC METHODS:

In anticipation of the implementation of a captive breeding program of the New Jersey corn snake, the authors selected adult snakes and kept them in the laboratory (Riches, 1976). HA staff captured the snakes in Burlington County (2 males and 2 females), and in Ocean County (2 males and 7 females). Initially, no attempt was made to breed the snakes. It was first necessary to see if each individual would feed in captivity. A specimen was kept until it shed its skin, and if it did not eat after this, it was marked and released where it was originally captured (one male from Ocean County had to be released). The snakes that accepted food (laboratory mice), were housed in 20 gallon glass aquaria or sturdy, glass fronted wooden cages (91 cm in length by 30 cm in height and 30 cm in width). The tops of the aquaria were covered with screen and secured with clamps, whereas, the wooden cages were secured with locks to prevent escape. The males were kept separately from the females with one or two specimens to a cage. The snakes were usually placed in hibernation around November 15, (for a thorough description of snake husbandry, see Kauffeld, 1969; Riches, 1976; and Tryon, 1985).

HIBERNATION IN THE LABORATORY:

Each snake was kept individually in a 20-30 gallon aquarium and were housed at HA headquarters in Ocean County, New Jersey and/or Trenton State College. The basement in HA's office has a "cold room" that is unheated. For the purpose of "photo-period", all cages were faced towards the four windows in the "cold room", which have a southerly exposure so that the snakes could experience natural daily light cycles. Since there was no heat source near the cages, the air temperature dropped gradually in the cages in correlation with the outside temperature (Tryon, 1985). It should be noted that the temperature where the cages were (along the inside wall) was 10 to 15 degrees warmer than the inside temperature next to the windows. Each cage was set up as follows:

1. The substrate consisted of 10 cm. to 20 cm. of Pine Barrens sand.

2. A hollow log was placed on the floor of the cage.

3. A medium of sphagnum moss, pine chips and/or pine bark was placed over the log and sand at a depth up to 25 cm.

4. A water dish was provided in each cage so the snakes could drink if they chose to.

Each cage was checked once a week and kept damp, not wet. The air temperature in the cages ranged from 10 to 18 degrees centigrade in November and December; 7.5 to 12.5 degrees centigrade in January; 5.0 to 10.0 degrees centigrade in February; and 7.5 to 12.5 degrees centigrade in March. The snakes were removed from the "cold room" about April 15th, and placed in the laboratory. During hibernation, the cages were provided with a constant supply of drinking water in order to prevent dehydration of the snakes.

MATING SNAKES:

Temperatures in the laboratory were kept between 20.0 and 28.5 degrees centigrade. After each snake was set up in its cage, they were offered food. Each snake was fed 2-3 mice per week. Once the snakes shed their skin, the pairs were placed together. The male was placed into the female's cage during May. The snakes were checked on an hourly basis in order to witness copulation. The following data were recorded for one of the pairs: May 10, 1983; 1330 hrs.: The male began courtship behavior; 1400 hrs.: The female was receptive to the courtship behavior; 1415 hrs: Copulation was observed; 1435 hrs.: The pair separated and the male was removed from the cage.

If there was no interest shown by the female initially, the male was left in her cage up to 3-4 days. When copulation was observed, the male was placed back in its cage for 24 hours, and then placed with another female in an attempt to have all females in the group fertilized. Gravid snakes were fed 2-3 mice a week for as long as they would accept food. Females usually go off food for a few weeks prior to egg laying (Riches, 1976).

CARE OF EGGS:

The gestation period is about 35-45 days. The female cited above was mated on May 18th, and began probing behavior or "nest searching" on June 20th, at which time a "nest container" was placed in her cage (i.e., a plastic shoe-box filled with damp sphagnum moss). Additionally, the water bowl was removed to prevent the female from depositing her eggs into it. The eggs were deposited on July 4th at 2100 hrs. into the "nesting container". The eggs were removed and placed in a one gallon, wide mouthed glass jar, half filled with Pine Barrens sand and damp sphagnum moss. The eggs were then covered with moss, the jar being filled to about one inch from the top. A ventilation hole was drilled in the lid of the jar to allow air exchange. The lid will also keep the humidity high during the incubation period. Eggs must be kept damp, but not wet. They should not be allowed to become

too dry either, because they may dehydrate and cause the death of developing snakes within. The eggs were kept at cycling temperatures ranging from 20.0 to 30.0 degrees centigrade, never higher or lower (Tryon, 1975 and Riches, p. 40, 1976). This will enable the snakes inside to develop at a normal rate. All hatchlings were permanently marked by branding an "X" on the dorsal scales in the center of a blotch (Clark, 1971). Most marked snakes were released into man-made snake hibernacula that were constructed by HA in the Ocean County study area. The Burlington County snakes were released at natural and man-made hibernacula.

RESULTS:

Between 1982 and 1986, this program has resulted in the registration and release of 135 captive bred corn snakes in Burlington and Ocean Counties, New Jersey (see Table 1). Little information was available on the survival rate of the initial 108 captive bred corn snakes released in the Ocean County study area. Only 21 hatchling snakes were produced and released from the Burlington County stock. Nothing was known of their dispersal route from the release site. In 1985, an intensive sampling regime yielded some information on dispersal routes of 7 recaptured captive bred snakes in Ocean County. Information also became available on activity ranges from 3 radio-tracked snakes in the late summer and fall of 1985. Two of the 3 snakes also yielded information on a natural corn snake hibernaculum within the Burlington County study area. The recapture of captive bred snakes also produced the first available data on growth in the wild. Three of the 7 snakes had nearly tripled their total length reaching sub-adult size in no more than 1.75 years of life. Up until 1986, we had no information whether any of these snakes reached sexual maturity, were sexually active, or had bred (Parker and Plummer, 1987). In 1986, captive breeding was de-emphasized in order to continue intensive monitoring of captive bred snakes in the wild to acquire more information with respect to the following objectives:

1. Determine survival of marked captive bred and wild corn snakes released in 1982, 1983, 1984 and 1985 (Dodd, 1987).

2. Determine dispersal patterns of marked captive bred and wild corn snakes in the Ocean and Burlington County study areas (Dodd, 1987).

3. Determine corn snake population size, structure and trends within the two study areas. (Parker and Plummer, 1987).

4. Survey historic areas and potential areas for new corn snake populations throughout the known range in southern New Jersey (Jenkins, pers. comm., NJDEP, 1986).

SNAKE AND EGG ACQUISITION:

In order to reach our goal of realistic population estimates and trends, it was necessary to continue marking a large enough series of snakes, to increase the probability of recapture. To achieve this, HA employed an intensive sampling regime. We searched traditional areas as well as likely areas well removed from our designated study sites. We used both the time-constrained technique and random opportunistic sampling (Campbell and Christman). We also sampled as follows: We investigated tree stump holes as corn snakes are often found further south by this procedure as noted by Kauffeld (1957, p. 218). In some cases we visually explored promising looking holes on the forest floor. Potential summer dens were decided upon by the similarity in appearance to a natural hibernaculum that had been found in 1985 or the presence of shed skins.

During the reproductive season, great effort was made to capture either gravid corn snakes or to locate wild egg clutches. The use of the wire-loop probes were carefully inserted (loop first) in long cracks and crevices of hollow logs; in order to dislodge eggs; particularly where either shed corn snake skins or egg shell remains were found.
All locations were noted in a field journal. These areas were investigated during the season for the presence of shed corn snake skin. Wherever shed skins were found, the logs were opened and carefully scrutinized for snakes or eggs. Afterwards they were closed and recamouflaged. Throughout the field season (April-October), both man-made hibernacula/dens as well as natural hibernacula/dens were visited frequently, often twice or more on the same day in an attempt to recapture or observe snakes.

Back-hoe employment was used to carefully take apart man-made mounds in 159 hectares of Holiday Heights area within the Hovsons tract in Ocean County prior to construction in order to remove snakes that otherwise may have been killed.

Captured gravid females were kept alone in the laboratory during the egg development period. Eggs were removed from the cage as soon as possible after deposition and placed in plastic containers partially filled with both fresh clean sand and Sphagnum moss. The eggs were incubated as described above.

During the reproductive season, (April-June) we also bred captive snakes which added to the number of eggs to be hatched. The eggs were incubated for a period of seven to eight weeks.

MARKING TECHNIQUES:

Hatchlings were measured, sexed, by the hemipenis-popping method (Gregory 1983) and marked by branding an "X", "Z", or "H" on the dorsal scales at mid-body, using a soldering iron (Clark, 1971). All distinctive hatchling markings and the number of dorsal patches were recorded. This was also done for all initially captured snakes. Drawings were made of all distinctive dorsal blotches and correlated with a field number in lieu of branding hatchlings. Larger corn snakes were given their own distinctive brand using a technique modified from Clark (1971, Figure 3). Later this information was transferred to a laboratory log book. Duplicate copies of this information are kept by both HA and Trenton State College. All hatchlings and older snakes were released where they (eggs or animals) had been found.

RADIO TRACKING:

In anticipation of a more intensive investigation on activity range and habitat utilization by corn snakes, permission was requested and granted by the NJDEP to implant some corn snakes in the Burlington County study area in order to find hibernacula. The transmitters were surgically implanted using a technique described by Reinert and Cundell (1982). Between 1985 and 1987, a total of 5 adult corn snakes were radio-tagged with AVM Instrument Model SM-1 transmitter with a 3-6 month HG330 battery. The transmitter has a functional field range of 244 to 305 meters and was received with a AVM LA12-DS portable telemetry receiver and hand-held Yagi antenna. Dr. Howard Reinert of Allentown College, Pennsylvania, performed the surgical implants of the transmitters into the snakes at his laboratory. During the tracking study, we found one natural corn snake hibernacula 27.3 meters north of a known nesting area.

DRIFT FENCE TRAPPING SYSTEM:

The use of drift fences, combined with pitfall and double ended funnel traps, were found to be a practical way to uniformly collect and/or census small mammals, reptiles and amphibians in various habitat types (Campbell and Christman, 1982). In May 1985 we installed a 91 meter "T" shape drift fence in an open canopy pine-oak forest, near the general release site of the 81 captive-bred corn snakes in Ocean County (Figure 4). A second fence measuring 152 meters was

installed on the southern edge of a pine-oak forest in an area that was known to be habitat for corn snakes. Two similarly constructed drift fences with associated pit-fall traps and double-ended funnel traps were also installed at our Burlington County study area. The first fence (85 meters long) was installed near the boundary of pine-oak forest and adjacent cleared area with Pine Barrens heather, Hudsonia eriocoides, just north of an active blueberry field. The fence was located on the edge of a pine -oak forest on the south side. Immediately east of this drift fence was a north-south running irrigation ditch to convey water to the blueberry field. The second drift fence (60 meters long) was installed in a "fire break". The blueberry field area was selected for the first drift fence because in 1985, 9 new corn snakes had been found (both adult as well as hatchling) Similarly, the second drift fence site was also selected on the presence of adult and hatchling corn snakes. In 1985, seven corn snakes had been found in the area. The last 3 installed drift fences generally were arranged in more or less a straight line. Interposed on either side along their length, were several 95 and 133 liter plastic containers (pit-fall traps) which were buried to the brim. Funnel traps were also placed on either side of the fence under propped shade boards. In addition to these pit fall traps, 200 liter metal drums were buried to the brim under the drift fences (Figures 4 and 5).

ECOLOGICAL STUDIES:

The largest known corn snake population in New Jersey occurs in Burlington County. Corn snakes have been observed by HA staff between 1968-1988 as part of this mark-recapture study. During the 1982 field season, a total of 17 corn snakes (7 adults, 10 hatchlings) were captured or observed in this study area. An average of 15-20 adult corn snakes are captured or recaptured every year in both of our study areas. Most of the adults were marked and released where originally found. Recapture of marked snakes from previous years has suffered from limited success, due to the highly secretive behavior and their tendency to remain hidden, habitat disturbance by motorcycles and other snake hunters, and possible removal of marked snakes by illegal collectors.

In order to learn about the activity range requirements of the corn and pine snakes, a preliminary radio-tracking study was initiated during the summer of 1982 in Ocean County. This study was funded by the Ocean County Planning Board and several private landowners. Ten pine snakes and one adult male corn snake were surgically implanted with transmitters and released where originally captured. The corn snake's movements were followed by means of a radio receiver until it went into hibernation. Each time the snake was recaptured, its movements were plotted on a grid-map of the study area. It was determined, based on 20 recaptures/movements that the activity range of the single implanted corn snake was 4.5 hectares (11.3 acres).

The ability of snakes to hide in the forest floor is amazing. By implanting a snake with a transmitter, it allows the researcher to locate and observe the snake any time during the day or night. It is HA's opinion that a great deal of important ecological and activity range data could be gathered by an intensive study of this kind in the future.

During the past ten years, the authors have been compiling data on the important habitat variables of the corn snake. We compared known corn snake habitats in Burlington and Ocean Counties and looked for similarities in soils, vegetation, elevation, food source and water. These data gave us a common denominator and provided guidelines in the development of experimental management plans.

Some preliminary experimental work was conducted between 1982-1987. This included the construction of 39 corn snake and pine snake hibernacula in Ocean County. The sites selected were in the vicinity of historic corn snake and pine snake areas and possessed all of the known habitat variables which are preferred by them. The areas were monitored for six years and it was learned that snakes use the man-made summer dens/hibernation sites (Figures 6 and 7).

RESULTS OF HERPETOLOGICAL SAMPLING REGIME:

Precipitation markedly affects the activity of amphibians and reptiles in general, and certain snake species in the Pinelands in particular (Kauffeld, 1957). When there was rain, amphibians and some reptiles and small mammals, moved immediately or soon after it stopped. Based on personal observations (Zappalorti and Johnson, 1982-B), foraging migration behavior would continue for a day or so after rain, but once high temperature and dry weather returned, there was a drastic decline in fixed activity patterns of most herptiles.

No corn snakes were captured in the drift fence during 1985, however, a hatchling was trapped in 1986. During 1985, 14 corn snakes were found using the three other sampling methods described above. Some snakes are only active during the day, such as the hognose, northern black racer and northern pine snake. Other species, like the scarlet snake, coastal plain milk snake, king snake and corn snake, are nocturnal during the summer. Both rain and ambient temperature strongly affected the results of our sampling regime. Not only was our drift fence trapping system more successful after a rain, but road cruising and random opportunistic collecting were also more productive. Drought and high summer temperatures (July and August) forced herptiles to remain underground for prolonged periods. This trend is reflected in Tables 6, 7 and 8; with the absence and/or low number of corn snakes, and other herptiles, trapped or captured in the summer. The most productive months for sampling corn snakes were May, September and June in that order (see Table 8). During the summer, weeks would go by without herptile activity. Rain would always trigger improved sampling results using the four methods described above.

Small mammals were also captured in our drift fence with regularity, even during the summer. Since most small mammals are nocturnal, they would be less affected by the warm, daytime temperatures (Dueser and Shugart, 1978, 1979). We trapped 13 species of mammals between May and October. These data are presented in Table 9. All mammal identifications were made by use of various publications and field guides such as: Burt and Grossenheider (1964), Forman et al (1979), McCormick (1970), Buckles (1976) and Van Gelder, pers. comm. (1984, 1985).

We also trapped a number of other reptiles and amphibians in the drift fence throughout the duration of this study. We captured nine species of reptiles and 11 species of amphibians between May and October, 1985. The most common reptile trapped was the northern fence lizard, whereas, the most abundant amphibian was the Fowler's toad (Tables 10 and 11). It was determined that the time-constrained method of sampling was the best way to capture and observe corn snakes.

SURVIVAL OF CAPTIVE BRED CORN SNAKES IN THE WILD:

Although we released 81 captive bred corn snakes between 1982 and 1984, little information was available on their survival in the wild. Could captive laboratory bred snakes adapt and proliferate under the harsh natural conditions of the Pinelands ecosystem? It was our opinion they could, but in order to prove this hypothesis, we had to recapture marked individuals that were released in previous years. Our intensive collecting program provided the recapture of six marked specimens of which all were in good health and had attained rapid growth (see Tables 3 and 4).

In July 1984, one of our captive bred snakes (83.01) from 1983 was recaptured under a log in our study area. The mark on the dorsal scales was easy to see after 1.5 years. The snake, a male, had grown 15.5 cm. since it was released in September 1983. It measured 24.2 cm. when it was released and had grown to 39 cm. It also had a meal in it when it was captured (probably a fence lizard judging from the shape and size of the bulge). The snake was found near a man-made snake hibernaculum that was built by HA in conjunction with R.F. Doss, Inc., a building contractor. Two snake hibernacula were constructed as part of a mitigation program. Not only were captive bred corn snakes surviving, but this one was utilizing a man-made structure for shelter and foraging habitat. The snake moved 222.5 meters northeast from its original release site (Table 5).

These data were encouraging for our sampling regime in 1985. Our cooperative efforts produced 14 corn snakes from the Ocean County study area. This intensive collecting program was highly productive and revealed ecological and dispersal information that otherwise would not have been known. Table 3 and Table 5 summarize the movements and growth of the six recaptured Elaphe guttata in our Ocean County study area, (Fukada, 1969).

The hatchling corn snakes are sexed (Gregory, 1983), measured and marked prior to their release(Quinn and Jones, 1974 and Clark, 1971). It was determined that the snakes grew quite rapidly in their natural habitat. This reflects the spatial habitat differences of mammal-eating snakes in the Pinelands community. There are several important snake predators on small mammals in the study area, these are timber rattlesnake, northern pine snake, eastern king snake, coastal plain milk snake, northern black racer as well as the corn snake (Heck and Zappalorti, personal observations, 1988). Most of these snakes exhibit distinct habitat preferences (Zappalorti and Johnson, 1982-B; Heck and Zappalorti, 1985; Reinert and Zappalorti, 1988), but also have a great deal of overlap in their general habitat use. Table 9 represents the results of our mammal trapping efforts in the Ocean County study area during 1985. Trapping results compare favorably with the known food items in Elaphe guttata's diet (See Table 9).

GROWTH OF RECAPTURED CORN SNAKES IN THE WILD:

Between 1982 and 1984, HA released 71 captive bred corn snakes as shown in Table 1. On July 14, 1984, we recaptured our first captive bred marked hatchling (83.02) which was part of a 1983 cohort of 25 corn snakes. In 1985, we released 27 of 48 captive bred hatchlings at our Ocean County study area while 21 were released in Burlington County. In 1985, we recaptured 6 captive bred hatchlings. Three were from the 1983 cohort while the other three were from the 1984 cohort of 37 snakes. These 6 snakes provided our first growth data of captive bred hatchlings in the wild as shown in Table 3 (Heck and Zappalorti, 1985). Since 1983, we have only captured, registered and released 23 new wild snakes in Ocean County. For the first time in 1986, we recaptured three (13%) of these prior marked wild snakes and all provided growth data. We also recaptured six marked snakes which hatched in the laboratory in 1984 or earlier.

The growth data for all of these 18 corn snakes recaptured since 1984 are shown in Table 4 along with growth data from four recaptured snakes from our Burlington County study area. Although we recaptured seven snakes, the two radio tracked animals (once released) were never rehandled (as is our custom). Therefore, we do not have growth data on them. Likewise, one released 1986 recaptured hatchling showed no growth as it had been out in the wild for only two weeks. In Burlington County, snakes which provide growth data are all wild snakes. Three were sub-adults or older while the last was an 1985 wild-caught hatchling. Two of the adults were recaptured snakes from 1985.

Table 4 also includes/incorporates the growth data of wild and captive bred recaptured snakes reported for 1985 (Heck and Zappalorti, 1985). The data for snakes numbers 1 through 20 are arrayed according to age in years. The release and recapture dates only show month and year because of the need to conserve space in the table. To determine the age, we used an X month of 30 days and counted the months from the day of release to the day of recapture and divided by 12. For snakes numbers 21 through 26, the age column only shows the time-lapse between release and recapture. These too are arrayed in a trend of increased time lapse. The ratio column is obtained by dividing the final size by the initial size. The status column shows whether the snake was captive bred (C.B.) or wild caught (W) together with the location (e.g.: Burlington (B) or Ocean (O). In the study area column, the plus (+) sign indicates a snake that was recaptured and measured at least twice since its release. In these cases, both size differences were obtained like the others, by taking the difference from the smallest initial size and the recapture size.

Examination of the growth increment column in Table 4 shows that snakes whose age is 0.25 and 0.9 years; growth may be as much as 15 cm. in that elapsed time. H also indicates that a wild hatchling may grown more rapidly than a captive bred hatchling in the same interval of time. Likewise, it shows that snakes 1.0 and 1.2 years old have twice the growth increment of a snake whose age is 0.9 years or less. Snakes that are 1.6 to 3.0 years old were 10 in number and their mean growth increment was 53.6 cm. This was three times the growth increment of a 0.9 year old snake. The average recapture size of these 10 snakes was 80.9 cm. Likewise, these same snakes had tripled the average hatchling size (26.9 cm.) of the captive bred hatchlings shown in this table. Snake #3 was omitted because it was a wild hatchling and we did not know its hatchling size or hatchling data. The omission of snakes 16 through 18 and #20 is due to their second entry into the table. Our oldest recaptured captive-bred snakes were 3.1 to 3.6 years of age and their average recapture size was 86 cm. Their mean recapture size was exactly three times the average hatchling size (28.6 cm.) of all 84 hatchlings released in 1986. Furthermore, the recapture of three captive bred gravid snakes (at our Ocean County study area) that hatched in 1983 indicated that sexual maturity is attained in three years or less. The three gravid snakes (86.03, 86.13 and 83.16) had an average size of 81.8 cm.

The youngest to lay eggs was 86.03 and she was only 2.6 years old and was 82 cm. long. All three of these snakes were recaptured again after they had been released after egg deposition and their final average size was 84 cm. (after a mean lapse of 1.5 months. Female snakes which have recently oviposited (after shedding their skin) forage repeatedly being opportunistic feeders and eat in earnest to compensate for their long fast prior to egg deposition.

Lastly, the average final size of snakes (numbers 18 through 26) which are 3.1 years or older, their mean size is only 90.5 cm. which is only 10 cm. longer than the 10 snakes whose age ranged from 1.6 to 3.0 years old (Heck and Zappalorti, pers. observations, 1988).

RESULTS OF FEEDING TESTS:

Small mammals that were captured in pitfall and/or funnel traps were removed and taken to the laboratory. The adult corn snakes in our breeding colony were used to conduct tests to determine prey acceptance. A total of 22 corn snakes were used (12 adults, 5 juveniles and 5 hatchlings) to test acceptance of 8 various small mammal species. Mammal identification was made by Dr. Richard Van Gelder of the American Museum of Natural History in New York City (pers. comm., 1985). Each corn snake was kept separately in a glass container and/or wooden cage that measured: 80 cm. long, 30.5 cm. high and 30.5 cm. in width. The floor of the cage was covered with 5-10 cm. of sandy soil and pine needles; a hollow log was provided as a hiding place. We tried to provide semi-natural conditions in each cage. A live and/or dead animal was quietly introduced into a cage. Prior to constriction, most snakes would demonstrate rapid tongue flicking and attack. Small rodents were always accepted by corn snakes that were not opaque (e.g.; a pre-shedding condition when the snake's eyes turn blue). Opaque individuals would usually reject prey items. They would resume eating after casting their skin. Larger sized rodents, such as small cottontails, gray squirrels and red squirrels, were always rejected. Shrews were accepted by large snakes, but juveniles would only occasionally eat them if they were dead. Northern fence lizards were always accepted in the tests, but there was a definite correlation between prey size and snake size. Hatchlings and juvenile corn snakes would attack and constrict small fence lizards and mice, but would retreat from large adult lizards or rodents. This was also true of adult corn snakes. Large mammals would elicit defensive behavior (e.g.: an "S" coil accompanied by a hiss and strike) and/or retreat behavior. Medium-sized rodents and shrews would elicit attack, constriction and acceptance of the prey item. Our observations suggest that corn snakes selected prey on the basis of size and catchability. There have been other studies on feeding behavior of snakes, both in the laboratory and in the wild. Most notably is Reynolds and Scott (1982) and Reinert, et al (1984). See Table 9 for a breakdown of small mammals eaten during our experimental feeding test.

PRELIMINARY POPULATION DYNAMICS:

Up until the recovery of the six captive bred E. guttata in 1985, it was not possible to speculate, with certainty, about the size of the Ocean County population. Of the original 81 captive bred hatchlings released between 1982-1984, the six recaptured snakes represent 43% of the total (N = 14) sampled. Thus, testifying not only to the efficacy of the captive breeding program, but provided data for the estimation of the population size by use of the Lincolin Index (Mosby, 1963).

Population size limits for our sample (95%) were determined by adding and subtracting two standard errors from the estimate. The Ocean County E. guttata population size was estimated at 189 snakes, with a range of 72-306 individuals. Continuation of this captive breeding program seems well justified since 43% of our sample were marked specimens. Future monitoring will not only provide additional information on the population size and range, but will also help to better understand the ecological habits and needs of this "endangered" species in the wild. We strongly recommend the continuance of the captive breeding program in order to restock suitable, protected habitat throughout the historic range of the corn snake in New Jersey.

POPULATIONS ESTIMATES:

In order to make some estimates of population sizes for both the Ocean and Burlington County study areas, it is necessary to summarize data from the captive breeding program and from the sampling program.

Captive breeding has produced the following (marked/released) hatchlings for the Ocean County study area:

YEAR	NUMBER OF CAPTIVE BRED HATCHLINGS
1982	19
1983	25
1985	37
1985	27
1986	6
1987	Discontinued

TOTALS: 5 Years = 114 Captive Bred E. guttata

Captive breeding has also produced the following (marked/released) snakes from the Burlington County study area:

YEAR	NUMBER OF CAPTIVE BRED HATCHLINGS
1985	21
1986	14
1987	16

TOTALS: 3 Years = 51 Captive Bred E. guttata

POPULATION SIZE ESTIMATION:

In 1986, we found 16 different corn snakes which included 11 recaptures in our Ocean County study area. Five of the 11 were released as marked laboratory hatched animals from 1983 while the others were captive bred 1984 hatchlings. Two of the 11 were marked 1986 hatchlings, both captive bred. Only three adult wild marked snakes were recaptured. One of the three was first caught in 1975 and was retained in the breeding colony until its release in 1985. From 1982 up until the end of 1985, only 18 new wild (juvenile to adult) snakes have been marked and released. Only five new wild snakes were found in Ocean County during 1986 and none of these were recaptured that year.

From 1982 through 1985, 108 marked hatchlings have been released. In 1986, 34 additional marked hatchlings were set free. Thus, a total of 142 hatchlings (plus 18 wild snakes, 1985) made up the marked (M) population of 160 snakes. The inclusion of the 34 (1986 hatchlings) in the calculation of M = 160 is legitimate, since all areas of release were repeatedly sampled in Ocean County for two more months after their release by the time-constrained technique. Furthermore, two of these marked hatchlings were recaptured in 1986. Upon substitution of 160 for M, when n = 16, and R = 11, the population estimate (N) by the Bailey (1952) formula would be 227 and the standard error is 34:

$$N = \frac{M(m+1)}{R+1} = \frac{160(16+1)}{11+1} = 227; \quad S.E. = \sqrt{\frac{M^2 (n+1)\ (n-R)}{(R+1)\ (R+2)}}$$

$$= \sqrt{\frac{160^2 (16+1)\ (16-11)}{(11+2)\ (11+2)}} = 34$$

The 95% confidence limits for our estimate (N) was determined by adding and subtracting two standard errors from the estimate. Accordingly, the Ocean County corn snake population was estimated to be between 159 and 285 snakes.

This estimate ignores mortality particularly in younger snakes. Unfortunately, we do not have enough recaptured data to calculate age specific mortality or annual rate of disappearance. However, we attempt to approximate such losses by use of estimates found in the literature. Porter (1972) notes young snakes of most species have a high mortality. The result of high juvenile mortality and increased life expectancy with age is that the adult population of snakes represents the accumulation of many year's reproduction. Gans (p. 217, 1977) notes that Porter concludes the annual rate of disappearance for rattlesnakes of all ages is 22%. Other annual mortality rates cited in this work were as low as 17.5% to a high of 50% for young ovoviparous snakes. Yet, Saint Girons (1957) states, "mortality of Colubrids is more age constant being lower in

younger snakes and higher in adult snakes". Finally, Gans (p. 217, 1977) in his survey of mark-recapture results of other workers, notes that young snakes are often not captured in proportion to their true abundance. Since we are dealing with a fossorial-cryptically colored species that when approached, remains motionless and are difficult to see. We hypothesize (like Saint Girons) that our study population has a lower mortality rate when young. This is also somewhat substantiated by the fact that between 1985 and 1986 we have recaptured nine (35%) of the 25 cohort released in 1983. With this in mind, if we hypothesize 20% of the hatchlings die, then the population estimate (N) will equal 187 and the standard error (SE) would be 28 when M=132. (The recalculation of M=132 = 18+114 (80% of the 142 hatchlings that survive).

$$N = \frac{132(16+1)}{11+1} = 187; \quad SE = \sqrt{\frac{(132)\ 2\ (16+1)\ (16-11)}{(11+1)\ \ (11+2)}} = 28$$

Our most conservative estimate would still be inflated because it doesn't assume any adult mortality. The 95% confidence limits for our estimate would be between 131 and 243 snakes.

During 1986, in our Burlington County study area, we found 16 different corn snakes which included seven recaptured snakes from traditional and non-traditional searched areas. In traditional areas, we found 11 different snakes plus one that had been recently released from the breeding colony at Trenton State College. (This snake is not included in our calculation of population estimates). Five more snakes were found in non-traditional searched areas including a recaptured snake (in this total). Five of the seven recaptured snakes were wild (initially captured and recaptured in 1986) snakes, two of which were also seen (a number of times) in 1985. The other two recaptured snakes were a 1985 wild hatchling (first caught in May 1986 and again in August 1986) and a 1986 wild hatchling from a wild egg clutch (which was incubated in the laboratory). In 1985, we caught, marked and released 16 new wild snakes. Likewise in 1986, nine new snakes were encountered, marked and released and five of these were recaptured as already noted. Captive breeding produced 21 and 14 marked hatchlings in 1985 and 1986. Wild egg clutches produced 36 more hatchlings. All marked hatchlings and wild snakes were released in traditional areas except for the five snakes that came from non-traditional searched areas. The number of marked (M) snakes then would be 57 surviving hatchlings (after 20% mortality of the original 71) plus the 16 and nine new marked snakes encountered in 1985 and 1986. Thus, M=82 and r=7 when n=16. Calculation of the population estimate (N) and standard error (SE) is 174 and 42 respectively.

$$N = \frac{82(16+1)}{7+1} = 174; \quad SE = \sqrt{\frac{82\ 2(16+1)\ (16-7)}{(7+1)\ (7+2)}} = 42$$

The 95% confidence limits for this Burlington County population would be 90 to 258 snakes. Since neither the hatchlings were released in non-traditional searched areas nor were they extensively and repetitively searched like the traditional areas, HA questions this estimate.

However, if we wish to make an estimate for the two time-constrained searched areas (in Burlington and Ocean Counties) we must not count both the five snakes found in non-traditional searched areas along with one recaptured snake. The values of N become 11 when r is 6. The number of marked animals (M) is 57+16+9 = 85 as noted in the Burlington County study area (above). The population estimate (N) then falls to 141 and the standard error is 32.

$$N = \frac{82(11+1)}{6+1} = 141; \quad SE = \sqrt{\frac{(82)\ 2\ (11+1)\ (11-6)}{(6+1)\ (6+2)}} = 32$$

The 95% confidence limit for this exploited population would be between 77 and 205 snakes.

Since intensive searching did not produce any of these marked snakes, but plenty of evidence of other collectors (e.g.: fractured and busted logs, over-turned boards and tin), the available evidence suggests that the population is decreasing. However, we are somewhat comforted by the fact that several corn snakes turned up both north and south as well as east and west of this heavily collected area.

Additional captive breeding and habitat manipulations may increase the species numbers in portions of the former known range in New Jersey. The Manumuskin River drainage basin in Maurice River Township, Cumberland County is currently proposed to be incorporated into the National Wild and Scenic Rivers System. Since the NJDEP owns vast areas of land in the basin, a corn snake reintroduction program would be quite appropriate in the area.

A PROPOSED MANAGEMENT PLAN FOR THE CORN SNAKE, *Elaphe guttata*

JUSTIFICATION FOR MANAGEMENT:

The corn snake reaches the northern limit of its range in the Pinelands of southern New Jersey, where it is classified as an "endangered" species. Although known historically from four counties - Atlantic, Burlington, Cumberland, and Ocean (Figures 1 and 2), we have confirmed its presence only in Ocean and Burlington Counties. Corn snakes have experienced a serious loss of habitat in Ocean County. Another factor contributing to the corn snake's decline is the fact that they make good pets, and will thrive in captivity. All of the known populations are under serious pressure from both professional collectors and private hobbyists.

Management is needed to preserve and improve remaining habitat, some of which has become unsuitable due to natural succession. A captive breeding program needs to be initiated to restock declining wild populations.

THE PROBLEMS:

One probable reason for the corn snake's decline is that they have rather specialized habitat requirements, which are very similar to those preferred by the northern pine snake. They inhabit high (> 50 feet), dry sandy areas of pitch pine-oak forest, where the understory is typically composed of low bush blueberry, green briar and bracken fern. Corn snakes choose nesting areas that are open and sunny with an abundance of rotten logs and/or railroad ties for depositing their eggs. A permanent source of water is usually within 600 meters of a nesting area.

The type of habitat preferred by corn snakes is also in great demand by land developers. This problem is especially evident in Ocean County, where a serious decline in the corn snake population has been noted. Loss of habitat has placed this species in constant jeopardy. A good illustration of this is the Ocean County study area. Corn snakes were once found in Lakewood/Lakehurst areas, but none have been seen there for the last 25 years.

Corn snakes have also suffered a loss of habitat due to natural succession. However, this is one problem that can be dealt with by applying standard management procedures. As the pine-oak forest matures, the oaks will eventually crowd out the pines, changing the character of the forest and the surrounding habitat. The corn snakes may respond to this change by either dispersing out of the area to more suitable habitat, or seeking the edge of the forest for optimum egg-laying sites.

Illegal collecting of corn snakes has been an increasing problem over the past ten years. Our study areas in Ocean and Burlington Counties are constantly hunted by collectors, especially during the June egg laying season. Overturned logs and railroad ties are sure signs of collectors having been in the area. It is unknown how many marked snakes have been permanently removed from these study areas. Unfortunately, little can be done to halt illegal collecting, other than increased patrolling by NJDEP Parks and Forest Wardens, Conservation Officers and strong enforcement of the current laws. Scientific collecting permits are available from the NJDEP if one has a legitimate reason for taking snakes.

Another problem with some corn snake populations is that they have experienced such a serious decline in numbers that there may not be enough specimens left in the wild to replace those that are taken or killed by predators or cars (e.g., Lakehurst, Ocean County; Hammonton, Atlantic County; Port Elizabeth, Cumberland County, etc.). A possible solution to this problem is to breed the snakes in captivity and release their hatchlings into historic areas that still have suitable habitat with pine-oak forest that is state owned and protected.

THE PLAN:

The management procedures for the corn snake are presented in two parts: Habitat management and captive breeding (Zappalorti and Johnson, 1981).

First, the purchase of large tracts of land containing confirmed nesting and hibernating sites would be very beneficial to the survival of this species. Management of State-owned land could then be carried out by applying the following procedures: selective cutting of oaks, controlled burning, and the creating of hibernacula/denning mounds and brush piles. These will serve to improve the habitat for both corn and pine snakes. The various methods are detailed below:

1. Selective Cutting of Oaks:

The preferred habitat of the corn snake is pine-oak forest. In the absence of fire, oaks will gradually dominate the pines, thus changing the habitat to oak-pine forest, and eventually to climaxed oak forest, making it unsuitable for corn snakes. In some areas where this is occurring, a certain number of oaks can be cut, to ensure that the pines are not dominated by hardwood trees and shaded out. The cut oaks can be used to build denning mounds.

2. Controlled Burning:

As an alternative to selective cutting, a controlled burn can be used to thin out the number of oaks on a given plot of land. As long as the fire is controlled, it will do only minor damage to the pines. Burning should be done in January or February, while the snakes are still in hibernation and no birds are nesting. Burning may only be necessary every 6-9 years and should be conducted by the Division of Parks and Forests.

3. Creation of Denning Mounds:

The first step in this procedure is to select a tract of land that fulfills all of the corn snake's habitat requirements: pine-oak forest, high elevation, sandy soil, nearby source of water. Then, clear cut a field approximately 122 x 122 meters in area, piling the branches and logs resulting from clearing around the edge of the field. The large tree trunks and stumps will be used to construct the denning mounds. This can be done by first digging pits about 2.5 meters deep and 3 meters square, and then filling them with the logs and stumps. When the pits are filled to ground level, additional stumps and logs should be piled on top. The whole pile is then covered with the sand that was previously excavated. It would be beneficial to seed the mounds with native grasses or other plants to prevent soil erosion. The smaller branches left over from this procedure should be stacked into brushpiles, which will serve as hiding places for rodents, birds and other small animals that corns snakes feed upon, Frier and Zappalorti, (1983) (see Figures 6 and 7).

One of the most important management procedures for this species is a continuation of a captive breeding program, in order to restock dwindling wild populations. This program can be undertaken in two phases:

1. Indoor Breeding in a Controlled Environment:

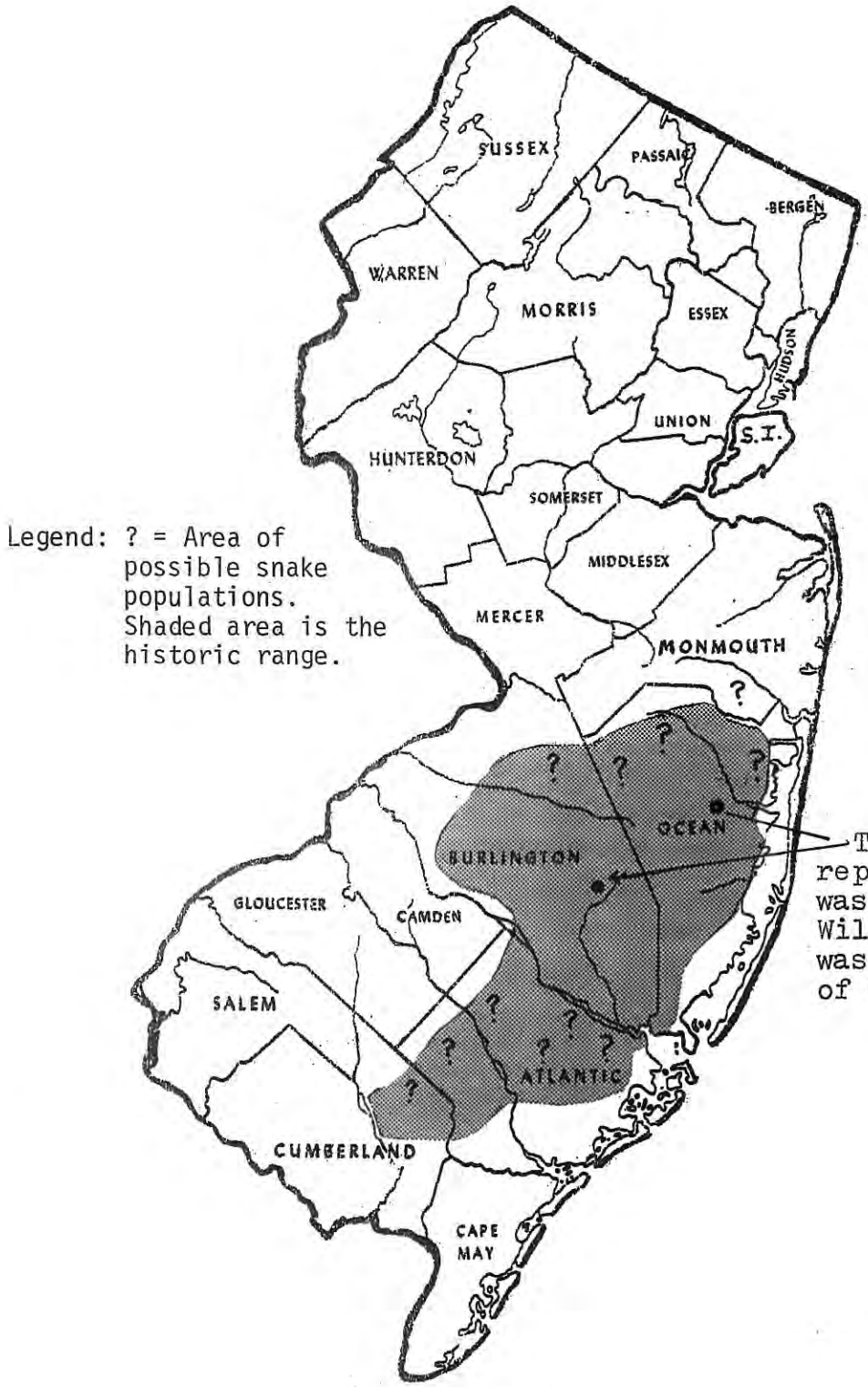
This would involve taking four male and eight female specimens from the wild, mating the pairs, hatching out the eggs, and releasing the young into areas where the corn snake population is low. The advantage to this method is that in a captive environment, variables such as temperature, photoperiod and food intake can be closely monitored and controlled (Heck and Zappalorti, 1985).

2. Breeding in Outdoor Pens Under Semi-natural Conditions:

This technique is similar to the preceding, except that the snakes would be kept in large 20 x 20 meters outdoor pens. For best results, it is advisable to have one male snake for every three females. The pens should be constructed of cement blocks, which have the advantage over wood of being "termite proof". The walls of the pen should extend 1/2 meter underground and 3 meters above ground, and should have the inside surfaces painted to render them smooth and escape-proof. An alternative to painting would be to line the walls with thin sheets of plastic. One end of the pen should have a hibernaculum constructed in it. For details on hibernation construction, see Figures 6 and 7.

The advantages to using this method are that the snakes would be experiencing natural changes in temperature, photoperiod, rainfall, etc. The snakes would also be able to enter into and out of hibernation in a more natural manner than if they were kept indoors. It is HA's opinion that the continuation of the experimental breeding program should be considered as a high priority project by NJDEP, in light of the serious decline in corn snakes noted over the past 20 years of our study.

Figure 1. The approximate known range of the Corn Snake, Elaphe guttata guttata



Legend: ? = Area of possible snake populations. Shaded area is the historic range.

The first corn snake reported from New Jersey was back in 1912 by William T. Davis. It was found in the vicinity of Chatsworth and Lakehurst.

After Kauffeld (1957); and Conant, pers. comm.(1977).

Figure 2. STATE OF NEW JERSEY

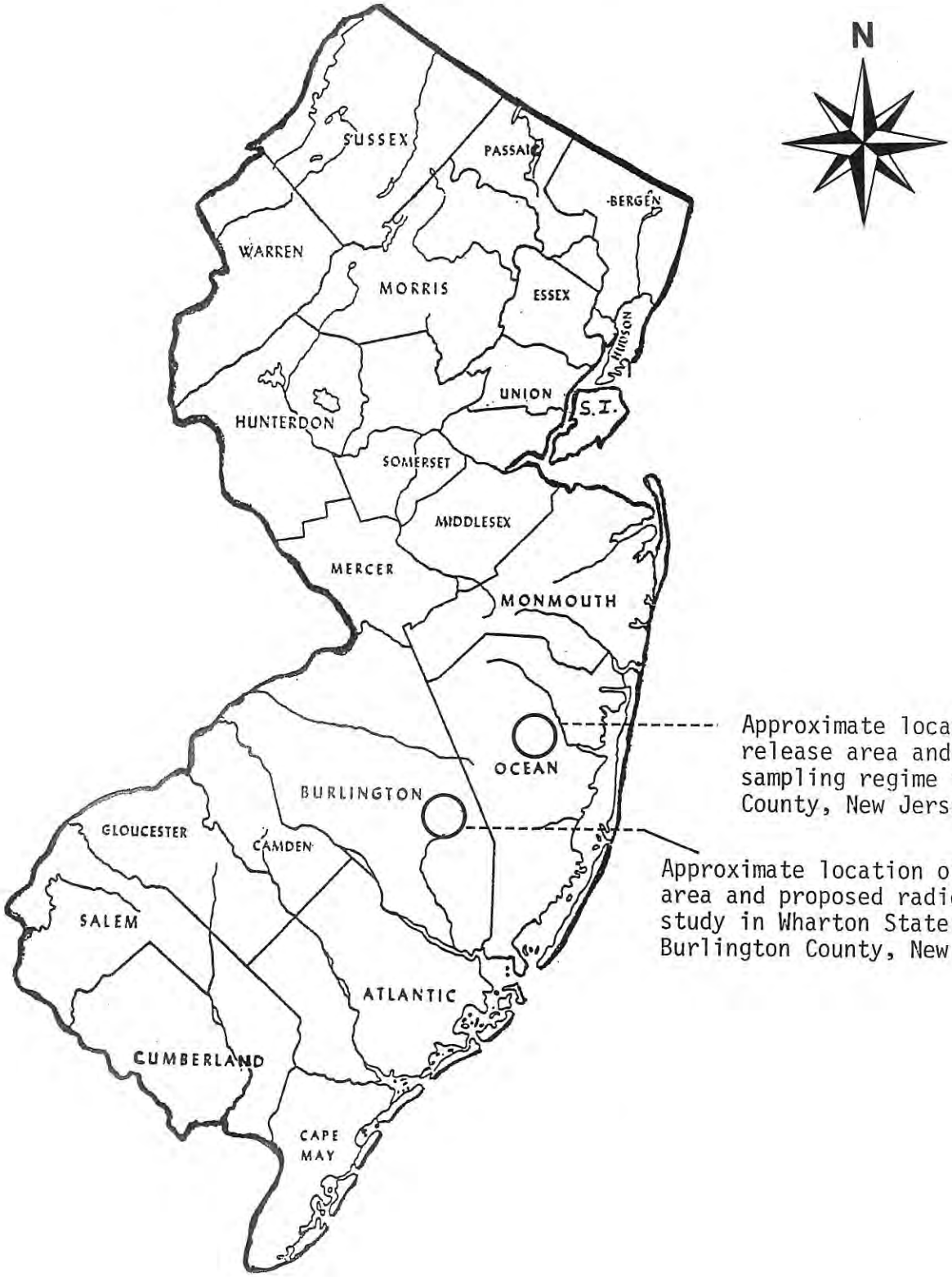


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Figure 3. Method of Branding Snakes for Identification

Modified from D.R. Clark, 1971. Branding as a marking technique for reptiles. Copeia

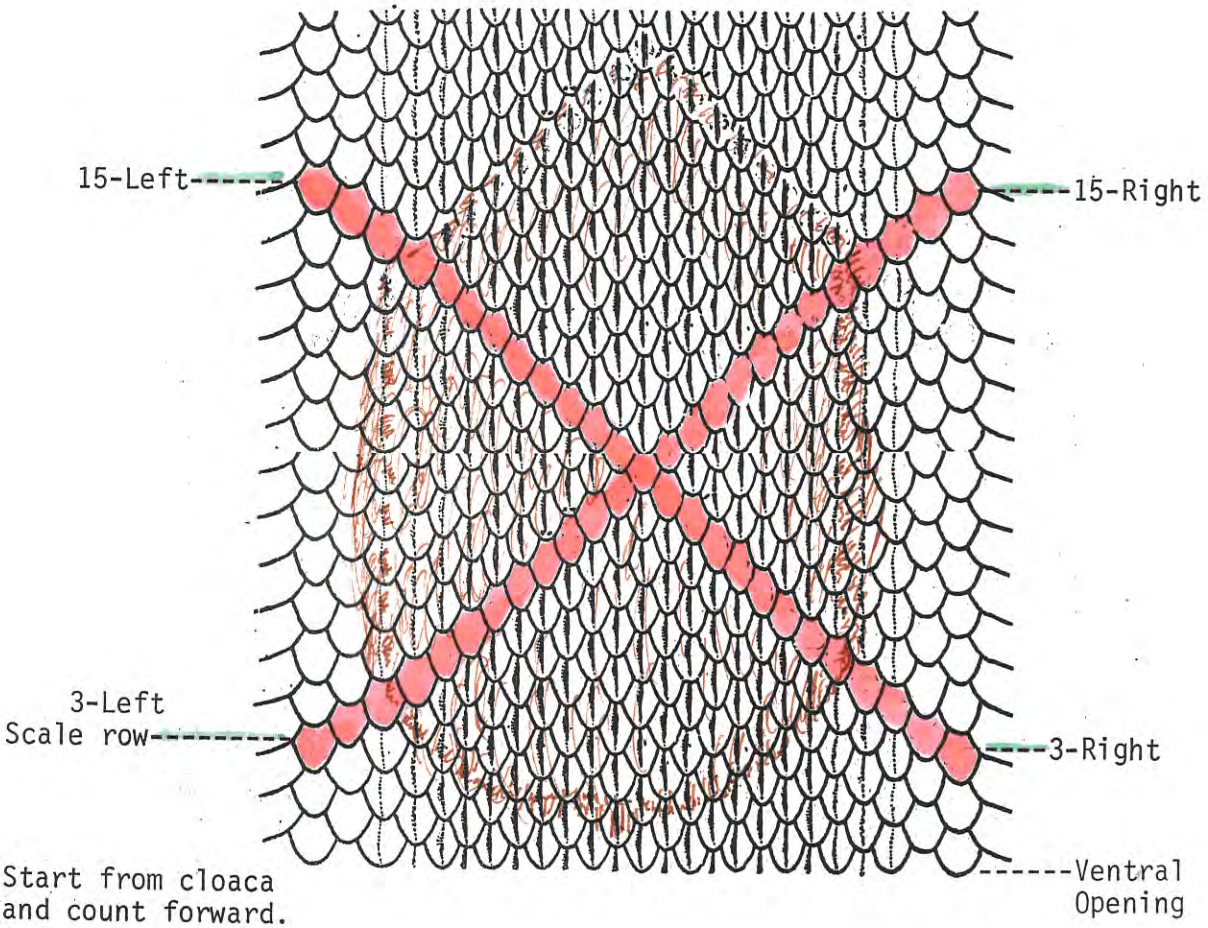

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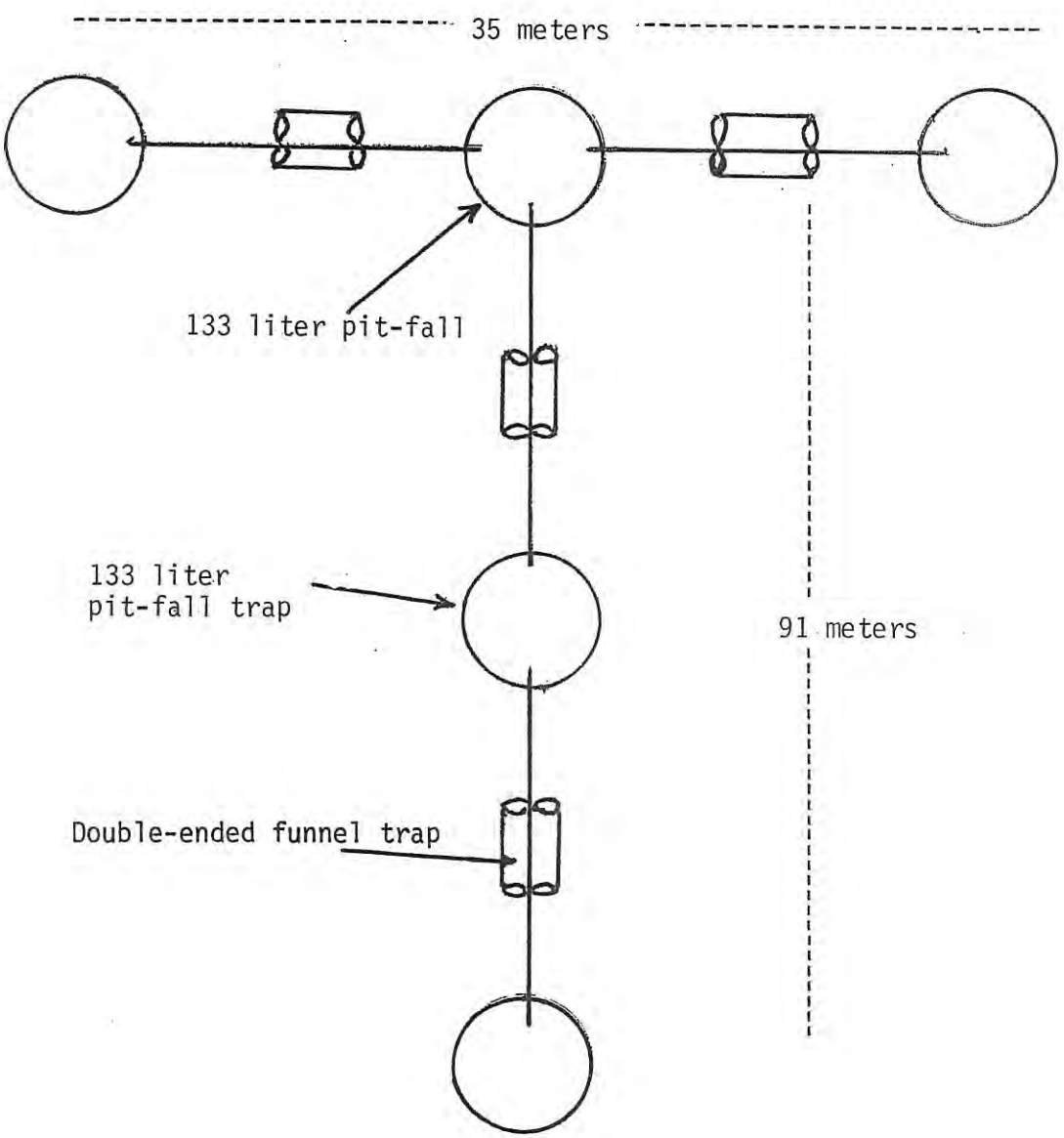
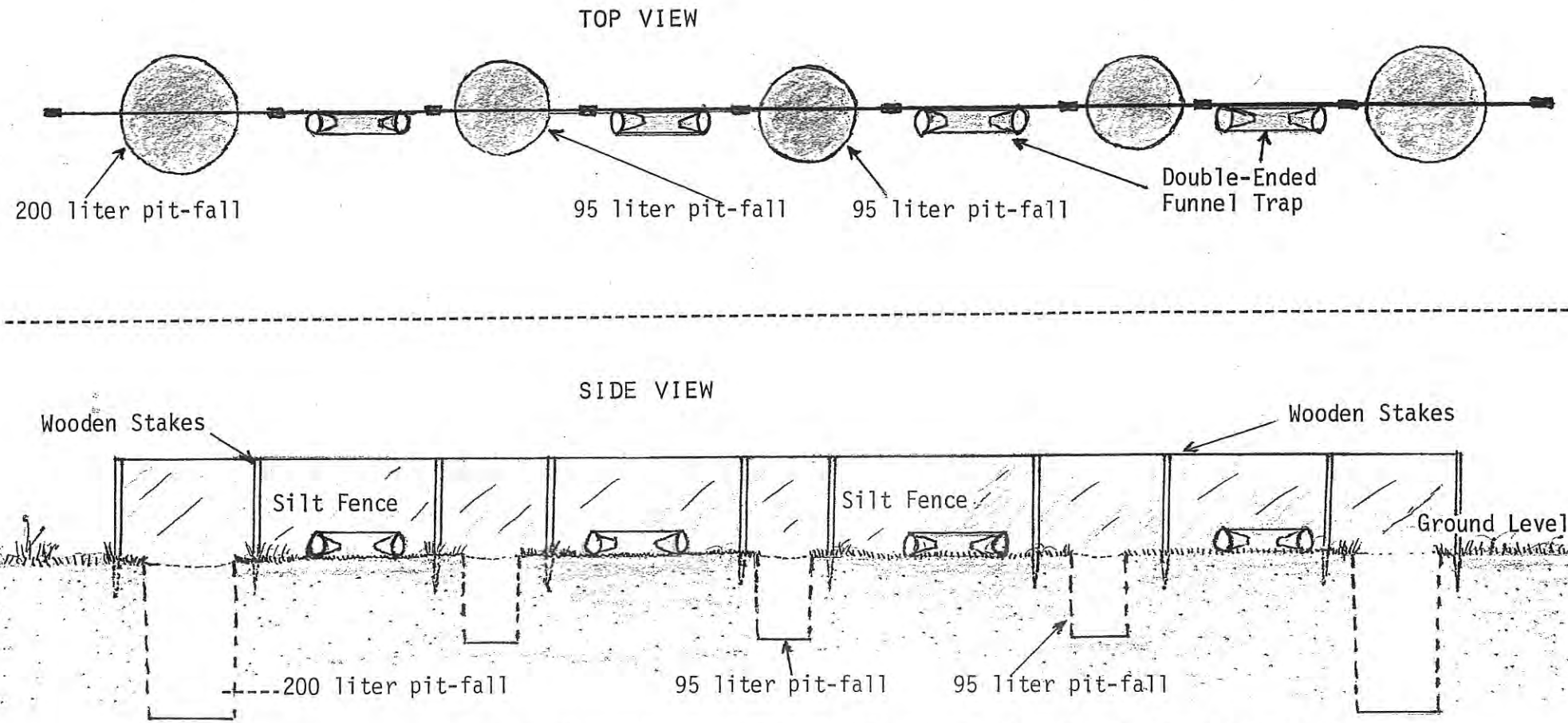
Figure 4. DIAGRAMATIC DRAWING OF "T" SHAPED DRIFT FENCE SHOWING TOP VIEW

(Not to Scale)



Source: Modified from Campbell and Christman, 1982; drawing by Peggy A. Vargas Herpetological Associates, Inc., 1988.

Figure 5. DIAGRAMMATIC DRAWING OF DRIFT-FENCE TRAPPING SYSTEM



Source: Herpetological Associates, Inc., 1987; Drawing by: Peggy A. Vargas
Modified from Campbell and Christman, 1982.

(Note: Drawing not to scale)

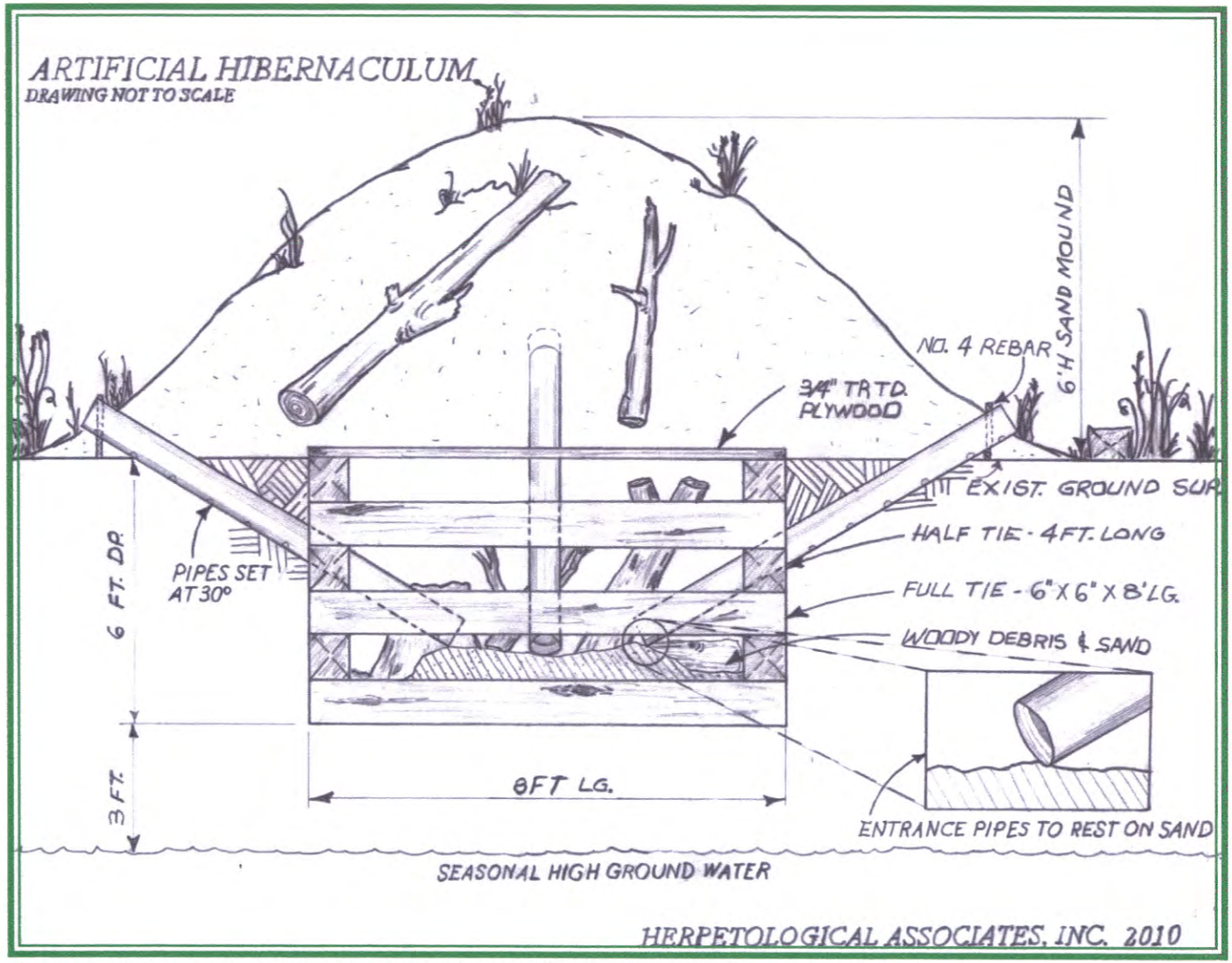


Figure 6. Diagrammatic drawing of an artificial snake hibernaculum, which serves as a winter den and/ or a summer shelter and shedding station. Snake use of these human-made dens has been documented for 30-years by R.T. Zappalorti.

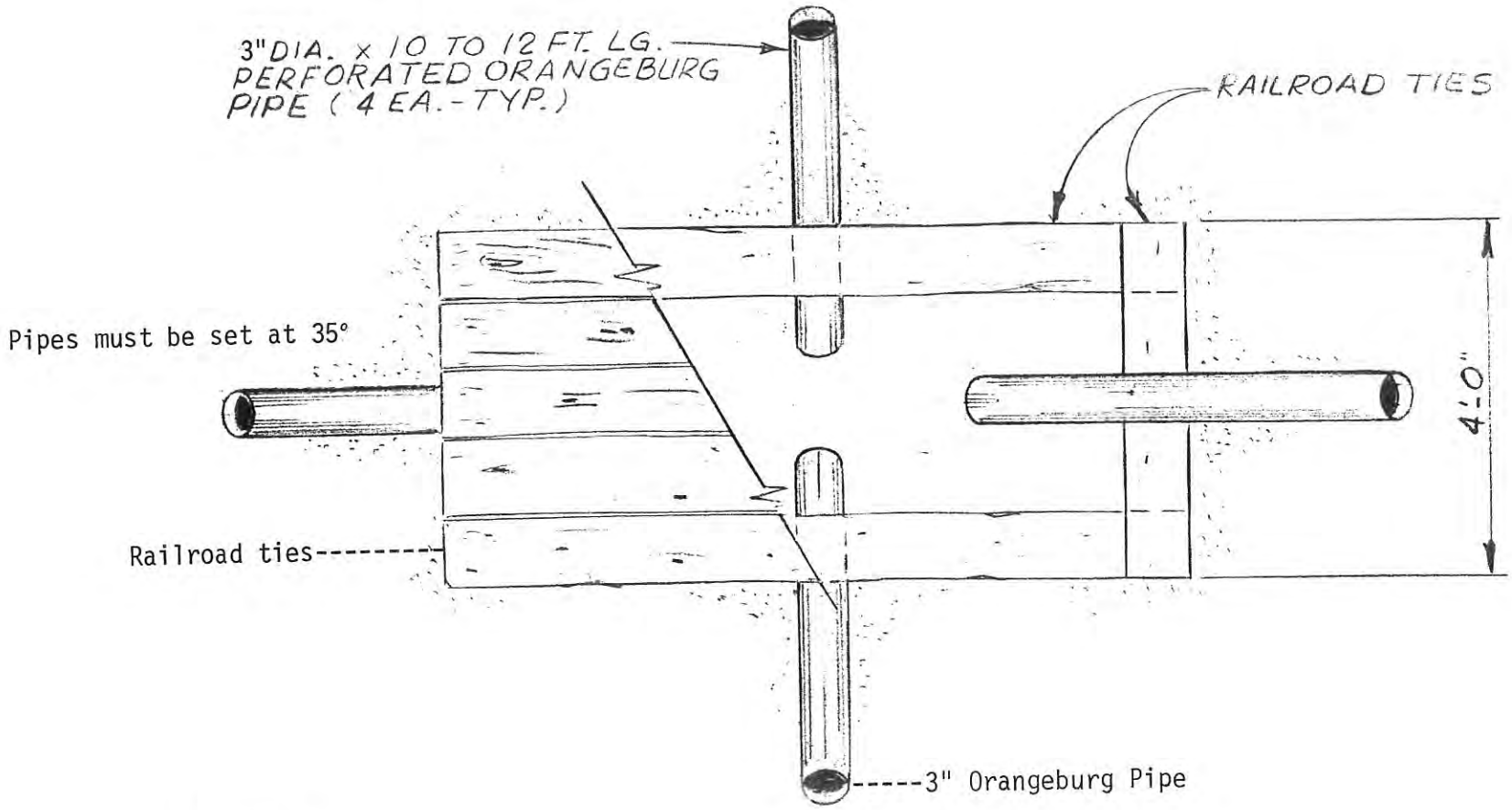


Figure 7.

PLAN BELOW SAND MOUND

(Top View)

Source: Herpetological Associates, Inc., 1987

TABLE 1 - COMBINED NUMBER HATCHLING CORN SNAKES FROM BURLINGTON AND OCEAN COUNTIES PRODUCED AND RELEASED FROM CAPTIVE BREEDING PROGRAM

YEAR BRED	NUMBER OF MALES	NUMBER OF FEMALES	TOTAL	SEX RATIO
1982	10	9	19	10:9
1983	13	12	25	13:12
1984	21	16	37	21:16
1985	24	24	48	24:24
1986	3	3	6	3:3
TOTALS:				
5 YEARS	71	64	N=135	71:64

NOTE: Males represent 53% of captive bred corn snakes, whereas 47% were females (100%).

Adults from both Burlington and Ocean Counties were used as breeding stock during 1984-1985. We were successful in mating 10 of the 12 females held in captivity. Of these, a total of 75 eggs were deposited. Table 2 presents a breakdown of these data.

Since the initiation of this captive breeding program in the spring of 1982, our efforts have produced a total of 135 captive bred corn snakes that were released back into the wild. A breakdown of the sex ratio and number of snakes by year is presented above in Table 1. Of the 135 released captive bred *E. guttata*, only 19 were recaptured from 1-3 times. Most others were not recaptured since they are highly fossorial and cryptic. Additional studies are needed in order to measure the survival rate in the wild.

Source: Heck and Zappalorti, unpublished data (1991).

TABLE 2 - NUMBER OF CLUTCHES PRODUCED FROM CAPTIVE BRED CORN SNAKES IN 1985

CLUTCH NUMBER	NO. OF EGGS IN CLUTCH	NO. OF EGGS THAT HATCHED	NO. OF MALES	NO. OF FEMALES	SEX RATIO	AREA WHERE HATCHLINGS RELEASED
*85.01	8	6	3	3	3:3	Ocean County
*85.02	6	4	2	2	2:2	Ocean County
*85.03	11	11	6	5	6:5	Ocean County
*85.04	6	6	4	2	4:2	Ocean County
*85.05	10	0	0	0	0:0	-none-
**85.06	10	5	1	4	1:4	Burlington Co.
**85.07	4	0	0	0	0:0	-none-
**85.08	9	6	4	2	4:2	Burlington Co.
**85.09	5	4	2	2	2:2	Burlington Co.
**85.10	6	6	2	4	2:4	Burlington Co.
TOTALS	75	48	24	24	24:24	(50% x 50% Sex Ratio)

NOTE: * = Adults from Ocean County, New Jersey stock.
** = Adults from Burlington County, New Jersey stock.

Source: HA records from captive breeding program, unpublished data, Heck and Zappalorti, 1988).

TABLE 3 - GROWTH OF CAPTIVE-BRED *Elaphe guttata* IN THE WILD (1983-1985)

FIELD NO.	SEX	DATE RELEASED	SIZE WHEN RELEASED	DATE RECAPTURED	SIZE WHEN RECAPTURED	GROWTH ATTAINED
83.91	Male	8/25/83	29.5 cm.	5/05/85	82.0 cm.	52.5 cm.
83.02	Female	9/13/83	27.2 cm.	5/10/85	77.5 cm.	50.3 cm.
83.03	Male	9/13/83	28.1 cm.	6/26/85	79.4 cm.	51.3 cm.
84.01	Male	8/22/84	26.9 cm.	9/04/85	66.0 cm.	39.1 cm.
84.02	Female	8/22/84	25.5 cm.	10/08/85	64.5 cm.	39.0 cm.
84.03	Female	9/07/84	24.6 cm.	11/08/85	56.5 cm.	31.9 cm.

Each snake was only recaptured once, so activity range data could not be estimated. All were individually remarked and released where they were found. Previous radio tracking studies (Zappalorti and Johnson, 1982-B) have shown that the approximate activity range of a single adult male corn snake was about 4.7 hectares (11.4 acres).

TABLE 4 - GROWTH OF RECAPTURED (CAPTIVE BRED AND WILD) CORN SNAKES IN THE WILD BETWEEN 1983-1986

FIELD NO.	DATE RELEASED	DATE RECAPTURED	AGE IN YEARS (TIME LAPSE)	GROWTH INCREMENT	SEX	INITIAL SIZE	FINAL SIZE	RATIO	*STUDY AREA
82.26	9/86	9/86	0.06	7.9	F	25.1	33.0	1.3	C.B.-c.
86.21	5/86	9/86	0.25	2.0	F	31.0	33.0	1.0	C.B.-c.
86.06	5/86	8/86	0.25	12.0	F	30.0	42.0	1.4	W.C.-B.
83.00	9/83	7/84	0.9	15.3	F	24.1	39.4	1.6	C.B.-c.
84.01	8/84	9/85	1.08	39.1	M	26.9	66.0	2.45	C.B.-c.
84.02	8/84	10/85	1.16	39.0	F	25.5	64.5	2.5	C.B.-c.
84.03	9/84	11/85	1.16	31.9	F	24.6	56.5	2.3	C.B.-c.
83.02	9/83	5/85	1.6	50.3	F	27.2	77.5	2.8	C.B.-c.
83.01	8/83	5/85	1.75	52.5	M	29.5	82.0	2.8	C.B.-c.
83.03	9/83	6/85	1.75	51.3	M	28.1	79.4	2.8	C.B.-c.
86.08	9/83	5/86	1.75	61.3	F	27.2	88.5	3.2	C.B.-c.
86.02	9/83	5/83	2.6	50.0	M	29.0	79.0	2.7	C.B.-c.
86.03	9/83	5/86	2.6	57.8	F	24.2	82.0	3.4	C.B.-c.
86.13	9/83	6/86	2.8	51.8	F	28.0	79.0	2.8	C.B.-c.
86.22	9/83	9/86	3.0	49.3	M	28.2	77.5	2.7	C.B.-c.

TABLE 4 (Continued)

FIELD NO.	DATE RELEASED	DATE RECAPTURED	AGE IN YEARS (TIME LAPSE)	GROWTH INCREMENT	SEX	INITIAL SIZE	FINAL SIZE	RATIO	*STUDY AREA
86.03	9/83	6/86	3.0	59.8	F	24.2	84.0	3.5	C.B.-c.
86.13	9/83	9/86	3.0	52.0	F	28.0	80.0	2.9	C.B.-c.
86.02	9/83	9/86	3.1	53.0	M	29.0	82.0	2.8	C.B.-c.
83.16	9/83	10/86	3.1	62.0	F	25.0	87.0	3.5	C.B.-c.
83.16	9/83	10/86	3.6	64.0	F	25.0	89.0	3.6	C.B.-c.
86.07	5/86	10/86	0.25	21.4	M	66.6	88.0	1.3	W.C.-B.
85.08w	9/85	3/86	0.8	17.6	F	86.4	104.0	1.2	W.C.-B.
85.09	9/85	10/86	1.1	2.8	F	80.2	83.0	1.0	W.C.-C.
85.00	7/85	8/86	1.1	2.0	M	89.5	91.5	1.0	W.C.-c.
85.08c	5/86	6/86	0.08	3.5	F	93.5	97.0	1.0	W.C.-c.
84.08	9/85	10/86	1.1	10.2	F	96.5	106.7	1.1	W.C.-c.

N = 26 Recaptured Elaphe guttata

*Legend for Study Areas: C.B.-c. = Captive Bred - Ocean County Study Area
W.C.-w. = Wild Caught - Burlington County Study Area
W.C.-c. = Wild Caught - Ocean County Study Area

Source: Herpetological Associates, Inc., 1988

TABLE 5 - MOVEMENTS OF CAPTIVE BRED CORN SNAKES IN WILD

FIELD NO.	SEX	RELEASE SITE	DISTANCE TO RECAPTURE SITE	COMPASS DIRECTION
83.01	Male	Den #3	2,237 ft.	320 degrees NW
83.02	Female	Den #3	40 ft.	190 degrees SW
83.03	Male	Den #3	245 ft.	200 degrees SW
84.01	Male	Den #4	620 ft.	20 degrees NE
84.02	Female	Den #4	730 ft.	30 degrees NE
84.03	Female	Den #4	671 ft.	330 degrees NW
N = 6	3:3	2 Sites	Mean 757 ft.	R = 40'-2,237'

NOTE: 7.4% of the original 81 snakes from 1983 and 1984.

TABLE 6 - FREQUENCY OF CAPTURE BY MONTH AND HOUR IN 1985 FOR *ELAPHE GUTTATA* IN BURLINGTON COUNTY, NEW JERSEY

TIME	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	PERCENT BY HOUR
0800-0859										0	
0900-0959		1		1		1				3	18.75%
1000-1059		1								1	6.25%
1100-1159			1							1	6.25%
1200-1259		1				1				2	12.50%
1300-1359		1				1				2	12.50%
1400-1459							1			1	6.25%
1500-1559						2				2	12.50%
1600-1659							1			1	6.25%
1700-1759		1								1	6.25%
1800-1859		1								1	6.25%
1900-1959		1								1	6.25%
2000-2059										0	
TOTALS:	0	7	1	1	0	5	2	0	0	N=16	100%
% BY MONTH:		43.75%	6.25%	6.25%		31.25%	12.5%			=	100%

NOTE: These 16 corn snakes were all newly captured within our stuy area in Burlington County. Of these, 3 were implanted with radio-trasnmitters and followed into hibernation. These data were gathered by four persons which represent 200 man-hours of effort.

TABLE 7 - FREQUENCY OF CAPTURE BY MONTH AND HOUR IN 1985
FOR ELAPHE GUTTATA IN OCEAN COUNTY, NEW JERSEY

TIME	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	PERCENT BY HOUR
0800-0859										0	
0900-0959										0	
1000-1059						1				1	7.1%
1100-1159										0	
1200-1259						1*	1			2	14.3%
1300-1359		2				1				3	21.4%
1400-1459										0	
1500-1559			1				1*			2	14.3%
1600-1659		1*		1				1*		3	21.4%
1700-1759		1								1	7.1%
1800-1859						1*	1*			2	14.3%
1900-1959										0	
2000-2059										0	
TOTALS:	0	4	1	1	0	4	3	1	0	N=14	100%
% BY MONTH:		28.6%	7.1%	7.1%		28.6%	21.4%	7.1%		=	100%

NOTE: Of the 14 corn snakes captured in Ocean County, 6 were recaptured captive-bred specimens. These represent 42% of our sample. May and September were the most productive months for capturing corn snakes. These data were gathered by five persons which represent 300 man-hours of effort. None were trapped in the drift fence.

* = A recaptured captive bred corn snake.

TABLE 8 - FREQUENCY OF CAPTURE BY MONTH AND HOUR IN 1985
FOR ELAPHE GUTTATA IN BURLINGTON AND OCEAN COUNTIES, NEW JERSEY

TIME	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	PERCENT BY HOUR
0800-0859										0	
0900-0959		1		1		1				3	10.0%
1000-1059		1				1				2	6.6%
1100-1159			1							1	3.3%
1200-1259		1				2*	1			4	13.3%
1300-1359		3				2				5	16.6%
1400-1459							1			1	3.3%
1500-1559			1			2	1*			4	13.3%
1600-1659		1*		1			1	1*		4	13.3%
1700-1759		2								2	6.6%
1800-1859		1				1*	1*			3	10.0%
1900-1959		1								1	3.3%
2000-2059										0	
TOTALS:	0	11	2	2	0	9	5	1	0	N=30	100%
% BY MONTH:		36.6%	6.6%	6.6%		30.0%	16.6%	3.3%		=	100%

NOTE: These data were gathered by five persons which represent 500 man-hours of effort.

* = A recaptured captive bred corn snake from Ocean County, New Jersey.

TABLE 9 - SMALL MAMMALS TRAPPED AT DRIFT FENCE IN OCEAN COUNTY, NEW JERSEY

COMMON NAME	SCIENTIFIC NAME	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL	PERCENT BY SPECIES	KNOWN IN CORN SNAKES DIET
**Virginia Oppossum	Didelphis virginiana	0	1	0	0	1	0	2	1.8%	NO
*Masked Shrew	Sorex cinereus	5	2	2	12	9	8	38	32.4%	YES
**Short-tailed Shrew	Blarina brevicauda	1	3	1	1	2	1	9	7.6%	NO
**Long-tailed Weasel	Mustela frenata	0	0	0	0	0	1	1	0.9%	?
*Eastern Mole	Scalopus aquatieus	1	0	1	0	1	0	3	2.6%	NO
*Eastern Cottontail	Sylvilagus floridanus	1	0	2	1	0	0	4	3.5%	NO
*Gray Squirrel	Sciurus carolinensis	0	1	0	0	1	0	2	1.8%	?
*Red Squirrel	Tamiasciurus hudsonieus	1	0	1	1	0	0	3	2.6%	?
*White-footed Mouse	Peromyscus leucopus	3	4	4	7	6	5	29	24.7%	YES

TABLE 9 - (CONTINUED)

COMMON NAME	SCIENTIFIC NAME	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL	PERCENT BY SPECIES	KNOWN IN CORN SNAKES DIET
*Red-backed Vole	Clethrionomys gapperi	2	3	1	1	3	0	9	7.6%	YES
*House Mouse	Mus domesticus	0	2	0	2	1	1	6	5.2%	YES
*Jumping Mouse	Zapus hudsonius	0	1	1	1	1	0	3	2.6%	YES
*Woodland Vole	Pitymys pinetorum	1	1	3	2	1	0	8	6.8%	YES
TOTALS:	13 Species	15	17	15	28	26	16	117	100%	7 Confirmed
% BY MONTH:		12.9%	14.5%	12.9%	23.9%	22.2%	13.6%	=	100%	3 Unknown

NOTE: * = Various small mammals were offered, both live and dead, to corn snakes in the laboratory during this investigation. A YES means the snakes ate the particular species on several occasions.

** = Potential predators to corn snake eggs, hatchlings and/or adults under natural conditions.

TABLE 10 - REPTILES TRAPPED AT THE OCEAN COUNTY DRIFT FENCE DURING 1985

COMMON NAME	SCIENTIFIC NAME	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL NO. CAPTURED	PERCENT BY SPECIES
*Northern Fence Lizard	Sceloporus undaltus hyacinthinus	4	3	2	1	2	1	13	48.1%
Eastern Garter Snake	Thamnophis sirtalis	0	1	0	0	1	0	2	7.4%
Northern Water Snake	Nerodia sipedon	0	0	0	0	1	0	1	3.7%
Eastern Hognose Snake	Heteroden platyrhinos	1	0	0	0	2	0	3	11.2%
Northern Black Racer	Coluber constrictor	0	1	0	0	0	1	2	7.4%
Northern Pine Snake	Pituophis melanoleucus	1	0	0	0	0	0	1	3.7%
Southern Ringneck Snake	Diadophis punctatus	0	1	0	0	1	0	2	7.4%

TABLE 10 - (CONTINUED)

COMMON NAME	SCIENTIFIC NAME	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL NO. CAPTURED	PERCENT BY SPECIES
Eastern Worm Snake	Carphophis amoenus	0	1	1	0	0	0	2	7.4%
Eastern Box Turtle	Terrapene carolina	0	0	0	0	1	0	1	3.7%
TOTALS:	9 Species	6	7	3	1	8	2	27	100%
% BY MONTH:		22.2%	25.9%	11.2%	3.7%	29.6%	7.4%	=	100%

NOTE: * = Known in the diet of hatchling and adult corn snakes. Live and dead fence lizards were fed to snakes in the laboratory for the duration of this investigation. It was the most common reptile captured and observed in the Ocean County study area representing 49% of our sample.

TABLE 11 - AMPHIBIANS TRAPPED AT THE OCEAN COUNTY DRIFT FENCE DURING 1985

COMMON NAME	SCIENTIFIC NAME	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL NO. CAPTURED	PERCENT BY SPECIES
Red-spotted Newt	Notophthalmus viridescens	0	1	0	1	0	0	2	1.4%
Red-backed Salamander	Pithodon cinereus	2	1	0	0	3	1	7	5.2%
Northern Red Salamander	Pseudotriton ruber	2	2	0	0	1	1	6	4.4%
Northern Spring Peeper	Hyla crucifer	3	1	0	0	1	2	7	5.2%
Pine Barrens Treefrog	Hyla andersonii	2	1	0	0	2	0	5	3.8%
Fowler's Toad	Bufo woodhousei fowleri	18	16	8	6	13	3	64	47.4%
Spadefoot Toad	Scaphiopus holbrooki	1	1	0	0	2	0	4	2.9%
Leopard Frog	Rana sphenocephala	1	2	1	0	1	0	5	3.8%
Carpenter Frog	Rana virgatipes	0	0	0	0	2	0	2	1.4%

TABLE 11 - (CONTINUED)

COMMON NAME	SCIENTIFIC NAME	MAY	JUN	JUL	AUG	SEP	OCT	TOTAL NO. CAPTURED	PERCENT BY SPECIES
Green Frog	*Rana clamitans melanota*	7	5	2	1	8	5	28	20.7%
Bullfrog	*Rana catesbeiana*	2	1	0	0	1	1	5	3.8%
TOTALS:	11 Species	38	31	11	8	34	13	135	100%
% BY MONTH:		22.8%	22.9%	8.2%	5.9%	25.2%	9.6%	=	100%

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HA File No. 88.13

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