HA File No. 2002.13

A Standardized Protocol for Sampling Rare Snakes in the New Jersey Pine Barrens

Timber Rattlesnake (*Crotalus horridus*)

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to

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❀ TABLE OF CONTENTS ❀

FOREWORD

This document was written under a cooperative agreement between the Pinelands Preservation Alliance (hereafter PPA) and Herpetological Associates, Inc. (hereafter HA), for use by the Pinelands Commission and the New Jersey Department of Environmental Protection, Division of Fish and Wildlife. It was prepared as a teaching guide for standardizing the methodologies that should be used when conducting presence or absence surveys for the three legally protected Pine Barrens snake species. State agencies may wish to distribute this document to environmental consulting firms, engineering firms, non-profit conservation organizations, university, college, and high school teachers or biologist who are interested in conducting thorough **Phase I** and **Phase II** presence or absence surveys for rare snakes. This booklet provides various proven sampling methods that HA has used for the past 25-years. More important, these methods can be duplicated and replicated by other scientists and biologists conducting rare snake surveys. The three target snake species are: timber rattlesnake (*Crotalus horridus*), corn snake (*Pantherophis guttata*), and northern pine snake (*Pituophis melanoleucus*). This document was peer reviewed by several herpetologists in the scientific community before being submitted to the Pinelands Commission and NJDEP. This protocol is intended to establish minimum standards to be used for all rare snake surveys in the Pine Barrens. These recommended sampling methods will help bring greater reliability, stability and quality control to the Pinelands Commission' and NJDEP's development review process.

This document provides the following information:

- ❀ Descriptions of the natural history, behaviors and habitat needs of the three target snake species in the Pine Barrens;
- ❀ Methodologies to conduct a **Phase I** habitat evaluation of a property as to the likelihood of it being suitable habitat for one or more of the three target snake species;
- ❀ Methodologies for conducting an intensive **Phase II** survey to determine whether any of the three target species are present on, or use a given portion of the subject property;
- ❀ Specific techniques that must be used, and the best season(s) or time period(s) over which such surveys should be conducted;
- ❀ Methodologies for determining the critical habitat(s) of local snake populations of these target species, once it is determined that one or more is present on the study parcel; and
- ❀ The manner in which data should be recorded in the field and presented in a final report; and
- ❀ References and other scientific publications or sources for information about the three target snake species and the relevant survey methods.

INTRODUCTION

In his book “Snakes and Snake Hunting (1957),” the late Carl F. Kauffeld stated: “the Pine Barrens does not yield it’s snakes easily.” Anyone who has tried to consistently find snakes in the Pinelands knows how true Kauffeld’s statement was. Collecting and monitoring fossorial reptiles presents a unique set of challenges. Because so much of their life is hidden, large gaps exist in our knowledge of the behavior and ecology of fossorial species (Mattison 1995). Sampling methods must be efficient at finding the target species while producing little disruption in their habits. A working knowledge of the life history, thermal requirements, and activity patterns of the species to be studied is essential (Davis et al. 1998). Knowledge such as the type of habitat a particular reptile species selects on an hourly, daily, or seasonal basis is important information. Being able to predict when to search or trap for the target species may greatly enhance one’s capture results. Complications affecting capture success include: weather/climatic conditions, avoidance behavior by the target species, daily and seasonal activity patterns, and the experience and skill of personnel (Crosswhite, Fox and Thill 1999). Environmental conditions such as temperature, precipitation, soil moisture, humidity, light intensity, wind, and season also have strong influences on reptile and amphibian activity patterns (Vogt and Hine 1982). Unsuitable weather conditions may lead to decreased terrestrial behavior, markedly reduced activity, shifts in habitat types used, and/or estivation.

If a parcel of land is small (less than 5-acres) and close to existing development the scale of a study can be limited in scope, because the target species may not survive in such a small, disturbed area. Nevertheless, a **Phase I** habitat evaluation should be done in conjunction with appropriate sampling methods. The use of more than a single sampling method is preferred, and should be utilized if the study area is larger than 10-acres. Larger tracts (greater than 25-acres) require that the entire potential habitat(s) on site be surveyed during the active Spring, Summer, and Fall seasons (Corn and Bury 1990). Vogt and Hine (1982) found that repeated short sampling efforts during the activity season resulted in the most accurate species composition and abundance estimates. Use of several sampling techniques which take into account the various aspects of an animal’s biology often result in the best assessment of species abundance and richness (Gibbons and Semlitsch 1981). This protocol provides instructions on how to effectively sample secretive reptiles, with particular emphasis on New Jersey’s three legally protected snake species:

- Timber Rattlesnake (*Crotalus horridus*) - State Status: Endangered
- Corn Snake (*Pantherophis guttata*) - State Status: Endangered
- Northern Pine Snake (*Pituophis melanoleucus*) - State Status: Threatened

Many of the citations and sampling examples provided in the literature cited section of this protocol are not specifically from studies performed on snakes, but the techniques and information are of value nevertheless. The techniques used to observe, survey, and capture lizards, turtles, and amphibians can in many cases be directly applied to finding and capturing snakes in the Pine Barrens of southern New Jersey.

LIFE HISTORY ACCOUNTS

TIMBER RATTLESNAKE

Description

Figure 1. An adult male timber rattlesnake exactly as it was found basking near the entrance of its hibernaculum in late April. A recent forest fire had burned all the vegetative cover from the stream corridor, allowing the snake to be easily seen. This specimen is from Greenwood Forest Wildlife Management Area, Lacey Township, Ocean County, New Jersey. Photo by Pete Mooney, HA Staff.

The timber rattlesnake is classified taxonomically into the class *Reptilia*, order *Squamata*, suborder *Serpentes*, family *Viperidae*, subfamily *Crotalinae*, genus *Crotalus*, species *horridus*, and subspecies *horridus* (Linnaeus, 1758). This heavy-bodied venomous snake has an average length of 90-152 cm (36-60 inches), with a maximum recorded length of 189.2-cm (74-inches; Conant and Collins, 1991). This snake is highly variable in color throughout its range. In the Northeast, the two common color phases are yellow and black, with the yellow phase being much more prevalent in the Pine Barrens of New Jersey.

These snakes display black or dark brown cross bands, often v-shaped, on a ground color of yellow, light brown, or grey. Towards the head, the bands are often broken into lateral and dorsal blotches. As its name suggests, the snake has a conspicuous rattle on its tail. Scales are keeled and the anal plate is single.

Status

Global Rank	G5T5Q	Globally secure, but rare in parts of its range
State Rank	S2	Imperiled in state with 6-20 occurrences
Federal Status	None	Being considered to receive threatened status
State Status	E	Endangered - Survival in N.J. is in immediate danger

Range

The timber rattlesnake ranges as far north as northern New York in the east and southeastern Minnesota in the west. It ranges eastward to western Massachusetts, south to northern Florida, and west to eastern Texas. This snake is absent from much of the area surrounding the Great Lakes, including the northern portions of Indiana, Illinois, and Ohio (except for small, isolated populations). In New Jersey, there is a disjunct population located in the Pine Barrens; the next nearest population occurs in the mountainous region of northwestern New Jersey (Conant and Collins, 1991).

Habitat and Life History

The timber rattlesnake is 1 of 2 venomous snakes found in New Jersey. The other, the northern copperhead, is found only in the northern part of the state. During September, when the day length shortens and the evenings begin to cool, timber rattlesnakes make their way to their hibernation sites. Timber rattlesnakes in the Pine Barrens enter hibernation in mid- to late October, while those of northern New Jersey and New York may enter several weeks earlier due to the cooler temperatures of these areas. In general, Brown (1992) found that emergence and ingress of a population of timber rattlesnakes near the northern limit of their range was closely correlated to a maximum daily air temperature of 15^0 C. The disjunct population of timber rattlesnakes in the Pine Barrens of southern New Jersey are known to hibernate along cedar streams rather than in rocky outcroppings used by their northern New Jersey relatives. In the coastal plain, the absence of rocky outcroppings necessitates a different hibernation strategy (Zappalorti and Reinert, 1989; Reinert and Zappalorti 1988). The Pine Barrens rattlesnakes position themselves in underground flowing water at the base of cedar trees, where the root system of the trees provides protection. The constantly flowing water provided by a nearby stream prevents the snakes from freezing, enabling these ectothermic animals to remain relatively close to the surface of the ground. Warming water temperatures stimulate the snakes to emerge from hibernation, with first emergence occurring in mid to late April. This strategy is important because timber rattlesnakes, both in the Pine Barrens of southern New Jersey and in the mountainous regions of the northeast, are not adapted for burrowing; while the Pine Barrens rattlesnakes use underground moving water or springs to prevent freezing, snakes in mountainous areas use existing fissures in the rocks to position themselves below the area where the ground is subject to freezing. Activity range data for radio-tracked timber rattlesnakes and neonate scent-trailing behavior in the Pine Barrens was published in the literature by Howard Reinert and Robert Zappalorti (Reinert and Zappalorti,1988a and 1988b). These two papers should be read by anyone conducting timber rattlesnake surveys in southern New Jersey.

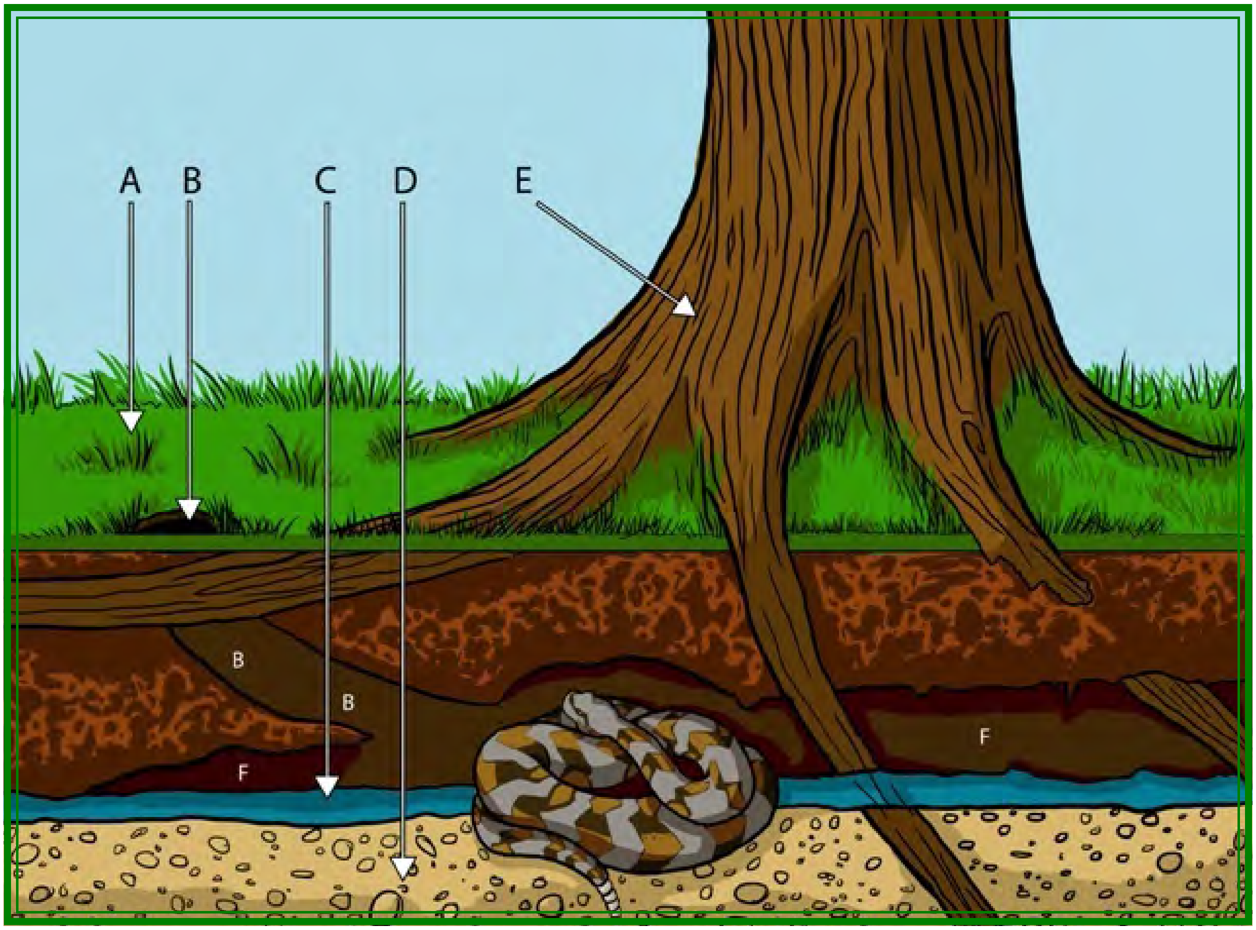
Dens in the mountainous regions of the northeastern United States are generally located in or near granitic escarpments and ledges which have accumulations of talus. Elevations of the dens are typically between 150 and 390 meters (500-1300 feet; Brown, 1993). Southerly exposures are often chosen, maximizing solar heating during the winter and providing excellent basking locations when the rattlesnakes emerge from hibernation in the spring. Increased canopy closure at or near these timber rattlesnake dens has been noted by some researchers to decrease the value of those dens for rattlesnake use (Brown, 1993). Direct sun exposure is necessary for snakes and other ectothermic, or "cold-blooded," animals for a variety of biological and behavioral reasons. Maintaining a warm body temperature through basking in warm or sunny areas, known as thermoregulation, promotes efficient digestion of meals, adequate agility and speed for defense or flight, and a proper gestation temperature for successful development of the young. The excessive shading, caused by increased tree and shrub growth over time, eliminates many basking areas surrounding a den, and may ultimately force the snakes to find more suitable areas along road edges (Reinert and Zappalorti, 1988) or near human dwellings. The abandonment of such dens has been observed on numerous occasions by several researchers (Brown, 1993); however, the importance of den shading is still a subject of debate.

Figure 2. A portrait of a yellow phase male timber rattlesnake (*Crotalus horridus*) as found coiled on the forest floor during a radio-tracking investigation (Field Number 95.03). Note the vertically elliptical eye-pupil and the heat-sensing facial-pit, located between the eye and the nostril. The boldly keeled dorsal scales are also quite visible in this photograph. Photo by Paul Metcalf, Herpetological Associates, Inc.

A second point of view argues that the time of rattlesnake emergence from hibernation occurs when few leaves are on the trees; therefore the shading over of dens is of little importance. In addition, fallen leaves from shade trees covering dens may act as an important insulating layer in years of low snowfall (Reinert, personal communication, 1994). The snakes in both areas of New Jersey do not remain in their denning areas for long, but quickly migrate to active season foraging areas.

Diet

Small rodents and chipmunks are hunted with the aid of a keen sense of smell as well as infrared or heat sensing pits located on the snake's face. Timber rattlesnakes are not active hunters, however, but are termed “sit and wait predators.” This name is derived for their strategy of positioning themselves along mammal runways (often for days at a time) and waiting for prey to run past. Once potential prey comes within close proximity to the snake, a strike is made and venom injected. The snake releases the prey immediately and then follows the scent of the dying animal, which may have wandered several feet away. After consuming the meal, as with other snakes, the timber rattlesnake remains sedentary in a warm location until digestion is complete.



An artist rendition of a Timber Rattlesnake hibernaculum in the Pine Barrens of southern New Jersey. The snakes typically hibernate along the edges of a flowing stream or spring. A = Surface vegetation and *Sphagnum moss*; B = the entrance to the chamber; C = flowing water; D = the sand and gravel substrate; E = a living cedar tree; and F = the underground chamber and air space where the snake spends the winter in hibernation. This drawing is based on actual observations by Reinert and Zappalorti, 1988.

Reproduction

Mating takes place in late July, August, and early September, occurring annually for males, whereas females are receptive only every few years. Rattlesnakes have been reported to reach sexual maturity at four to eleven years of age, although an age of nine to eleven years is more typical in the northern portion of its range (Galligan and Dunson, 1979; Martin, 1988, Brown, 1993). Brown (1991) found that 90% of the timber rattlesnakes he studied over an eleven year period attained an age of first reproduction at eight to eleven years in northeastern New York, while the remaining 10% had an age of first reproduction at seven years. In addition to this late age of reproduction, the frequency of reproduction is only once every two years for rattlesnakes in the Pine Barrens of southern New Jersey (Zappalorti, personal observation).

The frequency of reproduction has been reported to be even lower in mountainous areas of the northeastern United States, occurring only every three to four years in a New York rattlesnake population (Brown, 1991 and 1993). These factors combine to create a relatively low reproductive rate for timber rattlesnakes, leading to a slow recovery of depleted populations. Gravid females carry their offspring for a full year before giving birth in August or September of the year following mating. Timber rattlesnakes are live bearing; the female will give birth to from 4 to 21 snakes, each about a foot long. Although fully equipped to fend for themselves, the survival rate of neonate snakes is typically low, and the overall contribution of new snakes to the population is important. This is particularly true of a long-lived, slow-reproducing species, such as the timber rattlesnake. The overall consensus of timber rattlesnake researchers is that there is a definite population decline in populations over most of the rattlesnake's range. Stechert (1992) found that in a sample of 139 dens in New York, 76% were in various stages of depletion, while only 5% contained large populations of rattlesnakes. Martin (1982) stated that many long-term observers believe that most timber rattlesnake dens are at 15% to 20% of the level which they were at forty years ago. Numerous factors have led to population declines over the years, although the major cause is most likely linked to habitat disturbance and destruction.

Stechert (1992) and Brown (1993) outlined the factors contributing to the decline of rattlesnake populations in New York and northern New Jersey. These include:

1. Rural housing developments in the immediate vicinity of rattlesnake dens, or near the snakes' primary basking and summer foraging areas.

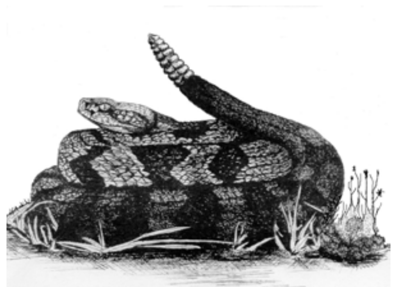
2. Illegal snake hunting by a few major collectors and a host of amateur herpetologists.

3. Logging and stone quarrying operations in the immediate vicinity of rattlesnake dens.

In the Pine Barrens of southern New Jersey additional problems include:

4. Clear-cuts or logging of cedar trees near rattlesnake dens.

5. New paved roads within the rattlesnake’s home range, or more traffic on old roads.



CORN SNAKE

Description

The corn snake, or red rat snake, is classified taxonomically into the class *Reptilia*, order *Squamata*, suborder *Serpentes*, family *Colubridae*, subfamily *Lampropeltinae*, genus *Pantherophis (formerly Elaphe)*, species *guttata*, and subspecies *guttata* (Linnaeus, 1766). This snake usually obtains a length of 76-122 cm (30-48 in.), although according to Conant and Collins (1998), a record specimen was measured to be 72 inches (182.9 cm). The coloration of this species is highly variable over its range, varying from a ground color of gray to orange with red or orange dorsal and lateral blotches, each boldly bordered by black. The scales are lightly keeled (as opposed to a pine snake or timber rattlesnake who have boldly keeled scales) and the anal plate is divided (**Figures 3** and **4**)

Figure 3. Corn snakes (*Pantherophis guttata*) are also know as red rat snakes because of their bright red, orange, yellow, and black dorsal blotches. Being a highly fossorial species, they spend most of their time hidden under leaf litter on the forest floor, or in the underground burrows of small mammals. Photo by R. T. Zappalorti, Herpetological Associates, Inc.

Status

Global Rank	G5	
State Rank	S1	Critically imperiled in state; 5 or fewer known populations
Federal Status	None	N/A
State Status	E	Endangered

Range

This snake ranges from Ocean County, in southern New Jersey to the Florida Keys, and west into Louisiana and Tennessee. It is absent from southern Virginia and northern North Carolina, and isolated populations exist in Kentucky (Conant and Collins 1998).

The History of Corn Snakes in New Jersey

The late William T. Davis, Curator of Science at the Staten Island Museum in New York, was the first biologist to describe the corn snake in Chatsworth, Burlington County, New Jersey (Davis, 1912). Then several years later in Ocean County, he found a specimen tangled in the wheels of a baby carriage right on Main Street in the town of Lakehurst. Davis published his finding in the Staten Island Museum Proceedings. Corn snakes or red rat snakes have a limited occurrence in Ocean and Cumberland Counties, where they exist only in disjunct populations within its historic range. However, the largest known population of this species occurs in Burlington County as shown by past surveys HA and Professor Otto Heck (College of New Jersey, Trenton) have conducted for the NJDEP.

None have been found in Atlantic County since 1928, when Carl Kauffeld found one near the Hammonton Race Track, even though HA spent a considerable amount of time searching for this "endangered" species in Atlantic County. HA staff searched all suitable habitat types such as upland pitch pine forests with Lakehurst soil, upland pine-oak forest along railroad tracks, and in pitch-pine lowland forest. Micro-habitats such as old log and brush piles, railroad ties, trash piles, and flat sheet metal or plywood on the ground surface were systematically searched. Although HA has periodically searched over the past 20 years, no corn snakes have been captured or observed in Atlantic County. Since there is so much habitat still available in Atlantic County, corn snakes may still remain, but probably in small numbers.

A population of corn snakes was found by HA in Cumberland County, on both sides of the Maurice River. The first specimen found was a road-killed gravid female with 6 eggs. This corn snake was found on June 4, 1990, on the west side of the river and was preserved as a voucher specimen. This corn snake measured 135.6 cm in total length. This important find suggested that a small population of corn snakes occurred in the oak - pine forest of Cumberland County, west of the Maurice River. Subsequently, several more were found on the east side of the river as well, between 1994 and 1998. Three major populations are know from New Jersey in Burlington, Cumberland, and Ocean Counties (Conant and Collins, 1998; Zappalorti and Merli, 1979; Zappalorti and Johnson, 1982). There is an historic record from Atlantic County, but to HA's knowledge, none have been seen or confirmed since 1928 (Kauffeld, 1957).

Habitat and Life History

Figure 4. A typically colored and patterned adult female corn snake from the Crossley area of Western Berkeley Township, Ocean County, New Jersey. Their coloration blends perfectly with oak leaves and pine needles on the forest floor. Photo by Robert T. Zappalorti, Herpetological Associates, Inc.

This is a highly fossorial species. Most often found in brush fields, pine barrens, open deciduous woodlands, rocky ledges (in western North Carolina), or trash dumps and old buildings. Corn snakes are also good climbers and can be found in trees and bushes. The authors observed a radio-tracked corn snake resting in a standing hollowed-out dead pine tree for one week. They also use fallen hollow logs on the forest floor. Hollow railroad ties are a favorite hiding place because they offer good ground cover, warmth from the sun, and protection from predators. Their bold coloration and cryptic pattern provides excellent camouflage against the brown and rust colored Pine Barrens leaf litter in which they often conceal themselves, making them nearly impossible to locate in undisturbed woodlands. Historically the New Jersey corn snake is known from Atlantic, Burlington, Cumberland, and Ocean Counties (Roger Conant, personal communication); however, more recently they have only been confirmed by HA and the NJDEP in Burlington, Cumberland, and Ocean Counties. Chatsworth, in Burlington County is the type locality for the corn snake in the New Jersey Pine Barrens, but it was subsequently found in the town of Lakehurst, in Ocean County. Lakehurst is the northern limit of its range.

In New Jersey, the corn snake may hibernate in communal dens with pine snakes and black racers, or alone in non-communal dens. HA's radio-tracking observations suggest that they appear to have less fidelity to a particular hibernaculum than pine snakes. Emergence from hibernation occurs in late March or early April, but HA has seen corn snakes basking on the surface during winter warm spells (air temperatures above 16 degrees C.) in January, February, and March (Otto Heck, personal communication). We once had an adult female basking in a low blueberry bush near her den entrance on March 18. She was elevated 12 cm off the ground, above dried oak leaves, thus maximizing solar radiation from above and below her body. Her cloacal temperature was 20 degrees C., even though the air temperature was only 16.5 degrees C. Corn snakes will hibernate in both natural dens such as tree stump holes or abandoned mammal burrows, or use human-made den structures that were designed and developed by HA specifically as artificial refugia (Zappalorti and Reinert 1994).

Reproduction

Courtship and mating occur in April or May. Egg laying occurs approximately 1.5 to 2 months after copulation, generally in June or very early July. Based upon HA's radio-tracking observations of gravid females, egg laying sites were always in open (canopy free), sunny areas such as fields, railroad beds, utility transmission line right-of-ways, or the edges of sand roads. Micro-habitat of the nest sites were in mole tunnels, rotting stump holes, hollow logs, or railroad ties (Zappalorti and Heck 1988). The average clutch size of an adult female is 8 eggs (range 4 to 16 eggs). The young hatch approximately two months later, and are typically lighter in color than the adults.

Diet

Corn snakes are non-venomous constrictors. Hatchlings and young corn snakes will eat lizards. There are 3 species of lizards in the Pine Barrens (i.e., northern fence lizard, five-lined skink, and ground skink). Since corn snakes are nocturnal in the summer they are able to capture the lizards at night when they are sleeping under logs or bark. Adults feed primarily on warm-blooded prey including mice, voles, shrews, moles, and small rats. However, birds and their eggs are also eaten. We once found an adult male corn snake eating quail eggs from a nest. We observed the snake eat one egg before it crawled off, and when we examined it, there were 5 more eggs in its stomach. This observation was made in June 1994 in Cumberland County. They are constrictors and feed on a variety of small mammals and birds, mostly rodents, but hatchlings and juvenile corn snakes also eat lizards and frogs.

Predators

In the New Jersey Pine Barrens natural predators include many mammals (*i.e.*, domestic cats, coyotes, foxes, skunks, weasels, raccoons, opossums, and shrews). Birds of prey such as red-tailed hawks, Cooper's hawks, sharp-chinned hawks, and owls also take corn snakes when they are seen crawling on the surface. Other snakes such as king snakes, coastal plain milk snakes, and black racers will capture and eat young corn snakes, especially hatchlings. Northern scarlet snakes will eat their eggs when they find them. Many are killed while crawling across paved or sand roads. Housing, commercial construction, and new roads cause habitat loss. Defense is largely restricted to tail vibration, rapid striking, hissing, and biting, although once handled they may tame down very quickly.

Results of Corn Snake Radio-tracking

When compared to pine snakes, corn snake captures were relatively low over the past 25 years. In Cumberland County only six individuals were found between 1993 and 1995. The 1995 study season was especially unproductive, with only one corn snake captured - a recaptured male from 1994 (field number 94.49). The low capture rate is probably due, in part, to the highly secretive nature of the corn snake and its fossorial and nocturnal summer behavior. They also remain hidden most of the time, whereas pine snakes hunt and prowl on the surface of the forest floor. The sex ratio of the six snakes is evenly split between males and female (1:1). The radio-tracking of corn snakes was productive during 1994 (sample size = 4 snakes; 2 males and 2 females).

Nevertheless, this snake did lead us to an overwintering location (den). Despite the small sample size monitored during 1995 (again, one snake), the radio-tracking provided useful activity range data since the corn snake was monitored for nearly its complete activity season. More importantly, this snake was also monitored during 1994, thus a “combined activity range” value is available. A summary of corn snake activity ranges from the Davenport Basin (Berkeley Triangle in Ocean County) and TNC’s Manumuskin River Preserve (in Cumberland County) is presented in **Table 1**.

Activity range values (home range) were calculated by using the outer-most telemetry locations of all radio-tracking points combined, and then connecting these outside locations to form the convex polygon area. The best results are gained when two or more years worth of radio-tracking data are combined. Then the activity range represents the total area used over several seasons, which provides a more accurate depiction of habitat use and shows the shifts in areas used from year to year. Activity ranges were calculated using the Convex Polygon Method. Clearly, an accurate depiction of corn snake activity range size is not provided here by the meager data collected thus far. Additional monitoring and an increased sample size (10 - 20 snakes) of radio-tracked corn snakes would add greatly to our knowledge of this species. More radio-tracking information is desperately needed to gain a better understanding on the habitat requirements, home-range size, and micro-habitat selection of this endangered species in New Jersey.

Table 1. Frequency Numbers, Sex, and Activity Ranges in Acres and Hectares for Corn Snakes (*Elaphe guttata*) at the Davenport Basin (Berkeley Triangle) in Ocean County between 1990 and 1991, and The Nature Conservancy Sanctuary in Cumberland County, New Jersey between 1993 and 1994.

Snake's Frequency Number	Sex of Snake	Activity Range in Acres	Activity Range in Hectares
874	Female	25.92	10.49
377	Male	19.24	7.70
141	Male	52.55	21.26
852	Male	28.64	11.59
548	Female	44.18	17.88
499	*Female (not included in the mean)	1.80	0.73
227	*Female (not included in the mean)	1.47	0.59
684	Male	23.99	9.71
240	Male	145.96	59.07
077	Female	16.86	6.82
265	Female	37.87	15.32
N = 11	**Sex Ratio = 5:6**	**Mean: 43.91**	**Mean : 15.77**

Note:

* These two female corn snakes were only monitored for 1.5 months and do not represent a complete activity season.

Activity ranges were calculated using the Convex Polygon Method.

Source: Robert T. Zappalorti, Gian Luca Rocco, and Frank Peterson, Herpetological Associates, Inc.

Figure 5. An adult male northern pine snake basking near a pitch pine tree. They subdue their prey with powerful coils of their body, thus killing by constriction. Photo by Robert T. Zappalorti, Herpetological Associates, Inc.

NORTHERN PINE SNAKE

Description

The northern pine snake is classified taxonomically into the class *Reptilia*, order *Squamata*, sub-order *Serpentes*, family *Colubridae*, genus *Pituophis*, species *melanoleucus*, and subspecies *melanoleucus* (Daudin, 1803). *P. m. melanoleucus* is a large, powerful constrictor reaching a length of 48-66 inches (maximum length of 83 inches). The pattern is variable, but generally consists of 20 to 30 large black or brown blotches leading down the back on a white background. The blotches tend to be darker and less defined near the head. The ventral scales may be immaculate white, flecked with varying quantities of black, or patterned with differing amounts of pink; combinations of black and pink are also encountered. Scales are keeled and the anal plate is single. There are 4 prefrontal scales. The snake is often gentle, although it may give a loud hiss when startled (**Figure 5**).

Range

The range occupied by this subspecies in New Jersey is spotty, with isolated populations restricted to the New Jersey Pine Barrens; the next nearest population occurs in north-central Virginia. Other populations are found south to South Carolina, northern Georgia, and Alabama; and west to northern Alabama and western Tennessee and Kentucky. The distribution is spotty over much of the range, except for South Carolina. Other subspecies are found through two-thirds of the western part of the country as well as Florida.

Status

Global Rank	G5T?	Globally secure, but rare in parts of range
State Rank	S3	Rare in state with 21-100 occurrences
Federal Status	C2	Being considered to receive endangered or threatened status
State Status	T	Threatened

Habitat and Life History

These large, powerful constrictors are confined to the central and south eastern portion of the State, known as the Pine Barrens. A true lover of the uplands, the northern pine snake inhabits the dry pitch pine/oak areas of the Pine Barrens, away from the creeks and cedar swamps that are also found in this unique ecosystem. In mid spring, usually April in New Jersey, pine snakes begin emerging from their hibernation dens. The snakes themselfs may have excavated the den the previous fall. However, it was probably dug years earlier by other pine snakes in the population. Pine snakes den communally, not only with conspecifics but with other species of snakes such as coastal plain milk snakes, black racers, and corn snakes. Dens are dug at the bases of old decaying stumps or in abandoned mammal burrows. The snakes follow the paths of rotted tap roots down to a safe, frost-free depth where they create hibernation chambers. In the spring the snakes remain around the den for a short period of time, until temperatures begin to remain consistently above the soil temperature. Mating may occur during this time but is not confined to it. Later in the spring and even into early summer, males may actively seek out females that are still laying pheromone trails and will attempt to mate with them. During the month of June and early July female pine snakes find sunny open areas where they proceed to dig meter-long horizontal tunnels ending in a chamber. The female lays 3 to 16 eggs in this chamber and then leaves. The eggs are similar to chicken eggs in size though they are somewhat more elongated and are parchment- or soft-shelled, as are most reptile eggs. The eggs hatch in about 2 months and reveal 14- to 20-inch-long vibrantly patterned replicas of the parents. These snakelets quickly begin foraging for small warm blooded prey. During early fall, pine snakes follow scent trails back to their original hibernation sites. New born of the year also follow these trails and will hibernate with the adults at these sites. Cold weather in mid October or early November will promote the descent of the snakes into the hibernation chambers, where they will remain until the spring thaw.

Figure 6. A large adult female northern pine snake (*Pituophis melanoleucus*) coiled and hissing in its defensive posture. Over the past 25 years, many gravid females were found at community nesting sites (Burger and Zappalorti 1986 and 1991). These discoveries add to the importance of protecting critical pine snake habitat in the Pine Barrens. Photo by Robert T. Zappalorti, Herpetological Associates, Inc.

Due to the lack of scientific literature on the nesting behavior of the northern pine snake, HA has pioneered original research on nesting behavior and nest site selection in the disjunct population of pine snakes found in the New Jersey Pine Barrens. This research was done in cooperation with Dr. Joanna Burger of Rutgers University. Observations on the nesting behavior of pine snakes were made quite accidentally, as is often the case in science, beginning in 1977. At that time, pine snakes were occasionally found partially exposed on the ground, with the anterior portion of the snakes' body concealed in a tunnel. Early assumptions attributed these observations to feeding behavior, with the snake attempting to obtain small, burrowing mammals. However, as more snakes were captured and detailed observations made, it was noticed that all of the snakes burrowing into these "rodent burrows" were gravid females. It was also discovered that the snakes would be seen only during a three-week period and always at the same time of the year (June 20 through about July 10). These early observations led to intensive research, which eventually unlocked the mystery of pine snake nesting behavior and nest site selection.

Table 2. Frequency Numbers, Sex, and Activity Ranges in Acres and Hectares for Northern Pine Snakes at the New Jersey National Golf Course Property in Ocean County in 1992, The Nature Conservancy Sanctuary in Cumberland Co. between 1993 and 1994, and Lakehurst Naval Air Engineering Station, Ocean County, New Jersey in 1995.

Snake's Frequency Number	Sex of Snake	Activity Range in Acres	Activity Range in Hectares
273	Male	230.14	93.13
280	Female	93.02	37.67
722	Female	97.64	39.51
854	Female	188.29	76.20
418	Female	296.17	119.86
341	Male	398.88*	161.42
770	Male	141.21	46.22
219	Female	55.39	22.41
245	Female	67.00	27.11
391	Female	91.53	37.04
417	Female	87.52	35.42
220	Male	70.28	28.11
246	Female	77.06	30.82
417	Female	60.72	24.29
341	Female	57.77	23.11
794	Male	49.70	19.88
3412	Female	54.24	21.69
946	Male	43.46*	17.60
116	Male	114.60	46.40
471	Male	177.74	71.96
982	Female	178.72	72.36
N = 21	**Sex Ratio = 8:13**	**Mean: 125.29**	**Mean: 50.10**

Note: * = Largest and Smallest activity ranges, all were calculated using the Convex Polygon Method.

Source: Herpetological Associates, Inc.

Like those of most other snakes, pine snake eggs require warm conditions provided by the heat of the sun in order to incubate successfully. The adult female pine snake provides these conditions by actively selecting open, sunny locations in the forest and then digging their own tunnel and nest-chamber. Similar to other members of the genus *Pituophis*, northern pine snakes are well-equipped for this task, possessing a large, pointed, shield-like rostral scale on the tip of the snout. In order to loosen the often compacted sand, the snake uses its powerful neck muscles to dig its head into the earth. It then turns its head to one side and draws backward, forming a "primitive scoop" with its neck to excavate the loosened sand. A completed nest opening has a large dump-pile that is formed by the dragging actions of the female pine snake and is quite characteristic and noticeable by the trained observer.

The average pine snake tunnel and nesting chamber is about one meter (3 feet) in length, but some have been found that as long as 7 feet. Many of the nest tunnels curve to either the left or right. Often, it is speculated, that the curve is the result of the snake encountering an obstacle such as a root or a stone and then tries to dig around it. If not successful, she may abandon the tunnel and start another nearby. The average depth of the nesting chamber from the surface is four to five inches, although some have been found almost a foot or more deep. Another curious feature is that all the tunnels make a downward dip six to twelve inches from the entrance. This low spot may act as a catch basin for water, preventing the nesting chamber from becoming flooded in times of heavy rain.

Through mark-recapture studies HA has discovered that a large percentage of female pine snakes return to the same general area to dig their nests. On several occasions, freshly laid eggs and the empty shells of eggs that hatched in previous years were found in the same burrow. In addition, several pine snakes were occasionally found nesting in the same burrow. Females nesting later were found to dig their own chambers off of the first, or main tunnel. This behavior may be attributed to decreasing the risk of predation by reducing the amount of time later nesting females spend exposed on the open surface. A second hypothesis for communal nesting is that siblings may nest together, and possibly with their mother. This second hypothesis is supported by the observation that individually marked hatchling female pine snakes imprint on the nesting area from which they hatched, returning to this nesting area after reaching sexual maturity and preparing to lay their own eggs. Adult females have been shown to return year after year to the same nesting area, and often to the exact location where eggs were laid in previous years; fidelity to particular sites have been shown to last as long as 14 years. Although unknown at the present time, olfactory cues left by the old egg shells or the snakes themselves, chemical cues in the soil, magnetic orientation, visual orientation, or some combination of these may aid the snakes in finding original nest sites over long periods.

While strong nesting fidelity has been observed with many of the marked snakes, there is of course some deviation, and this is necessary if the snakes are to expand their range and use all of the available habitat. The abandonment of long-term or parental nesting areas may be attributed to a loss of orientation, disturbance of the original nest site, natural succession of vegetation leading to excessive shading of the nesting area, or simple natural pioneering.

METHODS FOR CONDUCTING A PHASE I - HABITAT EVALUATION

It should be noted that the person(s) conducting **Phase I** and **Phase II** snake surveys should have a degree in herpetology or ecology (or in a related field), or at least two years of intensive training under a qualified herpetologist. The Pinelands Commission and the NJDEP should generate a list of certified persons who have published their research in a scientific journal or have otherwise demonstrated their ability to find the three endangered target snake species. In the past, people without the proper training, who lacked experience in identifying suitable habitat, or how to trap snakes have conducted surveys and submitted reports to their clients saying no endangered or threatened snake species were on the study area. Then after all approvals have been given by the state agency and construction began, one or more of the target species were discovered. This may happen when there are no Natural Heritage records in the immediate vicinity of the study area. That's why reporting new endangered species sightings to the NJDEP is so important. If consultants do their job properly and thoroughly, they will find whatever species occur naturally on a study site, and false results will not be given to the state review agencies.

Historic Records

Initially, a **Phase I** - Habitat Evaluation must be conducted to determine if the study site is even suitable for one or more of the target snake species. Historic records are very important and one should always contact the New Jersey Natural Heritage Program or the Endangered and Nongame Species Program HERP Atlas files in Trenton for available snake records in the state's data base. Locality records or voucher specimens in Natural History Museums or University collections should also be sought. However, historic or HERP Atlas records may not always be available, so one must conduct his or her own **Phase I** evaluation to determine if a study site is potential habitat for a target snake species. Just because there are no records in the Natural Heritage Program's data base does not necessarily mean there are no snakes present on your study area. It just means that no one has looked for the target species, or reported the occurrence to the Natural Heritage Program. The presence of historic records nearby the study area, or other habitat features that are typical for corn, pine, or timber rattlesnakes, should always be considered. Potential pine/oak forest habitat features to look for are: ecotone habitat, old forest surrounding grassy meadows, transmission-line, pipeline, or railroad right-of-ways, clear-cut forest with numerous stump-holes, large mounds of logs and brush, and old buildings are suitable for snakes. These landscape features are known to be habitat for timber rattlesnakes, corn snakes, and pine snakes because prey animals are often using these habitats as well.

Vegetation Types on a Study Area

The suitability of an area for one or more of the three target snake species can be determined by evaluating existing habitat structure. Components that should be considered are: forest type (McCormick and Jones, 1973), vegetative types, hydrological conditions, elevation topography, soil type, and surrounding terrestrial habitat are most commonly used to evaluate upland forest as potential habitat for timber rattlesnakes, corn snakes, and/or pine snakes. Typical vegetation in undeveloped forest is mainly large pitch pine (*Pinus rigida*) trees along with various oak species such as scarlet, chestnut, post, white, scrub, and the abundant black-jack oak (*Quercus marilandica*). Vegetation along wetland corridors or flood plains consists of large red maple, sour gum, sweet gum, gray birch, holly, and pitch pine. Dangleberry (*Gaylussacia frondosa*) often occurs with a dense thicket of common greenbrier (*Smilax rotundifolia*), bearberry (*Arctostaphylos uva-ursi),* and teaberry (*Gaultheria procumbens*). Interspersed between pine-oak forest, oak-pine forest, or old field habitat is often a dense area of low bush blueberry, huckleberry, and greenbrier. Over story trees that form the canopy are mostly oaks and pines, but the edges of the forest, or old fields are often dominated solely by grasses such as Pennsylvania sedge, broom sedge, or switch grass (*Panicum virgatum*).

Table 3. Check-List of Required Preparation, Field Work, and Tasks to Perform a Phase I Habitat Evaluation for State Listed Pine Barrens Snakes in Southern New Jersey.

Species Sought	Timber Rattlesnake	Corn Snake	Pine Snake
Task or Item to be Checked			
Historical Museum or University Records	Optional	Optional	Optional
New Jersey Natural Heritage Program Records	Required Office Work	Required Office Work	Required Office Work
NJDEP Herp Atlas Records	Required Office Work	Required Office Work	Required Office Work
Existing Land Use (On and Off Site)	Required Field Reconnaissance	Required Field Reconnaissance	Required Field Reconnaissance
Existing Site Conditions	Required Field Reconnaissance	Required Field Reconnaissance	Required Field Reconnaissance
Structure of Habitat	Required Field Reconnaissance	Required Field Reconnaissance	Required Field Reconnaissance
Forest Type	Required Field Reconnaissance	Required Field Reconnaissance	Required Field Reconnaissance
Dominant Vegetation Communities	Required Field Reconnaissance	Required Field Reconnaissance	Required Field Reconnaissance
Soil Type(s)	Check the USDA County Soil Survey Maps	Check the USDA County Soil Survey Maps	Check the USDA County Soil Survey Maps
Wetlands and Water Quality	Required Field Reconnaissance	Required Field Reconnaissance	Required Field Reconnaissance

Soil Types on the Study Area

Depending on what county the study area is in, always use the United States Department of Agriculture Soil Survey maps to identify what type(s) of soils are present. Habitat types for snakes can be closely correlated to soil and vegetation types. For example, Downer (DoA), Lakehurst (LhA and LmA), Lakewood (LwB and LwC), and Woodmansie (WoB and WoC) are loamy sands where corn snakes and pine snakes have consistently been captured by HA over the past 25 years. However, timber rattlesnakes also use these soil types as summer foraging areas, but usually hibernate in cedar swamps with wet soils such as Manahawkin Muck (Ma) or Mullica sandy loam (Mu). Recognizing the necessary structural habitat features, such as soil type, during a survey is very important as an indicator for possible snake use.

Ranking of the Habitat Type for Snakes

In order to standardize the results of HA's habitat evaluations, each area surveyed is given a numerical score or rank using a sliding scale of 1-5. These numbers allow reviewers to better understand the rationale used to reflect HA's overall evaluation of a wetland cedar swamp, upland pine-oak forest, or oak-pine forest as potential habitat for timber rattlesnakes, corn snakes, or pine snakes. **Table 4** provides a sample habitat ranking system. Based upon the existing conditions of a study site (i.e., highly disturbed, clear-cut, occupied housing, major road on its boarder, etc.), and the current land use of the surrounding area, it is possible to eliminate some parcels of land as critical habitat for snakes. All these limiting factors must be pointed-out, mapped, and photographed in your **Phase I** report to the state agencies. If a site ranks **3** or higher, then a **Phase II** presence or absence survey is required. Large tracts of land connected to natural forested areas, with little, or no disturbance are highly potential habitat for rare snake species.

Table 4. *Potential Pine Barrens habitat should be evaluated as to its suitability for one, or more of the target snake species. Natural upland or lowland forests can be ranked using a sliding scale from 1 to 5 as follows:

1 = The Study Area is not suitable for the target snake species (Phase I only)

2 = The Study Area is marginally suitable for the target snake species (Possible Phase II)

3 = The Study Area is potential habitat for the target snake species (Phase II required)

4 = The Study Area is highly potential habitat for the target snake species (Phase II required)

5 = Confirmed Critical Habitat - Evidence of one or more of the target snake species found.

*Note: Each site must be evaluated on its own merits based upon size, forest type, soil type, current adjacent land use, closeness of paved roads, percent disturbance, historic records, and Natural Heritage Program information.

HOW TO EVALUATE AND DETERMINE SNAKE HABITAT

In order to conduct a **Phase I** evaluation the reviewer must be familiar with the preferred habitat of the three target snake species. Recognizing landscape features that are suitable for snakes and the presence of prey animals are essential in the analysis. If a parcel of land is undisturbed pine-oak forest, has sandy - loamy soils, is over 5-acres in size, has no paved roads crossing it, and is contiguous with other open space forested areas, then it should rank high (3 or 4 on the scale) as potential habitat. A reviewer should also keep in mind that snakes go where their food is concentrated, so if no prey animals are using the habitat, chances are that snakes will not use it either. Likewise, habitat diversity often attracts insects, amphibians, lizards, birds, and rodents. These prey animals in turn attract snakes. One should always do their homework with respect to checking the Natural Heritage Program's data base. Conducting a proper habitat evaluation should include speaking with local resident who live near the site, or checking with Conservation Officers, or local police for snake information. HA has three criteria for judging the value of the existing conditions and the available habitat for endangered or threatened snake species. These are:

1. Structure of Available Habitat: Both the biotic and abiotic components are considered. The study area should have good habitat diversity and be connected to other open space. Ecotone between closed canopy and old field habitat often attracts corn, pine, and timber rattlesnakes. Looking at soil type, forest type, wetlands, and old field habitat are good indicators for the possible occurrence of one or more of the target snake species within a particular upland or lowland forest ecosystem (Zappalorti and Johnson, 1982; Frier and Zappalorti 1983; Reinert and Zappalorti 1988a and 1988b).

2. Water Quality: The clarity, turbidity, smell, and general appearance of the water is visually determined. The depth and flow of a stream is important to predict how long the water will last for drinking purposes or to allow successful hibernation for timber rattlesnakes and king snakes (Reinert and Zappalorti 1988a and 1988b). The presence of insect larvae, tadpoles, salamander larvae, fish, or adult amphibians also suggest clean water quality.

3. Physical Evidence: Historic records from an area as well as recent sightings of shed skins, hatched egg shells, road kills, or nesting or basking habitat (*e.g*., open sunny fields or right-of-ways for nesting are pertinent). Locating winter dens is also crucial to finding rare snake populations since they are known to form aggregations, especially during the spring (late March and April) and fall (mid-September to early November) seasons. Winter hibernation sites (November to March) are essential for the snakes to survive. Dens are sometimes recognizable by the trained observer (Zappalorti and Johnson, 1982; Frier and Zappalorti 1983; Burger et al, 1988; Reinert and Zappalorti 1988a and 1988b).

Plant Indicators and Botanical Identification

Figure 7. Sheep-laurel (*Kalmia angustifolia*) is a good indicator of pitch pine lowland forest or wetland corridors in the Pine Barrens. Its pungent, beautiful crimson-pink flowers are present in May or June. Timber rattlesnakes and corn snakes have been seen hunting in pitch-pine lowland forest. Photo by Robert T. Zappalorti, Herpetological Associates, Inc.

The biologist(s) conducting the habitat evaluation must understand the life history and preferred habitat that pine, corn, and timber rattlesnakes use on a daily, monthly, and seasonal basis. Distinguishing between habitat types is important when trying to conduct the site evaluation, and subsequent presence or absence survey. Seasonal use of a habitat type by snakes should also be considered because many snakes select open areas to bask and lay eggs, but remain in the forest the rest of the year. Finding snakes in undisturbed upland forest is not easy. So one must consider the structure and dominant plants present on a study area. Indicator plants and trees are useful for seperating a site into forest types. Vegetation should be identified and categorized by height, percent canopy, and percent ground cover at potential snake habitat. Only open forest edges or ecotone may be used as nesting areas or basking habitat, whereas all other available habitat is used for foraging. If many species of prey animals are present, it's a good sign that snakes may also use the site. During general habitat evaluation surveys the entire surrounding upland tract should be walked, both in the woods and along paved or sand roads at the study site. Plants should be identified by running transects in a set compass heading. Plant species in adjacent wetland habitats should also be identified by community type (*e.g.*, bogs, swamps, hardwood forest, oak-pine forest, wet meadow, *etc*.).

Various field manuals, dichotomous technical keys, plant guides to synonymy, and local New Jersey plant lists on floras should be used to prepare for the **Phase I** habitat evaluation. Based upon the results of the **Phase I** survey, a more intensive **Phase II** field survey may be needed. These botanical references will assist in identifying the vegetative community. They include the publications of: Stone (1911), Fernald (1950), Gleason (1963), Fairbrothers (1979), McCormick (1970), McCormick and Jones (1979), Kartesz and Kartesz (1980), Snyder and Vivian (1981), Gleason and Cronquist (1991), and Forman (1998).

PHASE II - SNAKE SURVEY METHODOLOGY

HA's survey techniques include a combination of all the methods listed in **Table 5**, and we shift from one technique to the other as the site conditions may require. We use Visual Encounter Surveys and Random Searching along the edges of sand roads or right-of-ways, and look under all available ground cover, including discarded plywood, rugs, sheet metal, rubber mats, and other debris, that a snake could use as a shelter. Suitable habitat in Pine Barrens forest should always be thoroughly searched for the three target snake species. Remember, the main objective is to find some sort of physical evidence of them, or if possible, find and confirm one or more of the protected snake species.

VISUAL ENCOUNTER SURVEYS

This technique is simply a visual search of appropriate habitat under favorable weather conditions. Visual Encounter Surveys include Random Opportunistic Sampling (ROS), Time-Constrained Searches (TCS), and Diurnal and Nocturnal Road Cruising (DNRC). Careful observations should be made not only of individual organisms but also for their signs, such as tracks, scat, skins, eggs, and bones (Zappalorti 1976; Ernst, Lovich, and Barbour 1994; Herman 1994). Flashlights and mirrors may be used to examine burrow entrances for snakes (Hallam, Wheaton, and Fischer 1998). Gillespie (2000) found that the larger species of reptiles, such as snakes, lizards, and arboreal species, were best detected with Visual Encounter Surveys. If only Visual Encounter Surveys are used, it is difficult to know when an area has been searched thoroughly enough to detect the target species on a particular study area. Detectability differences among species, observers, and sample times present significant disadvantages to the herpetologist (Rodda, Campbell, and Fritts 2001). Visual Encounter Surveys alone are probably not sufficient to determine presence or absence for extremely secretive species such as the timber rattlesnake or corn snake.

Random Opportunistic Sampling

A relatively simple method for the trained herpetologist, Random Opportunistic Sampling (ROS) can be employed while performing other sampling techniques on the study site. ROS involves searching an entire site thoroughly and recording all species encountered. This involves searching various areas of the site which show potential habitat for a species of interest, or areas which are conveniently accessible. Locations on-site which do not fall into any specific habitat classification (e.g., disturbed wooded areas, garbage dumps, discarded plywood or metal sheets, old buildings) may generate previously undiscovered species that would not have been found without the use of this method. All reptiles encountered should be recorded to supplement the species list generated by other field methods. This method is most effective if there are no time constraints on the survey and the survey area is visited often. ROS is utilized as a primary method to gather impressions of relative abundance, habitat, and the presence/absence of target species (Campbell and Christman 1982; Karns 1986).

Time Constrained Searches

Time Constrained Searches (TCS) are a refinement of ROS and involve targeting the most promising habitat within a study area for intensive searching. Spatial boundaries for each search may be set, or may be based on the selected habitat type. Time limits help ensure that damage to the habitat is minimal, while allowing each portion of the habitat to be adequately examined. In the TCS method, a specific habitat is selected (e.g., oak/pine forest, pine/oak forest, tree-lined wash, wetland corridor, field) and intensive sampling (generally using transects) is initiated. Particular emphasis should be placed on variances within the selected habitat, such as sunny openings, edges of sand roads, etc. Opinions vary as to the effectiveness of Time Constrained Searches (TCS) versus other sampling methods. Corn and Bury (1990) found that TCS are useful if several study areas need to be searched in a limited time. They warned that TCS are not suitable for providing population data much beyond presence/ absence and should not be used for population estimates. However, Campbell and Christman (1982) found that species richness, relative abundance, movement between habitats and other quantitative comparisons can be made after repeated TCS. Likewise, Karns (1986) also recommends TCS should be used in conjunction with other methods. Crosswhite, Fox and Thill (1999) found TCS to be the most efficient method at sampling herpetofauna, but that the greatest number of the most common species of lizards were caught by using pitfall traps with drift fences.

Diurnal and Nocturnal Road Cruising

Diurnal and Nocturnal Road Cruising (DNRC) is a popular method among amateur snake collectors and professional herpetologists alike, first formally recognized by Laurence Klauber (1939) and still regarded as one of the best methods for sampling large wilderness desert areas (Klauber 1972; Mattison 1995). This method is most typically used while driving a vehicle slowly along a low-volume road at night, although it may be used during the day for certain species. Snakes may utilize sun-warmed paved roads to thermoregulate (Kauffeld 1957; Knudsen 1966), or they may be found while migrating or foraging. Some snake species may avoid crossing roads, while other species frequently may be over-sampled by using this method (Shewchuk et al. 1998; Mackessey 1998). Road cruising can be used passively and opportunistically, such as while driving to and from a study site or while driving or walking to and from areas within the site, or it can be initiated as a specific surveying technique (Fitch 1949). In addition, roads which border a study area may yield dead reptiles or other animals, killed as they attempt to cross. These road-killed animals can be identified and provide useful information, such as locality, distribution, migration routes, activity patterns, and habitat utilization. The basic presence or absence of a species in a particular area can be determined by the identification of road-killed remains (Karns, 1986; Zappalorti personal observations). Road Cruising has been proven to be a highly effective method, especially in the southern United States. Unfortunately, this method is not as effective in New Jersey. The high traffic volume on many New Jersey roads is probably the primary cause, resulting in the elimination of many individuals that use habitats along roads. Although this technique should be considered when conducting snake surveys, it should never be used alone to determine the presence or absence of one or more of the three target snake species.

Figure 8. An adult female pine snake that was found dead-on-road (DOR). It was killed by a passing vehicle as it tried to cross the pavement from one section of the forest, to the other. Photo by Emile DeVito, New Jersey Conservation Foundation.

Artificial and Natural Cover

Fallen trees, stump holes, hollow logs, loose tree bark, flat stones, and matted grass or leaf litter are all potential hiding places for snakes. When conducting Visual Encounter Surveys, all natural cover should be searched for concealed snakes, but care should be taken not to destroy habitat. Any cover that is overturned should be replaced as originally found. Artificial hiding places such as discarded sheets of plywood, sheet metal, rugs, and old furniture should also be searched (Zappalorti and Burger 1985). Many species may seek shelter under cover in the evening and can be found there the next day (Kauffeld 1957; Konze 1998).

TRAPPING TECHNIQUES

Fossorial reptiles vary in their susceptibility to different types of traps. Use of a single trap type will not adequately sample a herpetofaunal community, but may be useful in capturing a target species. A combination of trapping techniques is the most effective way to sample a community, particularly in riparian systems (Homyack and Giuliano 2000). Multiple trapping techniques will often result in the capture of a target species more quickly than through one trapping technique alone. Descriptions of some of the various types of traps used to capture secretive reptiles follow.

Pitfall Trap Arrays

Pitfall traps are open containers imbedded in the ground and buried to their rims. They may be arranged in a systematic grid pattern or array. Funnel-shaped collars are commonly used to prevent escapes (Campbell and Christman 1982; Vogt and Hine 1982; Karns 1986; Konze 1998). Reptile species within a suitable size relative to the pitfall trap may fall or jump in and be captured. Pitfall traps commonly capture small mammal species as well as small herpetofauna.

Several authors (Bury and Corn 1987; Crosswhite, Fox and Thill 1999; Gillespie 2000) report that pitfall traps were very effective at capturing lizards, small snakes, and anurans. Fisher and Case (1998) found pitfall traps with drift fences particularly effective at sampling the majority of terrestrial fauna, particularly fossorial or nocturnal species. Pitfall traps are not an effective method of trapping large snakes or turtles (Crosswhite et al.1999; Enge 2001), but may be effective at capturing young individuals of large species. However, when pitfalls are used in conjunction with funnel traps and drift fences, they do capture large snakes and lizards (Fisher and Case 1998). Terrestrial traps must be checked daily and wood covers and wet sponges (or moss) should be used to prevent hyperthermia and dehydration (Konze 1998). Pitfall traps under shelter boards, installed either singly or in arrays on a study site, are not recommended for sampling corn snakes, pine snakes, or timber rattlesnakes in the New Jersey Pine Barrens. Enge (1997; 2001) determined that pitfall traps were relatively ineffective at capturing medium (32-76 cm total length) and large (>77 cm total length) snake species, although many medium sized snakes would have difficulty escaping from a 19-liter (5 gallon) pitfall trap. Pitfall traps used along drift fences, however, may capture some species not found through random sampling or with funnel traps, and in general should improve any herpetofaunal species list.

Funnel Traps

Based on the target species, traps should be tailor-made to capture those particular organisms. Some basic funnel trap designs are described by Campbell and Christman (1982); Enge (2001); Karns (1986); and Pedlar (1991). Modifications may need to be made to discourage escapes (Shewchuk et al. 1998). Hardware cloth funnel traps are most effective in capturing small to medium-sized snakes and lizards (Wells et al. 1997; Vogt and Hine 1982). Wire funnel traps and artificial shelters yielded the best capture results in a long-term (50+ years) study of snake communities in central Kansas (Fitch 1999 and personal communication). HA typically uses single-ended funnel traps, where the snake enters the trap through a hole cut in the drift fence. These traps are constructed to form a wooden box (hence the name box trap), with a locking, hinged lid for ease of access to remove trapped snakes. Each box trap measures approximately 1-meter (3-ft) long, 30-cm (1-ft) high, and 30-cm (1-ft) wide. The traps are constructed from 3/4 inch plywood, but for longevity pressure-treated wood should be used . Open portions are covered with 0.6-cm (¼ inch) galvanized hardware cloth.

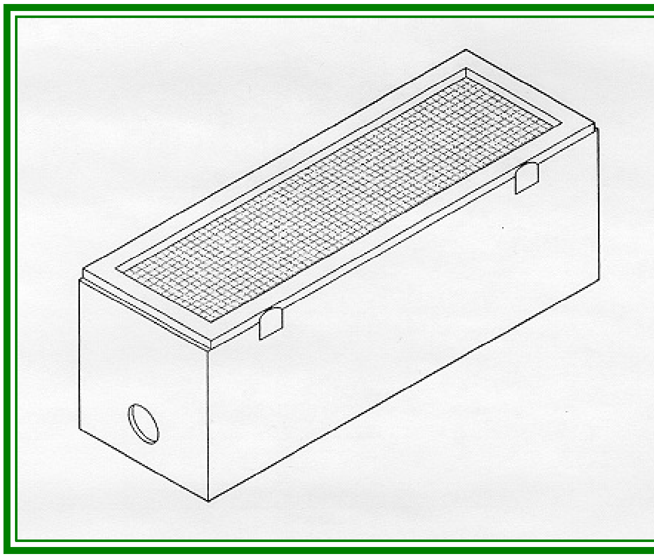


Figure 9. An isometric view of a wooden funnel trap showing the position of the entrance hole. Construction details are provided in this document. Drawing by Frank Peterson, HA.

Each trap has a 1.89 litter (64 fluid ounce) juice bottle which acts as a plastic funnel. The bottom of the plastic bottle is removed and placed with its wide end attached to the end of the trap, and the narrow end extending into the trap. The snake traps work on a principle similar to that of a minnow trap, where snakes are able to enter the trap, but have great difficulty in finding their way out (Zappalorti and Burger1985). Always place a plywood cover on top of the trap to provide shade from the heat of the sun. Additionally, leaves and humus should be placed in each trap to provide a cool, moist retreat for trapped snakes. The design specifications for building snake traps are illustrated in **Figures 9**, **10**, **11** and **12**. Homyack and Giuliano (2000) found funnel traps captured the greatest number and species richness of herpetofauna as well as the individuals with the highest body mass. Funnel traps used in conjunction with pitfall traps and cover boards yielded the best herpetofaunal community samples in one study (Homyack and Giuliano 2000). The use of funnel traps in conjunction with drift fences is described below.

Drift Fences

Drift fences are physical barriers that direct the movement of reptiles and other animals toward a trap. Generally, pitfall and funnel traps are used in conjunction with drift fences. Snakes encountering a drift fence generally follow along it to the left or right. Crosswhite et al. (1999) found drift fence arrays to be the most effective method of sampling snake populations. Two types of material are generally used in the construction of drift fences. These are nylon silt fence and aluminum flashing (Enge 2001). A number of other materials have been used in the construction of drift fences, including sheet metal, aluminum window screen, plastic coated screen, hardware cloth, chicken wire, tar paper, polyethylene, shade cloth, and pressure-treated boards. HA has experimented with 122 cm (48 inch) hardware cloth (0.64 cm [¼ inch] mesh) and found it to be useful for large snake species that might otherwise climb over silt fence or aluminum flashing. The main disadvantage of hardware cloth is the high cost. Enge (1997) noted that silt fence arrays were cheaper and as effective as 60 cm aluminum sheets, and easy to install. HA has found that silt fence is effective at capturing pine and corn snakes, but over time some snakes may learn to climb over it. The drift fence material must be partially buried in the ground and may be supported by wooden or metal stakes. Metal or oak stakes are better for long-term studies than softer wood, such as pine, because they decay more slowly.

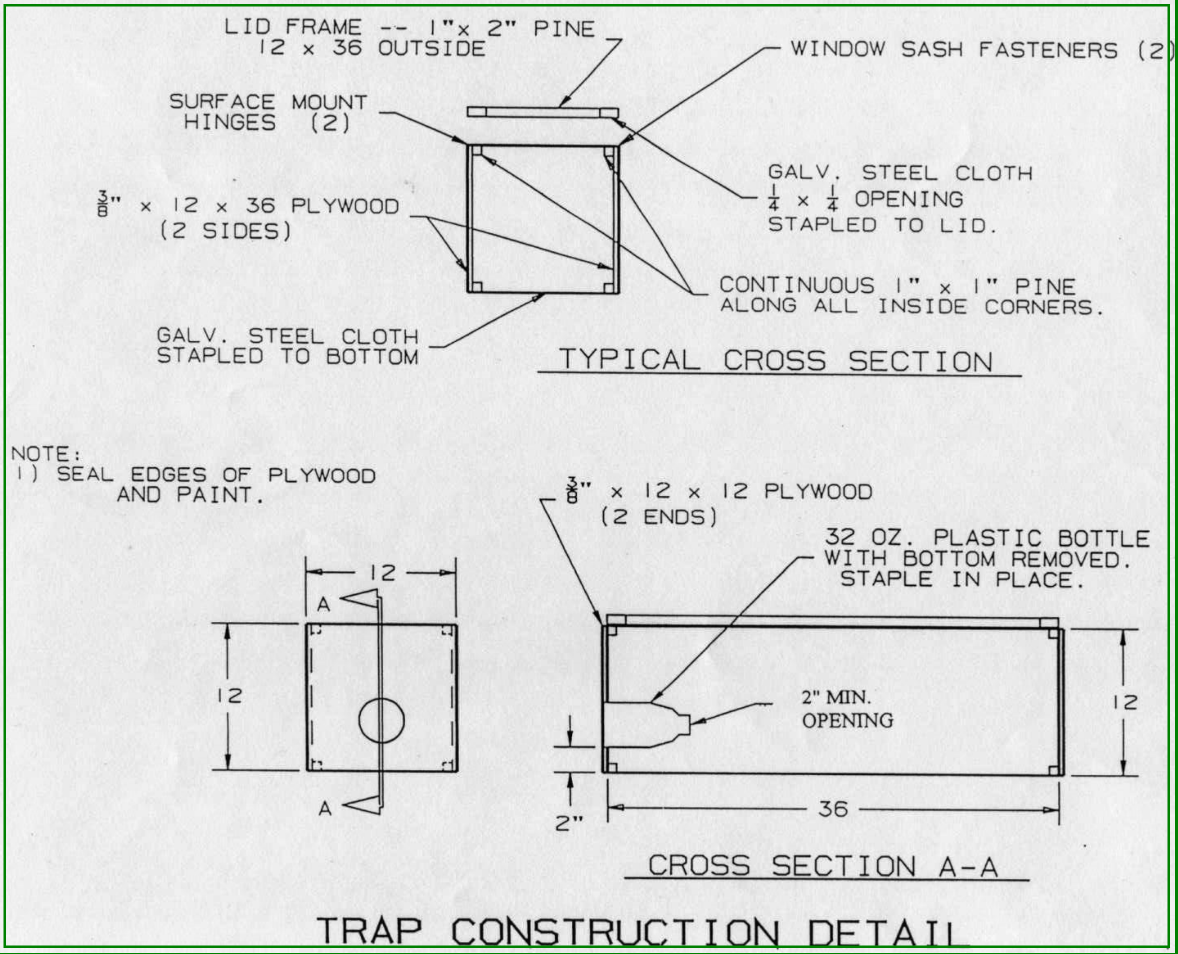


Figure 10. The material and method of building a snake trap. Design by Robert Zappalorti, drawing by Frank Peterson, HA.

The design, overall length, and position of each fence are important to the success of the sampling effort. Several array designs have been used successfully by other scientists. Enge (1997) recommends using a 30.5 meter roll of silt fence to construct a three-fence array, with each arm approximately 10-meters long. Three or more arrays of this design per habitat type are recommended to achieve a more comprehensive species list. If possible, these arrays should be situated 100-meters or more apart (Enge 1997). HA typically uses linear drift fences, which have proven to be effective. HA recommends that a minimum of one 500-feet linear fence or two 250-feet fences be used at sites less than 150-acres. For sites greater than 150-acres but less than 500-acres, a minimum of two 500-feet fences, or four 250-feet fences should be used. If a site is 500 to1000-acres, at least three 800 to 1000-feet drift fences should be used; these may be broken into multiple segments. Vogt and Hine (1982) found that longer fences caught more specimens, and fences less than 15 m in length were not worthwhile.

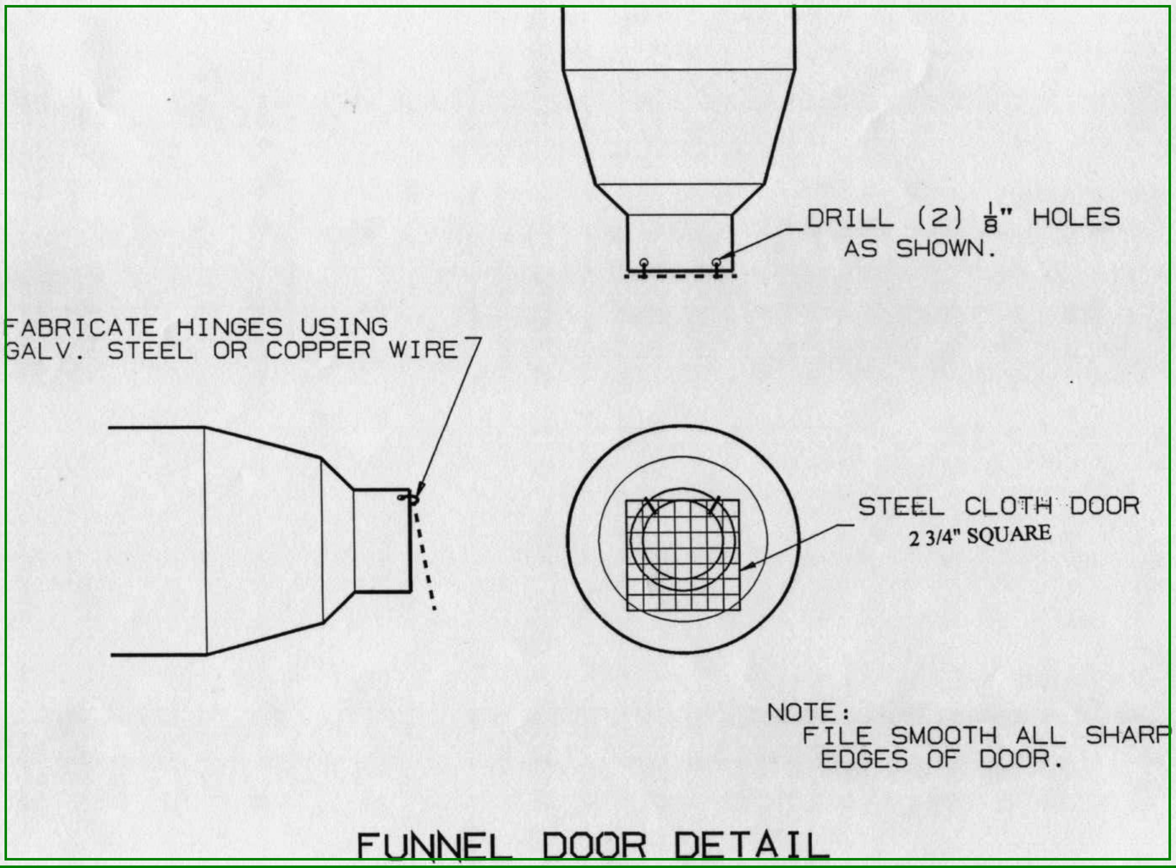


Figure 11. The funnel opening should have a one-way hardware cloth wire door, that allows snakes to enter easily but prevents them from escaping. Design by Bob Zappalorti, drawing by Frank Peterson, HA.

Shewchuk et al. (1998) found the most effective design combination for capturing snakes was funnel traps in conjunction with long drift fences. Enge (2001) reported that funnel traps captured significantly more snakes than pitfall traps, but pitfalls tended to capture more small snakes and small mammals, along with toads. The ineffectiveness of pitfall traps at capturing medium and large snakes has been noted by several researchers (Enge 2001; Vogt and Hine 1992; Greenberg et al. 1994a). However, Greenberg et al. (1994a) also found that pitfall traps were effective for capturing many species, especially semi-fossorial types. They also reported that all large snake captures were made in funnel traps, with double-ended funnel traps being twice as successful as single-ended funnel traps.

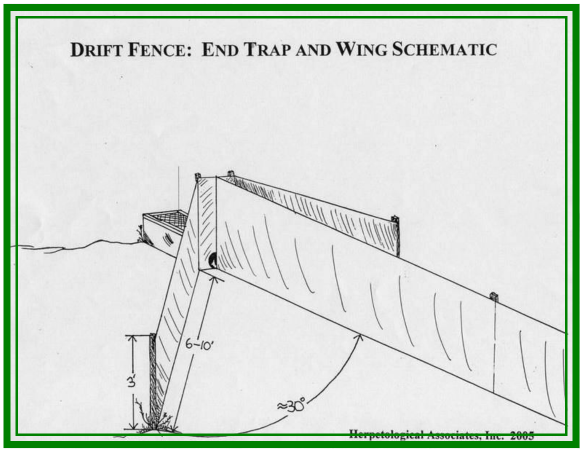


Figure 12. Two-meter long wings on end of fence to direct snakes into the funnel trap. Design by Bob Zappalorti, drawing by Matt McCort, HA.

Wells et al. (1997) used pitfall traps with drift fences and captured eight species of snakes. Gillespie (2000) found that pitfall traps with a drift fence bisecting them captured 12 reptile species, and 7 of those (4 snakes and 3 skinks) were not found with any other method, thus providing a reasonably systematic sampling of the small terrestrial species. Since funnel traps and pitfall traps tend to be complimentary, it is recommended that a combination of these traps be used on drift fence studies in the New Jersey Pine Barrens. However, due to the proven effectiveness of funnel traps for capturing medium and large snakes, it is recommended that a larger proportion of traps be funnel traps to capture rare snakes.

Figure 13. A drift fence erected on the edge of a Pine-Oak Forest to sample snakes. The ecotone between two habitat types often yields rare snakes and other reptiles and amphibians. Photo by Bob Zappalorti, HA.

Figure 14. Checking snake traps on a 1500-feet drift fence.

Figure 15. Trap opening at the base of the drift fence.

Figure 16. Terminus of drift fence showing the 1.5-meter wings on each side of the trap entrance.

Figure 17. An adult Northern Pine Snake that was captured in a funnel trap associated with a 1500-feet drift fence. Photo by Bob Zappalorti, Herpetological Associates, Inc.

Cover Boards

Cover boards (artificial shelters) were used by Henry Fitch (1999) during his famous 50 year study of snakes at the University of Kansas research station. More recently, their use as a sampling technique has been evaluated (Grant et al.1992). Cover boards are plywood or sheet metal squares that are placed on cleared ground to create an inviting place for reptiles and amphibians to retreat. Warren (2000) placed 61 cm (2 ft) by 61 cm (2 ft) plywood boards atop wooden legs 5 cm (2 in) by 5 cm (2 in) by 10 cm (4 in). The cover boards were then covered with 61 cm (2 ft) of grass clippings, which due to grass fermentation and radiant heat collection, created a "snake magnet" (Warren 2000). All the snake species surveyed in this study in Wisconsin were found by carefully lifting the cover boards and identifying them. A Pennsylvania study of riparian zones found that though cover boards captured fewer total species than funnel traps, they did yield some species not found with other methods (Homyack and Giuliano 2000). In a study on the effectiveness of cover boards for sampling salamanders, Houze and Chandler (2002) found that cover boards were comparable to natural cover for determining the species composition on a study site. Despite the fact that salamanders colonized the cover boards relatively quickly, significantly more salamanders were captured under natural cover than under cover boards.

Figure 18. A plywood shelter board positioned on the forest floor to attract snakes. HA sets-out shelter boards across a study area in all habitat types. The boards are numbered and plotted on a site plan, usually in transect form, spaced about 20 meters apart. Photo by Mike Torocco, Herpetological Associates, Inc.

Cover boards have proven to be highly effective for capturing snakes in the New Jersey Pine Barrens, provided that they were placed in optimal locations. Unlike Houze and Chandler's study of salamanders (2002), the greatest success with cover boards for sampling snakes has occurred when they have remained in place for at least one full season. This apparently gives prey animals a chance to find and use them for shelter. Once the scent of prey has been established, snakes locate the cover boards and feed on the prey. Snakes find cover boards suitable refugia within their activity ranges.

Artificial hiding places on the ground surface such as discarded sheets of plywood, flat sheet metal, rugs, old furniture, etc. should also be searched (Zappalorti and Burger 1985). Snakes are often sluggish on cool mornings. Since they seek shelter under cover in the evening they may often be found there the next day (Kauffeld 1957). For short-term presence or absence surveys (i.e., one season or less), establishing cover board sampling sites may be labor intensive and relatively unproductive. A more effective method would be to locate existing artificial and natural cover on a study site and use these sites as sampling stations. HA always numbers the shelter boards for easy record keeping and plotting capture locations on the study area (**Figure 18**). During a one-year study of an 80-acre site in Jackson, New Jersey, HA set-out 40 shelter boards in conjunction with drift fences and 12 traps, between April and August. While no pine snakes were captured anywhere on site, several black racers and coastal plain milk snakes were found under the "sucker boards," and only black racers were captured in the traps. However, at several other study sites pine, corn and timber rattlesnakes have been captured under shelter boards. Old roofing tin and car hoods are especially productive for finding snakes concealed under them (Fitch 1999; Zappalorti personal observations).

Figure 19. Illustrates a pine snake and black racer winter den that was found by radio-tracking. The den was encircled with nylon silt fence and four traps were set in each compass direction. In the spring, the traps are placed on the outside of the fence to capture snakes as they emerge from the den, as shown here in this picture. In the fall, the traps are moved to the inside of the fence and snakes are trapped when they try to enter the hibernaculum. Photo by Robert Zappalorti, HA.

Sampling at Known Hibernacula

When the target species has not been confirmed on a site, but the habitat appears highly potential, additional measures may need to be taken to prove presence or absence. One of the most productive ways of locating large numbers of snakes is to find their den sites or hibernacula, sometimes by following radio-tracked snakes (Zappalorti et al. 1983; Shewchuk et al. 1998). One technique which has proven useful in the New Jersey Pine Barrens is to radio-track one or more black racers (*Coluber constrictor*) until they enter hibernation. Black racers commonly hibernate with pine snakes and corn snakes (Burger et al. 2000), therefore locating a black racer den may result in the identification of a target species den. This den site can then be further examined to determine the presence or absence of pine and corn snakes. Due to the difference in the hibernation strategies of upland snakes (e.g., pine, corn, and black racer) versus timber rattlesnakes, this technique will not be useful to find rattlesnake dens. Care should be exercised that repeated visits by humans do not alter the behavior of the snakes, drive away some species, or damage the den site. Artificial hibernacula are utilized by a variety of snake species and afforded good opportunities to observe behaviors and collect data (Zappalorti and Reinert 1994). Known den sites can be surrounded with drift fences in the late winter to facilitate capture of snakes emerging from hibernation (Brown and Parker 1982). Drift fences with single-ended funnel traps were used to monitor hibernacula in the Pine Barrens of New Jersey (Burger, Zappalorti, and Gochfeld, 2000). Drift fence sampling at dens provides a useful way of inventorying the species composition, sex ratios, and age classes of snakes present within a den without causing undue disturbance to the den or the snakes (**Figure 15**).

Secretive snake species such as the corn snake (*Elaphe guttata*) and northern pine snake (*Pituophis melanoleucus*) were captured by the use drift fences with funnel traps placed around dens in the New Jersey Pine Barrens (Burger, Zappalorti, and Gochfeld, 2000). Individual drift fences measured approximately 15-45 m (100-150 ft) in length, and provided no gaps through which a snake might escape. Each drift fence was constructed of either heavy duty nylon silt fence, 1 meter in height, and supported with 2.54 cm(1 in) by 7.62 cm (3 in) wooden pine stakes. Alternatively, 122 cm (48 in) hardware cloth was used at some locations. Approximately 12 cm (5 in) of the drift fence material was buried in a trench around each den and all entrance holes, thereby preventing snakes from escaping under the fence. Three small holes (approximately 10 cm [4 in] in diameter) were cut into the fence material (at the ground surface) at nearly equal distances from each other along each fence. One box trap was connected to each hole, thereby providing a place for snakes to crawl through the fence and become trapped. As with linear drift fences, double-ended funnel traps can be placed along the fence as an alternative to the single-ended box traps (Zappalorti, personal observations).

SURVEY TIMING

The general timing of emergence from hibernation in the New Jersey Pine Barrens depends on the species in question and the weather conditions in any given year. Typically, pine snakes begin emerging from hibernation during the first week of April, although records of emergence during mid-March are not uncommon in warm years (HA, unpublished data). Most pine snakes will remain near their hibernaculum when emerging early in the season, where they may be found basking on warm days. During this period they will retreat into the den during cool periods and at night. There tends to be a lag of three to four weeks before all of the individuals from the den have emerged, but this lag time is strongly influenced by temperature fluctuations during the spring period of emergence and how far down in the tunnel system the snakes are from the surface. Dispersal from the den into the surrounding foraging habitat may begin by mid-April, with the first individuals to emerge dispersing before later individuals (HA unpublished data).

Other New Jersey snakes in the Family Colubridae, such as corn snakes, king snakes, coastal plain milk snakes, and black racers, typically begin emerging several days to several weeks before pine snakes, and tend to disperse more quickly from the den. Records of March emergence are not uncommon for black racers and corn snakes, with typical first observations occurring around March 18 at known hibernacula.

Timber rattlesnakes tend to emerge more slowly from their cedar swamp hibernacula, cuing in on rising water temperature. Generally, timber rattlesnakes begin emerging by middle to late April, but this may depend again on ambient temperature and the level of sunlight penetration at the hibernacula. Timber rattlesnakes tend to disperse more quickly into the surrounding upland habitat once they have emerged from hibernation. Based on the long-term data that has been accumulated by HA, rattlesnake surveys can begin as early as April 15. However, if trapping at hibernacula is to be conducted (as by drift fences, described later), the fences should be installed and operational by late March.

For basic presence or absence surveys, the optimal months to conduct snake surveys are May and June. During these months, all snakes have emerged from hibernation and are at their peak activity levels. Warm, but not excessively hot daytime temperatures allow snakes to bask for longer periods of time. In addition, most snakes will actively forage after the long hibernation period, and males are actively searching for females. By July, rising summer temperatures force most snake species to remain hidden in burrows or leaf litter. Activity is usually reduced to the morning or evening hours, and corn snakes may switch to nocturnal behavior. Cooler temperatures in September may provide an additional opportunity to survey for snakes. August and early September also provides an excellent time to survey for timber rattlesnakes since males are actively searching for mates. During this period males may be found crossing roads, and road-killed specimens become much more common.

Based on these aspects of snake life history, timber rattlesnake, corn, and pine snake surveys should be largely restricted to the months of late April, May, June, early July, September, and early October. The optimal period to conduct surveys is considered to be May, June, and September. Although snakes can be captured during July and August, a survey result of “no target species found” may be erroneous.

SURVEY DURATION AND LEVEL OF EFFORT

Habitat Evaluations

Habitat evaluations (**Phase I** surveys) usually can be performed during one day. Depending on the size of the property (Study Site) and its connectivity to adjacent undisturbed habitat. An accurate habitat assessment of snake occurrence can be made in some cases without performing a presence or absence survey. This assessment is based on the life history and habitat requirements of each species. However, for most sites larger than 100-acres with one or more of the property boundaries bordering undisturbed habitat, a presence or absence survey (**Phase II** study) is necessary. The level of effort will vary based upon the existing conditions of each site, but a basic (or minimal) level of effort should be conducted.

Visual Surveys

If visual surveys (a **Phase II** survey) are to be conducted without trapping methods, the surveyors qualifications should be rigorously reviewed. The effectiveness of this method alone, even with a highly experienced field team, may not be enough to accurately determine the presence or absence of the target snake species. However, specific habitat features, such as fields or abundant artificial debris, may greatly enhance the success of visual surveys. In contrast, monotypic habitats (e.g., uniform pine-oak forest with little edge habitat), may make visual surveys extremely difficult. Minimally, visual surveys should be conducted on 4 days in May, 4 days in June, and 4 days in September by an experienced three-person team; or, 288 person-hours of searching. However, it is recommended that drift fence trapping accompany visual surveys, especially when highly secretive species are sought like the timber rattlesnake, or corn and pine snakes.

Drift Fence Trapping

HA uses a "Ditch-Witch" to dig the trench for our drift fences. We sometimes place our fences along the edges of existing sand roads or forest fire breaks, which reduces the cutting and removal of vegetation. Each fence should be in a different habitat type, or extend into the ecotone between wetland and upland. Likewise, the fence should extend from old field habitat to pine-oak forest habitat. Drift fences with pitfalls and funnel traps can be used alone to survey for pine snakes, corn snakes, and timber rattlesnakes. The greatest advantage of drift fence trapping is that numerous species of reptile, amphibian, and mammal are captured, and a thorough wildlife inventory can be obtained. A minimum of three months of drift fence trapping is recommended. At least two of these months should include May, June, or September. The remaining one month of trapping can be conducted in July or August. Depending on temperature, trapping can be conducted through the first two weeks of October.

Figure 20. Shows a newly installed 4-foot high, 1/4 inch hardware cloth drift fence with funnel traps. This 1000-feet fence was erected along the edge of a sand road that had evidence of snake use (trails on soft sand). Photo by Robert Zappalorti, Herpetological Associates.

Figure 21. HA always places a funnel trap on the end of each drift fence to capture snakes as they crawl along. Note the two hardware cloth arms which direct the snakes into the funnel opening. Note the sand ramp which gives the snake a natural substrate to crawl upon. The plywood shade board was removed for the picture. Photo by Robert Zappalorti, Herpetological Associates, Inc.

If a discontinuous period of trapping is to be conducted (e.g., May, June and September; or June, July, and September; etc.), then all funnel traps and pitfalls must be closed or removed during the interim month(s). The drift fences themselves may remain in place, but they must not be able to trap animals during the period when the will not be checked. Failure to check traps or pit fall buckets frequently (at least every-other-day) may result in the death of animals from overheating, dehydration, or predation by racoon, fox, or skunk. Vandalism of the fence, or theft of traps may also be a problem. Signs and copies of your NJDEP permits should be posted on the fence and traps. The months of May, June, and September for drift fence trapping are suggested due to the increased activity of many snake species. However, continuous drift fence trapping through July and August can be conducted, and is recommended if the particular site warrants additional trapping. Drift fence trapping success can still be high during these warmer months, especially surrounding the passage of storm fronts. In addition, long-term radio-tracking studies have shown that many individuals remain highly active during July and August, but do not remain on the surface for as long. Many snakes that are diurnal in May and June will become crepuscular as daytime temperatures exceed their tolerance in July and August. Despite the shift in behavior over the course of the season, these animals are still easily captured in drift fence traps (Bob Zappalorti, unpublished observations).

Figure 22. HA staff members Frank Peterson (left) and the late Bill Smith (right) removing a northern pine snake from a drift fence trap. Each snake captured is given a Pit Tag identification number, and all pertinent data is recorded on a data sheet. The red object on the ground by Frank is the Pit Tag reader. Photo by Robert Zappalorti, Herpetological Associates, Inc.

Drift Fence Trapping Combined with Visual Surveys

Ideally, drift fence trapping should be used in conjunction with visual surveys and searches of natural (hollow logs, stump holes) ground cover and artificial cover such as plywood or metal sheets of roofing material. By using all these methods combined, it will result in a greater number of snake captures and a higher likelihood that a target species may be found. The number of visual survey days and/or the duration of drift fence trapping can be reduced from 3 months to 2 months, if these methods are combined. However, if a reduction in survey duration is sought by an applicant or consultant based on the combined use of techniques, it is recommended that a minimum of two full months of drift fence trapping be conducted in May and June. Additionally, at least three visual survey days per month for a three-person team should also be conducted during the months of May and June. September and early October are also acceptable, if the three person team has ample experience conducting snake surveys. Longer survey periods (mid-April to mid-October)are best, always more productive, and usually give the best results of the herpetofauna present on a study area.

Table 5. Check-List of Required Field Work, Survey Methods, Trapping Techniques, and Tasks to Perform a Phase II Presence or Absence Survey for Three State Listed Pine Barrens Snakes in Southern New Jersey.

Species Sought	Timber Rattlesnake	Corn Snake	Pine Snake
Task or Method to be Used			
Use a Confirmed Habitat as a Control Area	Optional Field Method	Optional Field Method	Optional Field Method
Visual Encounter Surveys	Required Field Method	Required Field Method	Required Field Method
Random Opportunistic Sampling	Required Field Method	Required Field Method	Required Field Method
Time Constrained Searches	Optional Field Method	Optional Field Method	Optional Field Method
Diurnal and Nocturnal Road Cruising	Optional Field Method	Optional Field Method	Optional Field Method
Artificial and Natural Cover	Required Field Method	Required Field Method	Required Field Method
Search for Physical Evidence of Snakes	Required Field Method	Required Field Method	Required Field Method
Shelter Boards	Optional Field Method	Optional Field Method	Optional Field Method
Drift Fence Trapping	Required Field Method	Required Field Method	Required Field Method
Pitfall Trap Arrays	Only good for neonate snakes Optional Field Method	Only good for neonate snakes Optional Field Method	Only good for neonate snakes Optional Field Method
Funnel Traps	Required Field Method	Required Field Method	Required Field Method
Combined Surveys	Required Field Method	Required Field Method	Required Field Method

Source: Herpetological Associates, Inc.

Data Recording and Documentation

Sample site survey forms and inventory data sheets are provided in the appendices. Use these types, or similar data sheets to record field notes and keep records. Photography is also a useful tool for documenting habitat and rare snake species found on a study site. If observed, one can photograph predation or feeding events, courtship or mating events, nesting or egg-laying events, sickness or injuries, unusual habitat use or behavior, and other snake activities or observations.

Control Areas

During an investigation, it is wise to use a known confirmed timber rattlesnake, pine snake, or corn snake location as a control area. Observed activity of snakes, such as nesting or shedding at the control area will help to gauge the possible activity on the study site at a particular time of year. Through the use of control sites it is possible to judge exactly when the target snakes are migrating, mating, nesting, giving birth, shedding, and hibernating. Therefore these same activities would be expected by the snakes that may occur on the subject property. For example, if pine snakes were observed nesting on a known control site, then any adult female pine snakes on the study area should also be nesting at approximately the same time. Therefore, HA recommends the use of a control area when doing presence or absence surveys for rare snakes on a site with suitable habitat.

Snake Signs or Physical Evidence

Snake signs or their physical evidence includes:

1. Shed skins (pine snakes, corn snakes, and timber rattlesnakes are all different).
2. Skeletons or bones of dead individuals.
3. Eggs of corn or pine snake, or hatched egg shells in the nesting chamber.
4. Broken off rattle of a timber rattlesnake.
5. Rattlesnake stools often contain shed fangs.
6. Fresh trails in soft sand or earth (each species makes a distinct trail when crawling).
7. Dead on Road (DOR) snakes (road-killed individuals can be identified from their remains and make good voucher specimens for museums).

While using their selected habitat, northern pine snakes, corn snakes, and timber rattlesnakes often leave some sort of physical evidence, albeit subtle. A skilled herpetologist knows what signs to look for, as listed above. While conducting random opportunistic sampling, time constrained searches, and diurnal road cruising (described above), HA always looks for snake sign or other physical evidence. Pine snakes and corn snakes typically begin to disperse from their dens into summer foraging habitats, which include old fields, log and brush piles, and forest edges in late April. June is when they deposit their eggs, so gravid females spend their time basking. Look for nest sites in open sunny areas. Finding eggs proves the species is using the study site. HA's survey techniques include a combination of all the above listed methods, and we shift from one technique to the other as the site requires. Intensive random searching should be used along the edges of sand roads and all available ground cover, including discarded plywood, rugs, sheet metal, rubber mats, and other debris, that a snake could use as a shelter should be looked under. Suitable habitat in Pine Barrens forest should always be thoroughly searched for all three snake species. The objective is to find some sort of physical evidence of them, or if possible, the snakes themselves.

TECHNOLOGICAL AIDS

Radio-telemetry

Figure 23. A basking gravid female timber rattlesnake in its defensive position, with its rattle elevated. Photo by R.T. Zappalorti, Herpetological Associates, Inc.

The use of radio-transmitters has greatly enhanced the ability of researchers to track secretive species and learn more about their behavior, habitat requirements, movements, and ecology (Reinert and Zappalorti 1988; Plummer and Congden 1994; Reinert 1992; Weatherhead and Hoysak 1989; Brown and Parker 1982). Snakes equipped with radio-transmitters may lead researchers to den sites or nest sites (Shewchuk et al. 1998). However, the transmitter implantation procedure is not without its risks to the study animal, which is clearly a concern when dealing with legally protected species. Radio-telemetry does have its merits and advantages, which far outweigh the disadvantages, especially when a housing development is imminent or permissible on a site. Radio-tracking will allow sound design plans to be produced with the welfare of the species in mind. Radio-telemetry should only be permitted when it's absolutely necessary, and by a site by site basis, depending on the situation.

The qualifications of the person doing the surgery and surveys should be rigorously examined, with emphasis being paid to their experience doing surgery. They should only follow the procedure of Reinert and Cundall (1982). Their radio-tracking experience should be learned from Reinert (1992). The person applying for a permit to conduct radio-tracking studies should submit a "Study Plan" for review and approval by both state agencies. A study plan should be designed specifically for each job, in the context of the information needed (e.g., location of hibernacula, complete seasonal activity ranges, critical nesting habitat, shedding stations, and important feeding areas). This information, in most cases, can only be gained by radio-tracking.

PIT Tags

PIT tags (passive integrated transponders) have been used in lizard studies (Germano and Williams 1993) and some snake studies (Mackessey 1998). These identification tags are highly useful for studies in which multiple animals may be captured and recaptured. In addition, the tags can be read by anyone with a compatible reader, facilitating future inventory work. The glass-encased microchips are implanted subcutaneously, and the digitized code can be read after recapture up to 100,000 times (Mackessey 1998). Each tag has a unique 9-digit number, allowing quick, easy, accurate identification of any marked animal. The AVID ID tags are small, measuring 14 mm x 2.1 mm (0.55 in. x 0.08 in.) and weighing 0.08 grams (0.0028 oz.), which allows their use even in large neonate snakes. The power requirements of the tags are passive, meaning that they are activated by the electromagnetic field of the portable reader. PIT tags are an excellent way to permanently identify snakes.

DISCUSSION

Advice for Sampling Snakes

Diligent search efforts conducted within potential construction areas and associated access roads will eventually lead to snake encounters. Rattlesnakes, corn snakes and pine snakes will use both upland pine-oak or hardwood forest habitats. Likewise, they will use the ecotone between the forest and open areas for foraging and basking. Timber rattlesnakes, Corn Snakes, Pine Snakes, as well as some other species (*i.e*., King Snakes, Black Racers, Black Rat Snakes, Garter Snakes, Hognose Snakes and Milk Snakes), are known to gather at communal den sites in the fall where they all overwinter together, sometimes, collectively, in large numbers. In addition, they typically show a high degree of fidelity to a particular den, returning year after year (Brown,1992; Reed et al., 2012).

However, it has been shown on some occasions through the use of radio- telemetry there can be variation in this trend with some individuals who shift to, and overwintering at, other den sites within their home range. During HA's ongoing mark- recapture studies of Pine and Corn Snakes in the New Jersey Pine Barrens, some individuals have been known to shift to den sites up to one-half mile away from where they had previously hibernated (Zappalorti, personal observation). This change in behavior appears to be natural with individuals from surrounding den sites being part of a larger meta-population (Brown, 1992; Clark et al., 2010; Burger and Zappalorti, 2011).

This type of den shifting behavior would likely increase the genetic diversity of the population as snakes tend to seek and find mates at the den sites prior to fall ingress, and again during emergence in the spring. In addition, this den shifting behavior could also be the result of increased human disturbance at hibernation sites with the snakes altering their overwintering den (predator avoidance behavior), to decrease the likelihood of falling victim to collectors or misinformed humans; thereby increasing their survival rates.

SUMMARY

New Jersey's rare snake populations are in real need of protection. As such, qualified personnel are required at sites associated with construction activity (*i.e*., site preparation, residential or commercial construction, utility installation or restoration, and road or highway construction), in an effort to minimize harm to these serpents. HA recommends the NJDEP should have state-approved snake surveyors or monitors that have demonstrated their ability to conduct thorough presence or absence surveys in the Pinelands. State-approved snake surveyors or monitors play an important role in the protection and persistence of these rare species in New Jersey. Snake surveyors and monitors with less experience and knowledge of these snakes should endeavor to learn more from experienced herpetologists to further their knowledge and understanding of the methods to find Timber Rattlesnake, Corn Snakes and Pine Snakes. They must gain additional guidance on assessing behavior and improving safe-handling and capture techniques.

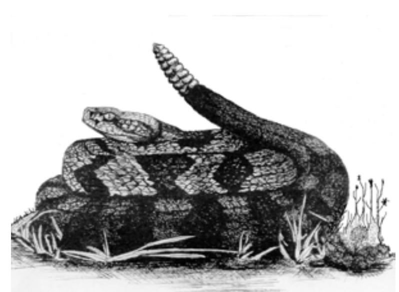
The Pine Barrens does not reveal its snakes easily. If a **Phase II** presence or absence study is needed to determine if rare snakes are living on a parcel of land, the person(s) conducting the investigation should make every effort to use the best methods known to science in order to conduct a thorough survey to locate these secretive reptiles. Individuals who do not do their homework, or do not use the proper techniques to sample for rare snakes, may miss important physical cues which demonstrate their presence on a parcel of land. Those who do not conduct a thorough investigation run the risk of providing their client and the Pinelands Commission with poor, or false information.

Important land use decisions are made based upon habitat assessments and endangered species surveys, so the data collected on a study site should be reliable and accurate. The correct survey knowledge will allow a surveyor to conduct intensive studies during the proper seasonal window and give the best study results. If everyone follows the method guidelines set fourth in this document, then most studies will be equal and comparable. More important, the state review agencies will have more confidence in the sampling results and can make better conservation decisions with respect to issuing building permits to land developers in the Pinelands National Reserve.

Respectfully Submitted,

Robert Zappalorti and Michael Torocco

HERPETOLOGICAL ASSOCIATES, INC.



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Typical habitat for snakes in the New Jersey Pine Barrens.