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Do Drift Fences, in Conjunction with Funnel Box Traps, Capture Secretive Terrestrial Snakes?

By

Robert T. Zappalorti, Sr.

Herpetological Associates, Inc.
405 Magnolia Road, Pemberton, New Jersey 08068

Mobile: 609-618-0314

Visit our web site at: HerpetologicalAssociates.com

INTRODUCTION

This report presents the combined data from a four-year drift fence trapping study in conjunction with a 6-year radio-telemetry study of a Northern Pine Snake (*Pituophis m. melanoleucus*) population (**Figure 1**). This investigation was a joint research venture by Herpetological Associates, Inc. (hereafter HA), and the Endangered and Nongame Species Program (ENSP), Division of Fish and Wildlife, New Jersey Department of Environmental Protection (NJDEP). It presents the results of a long-term monitoring program at a commercial and residential development site known as the Stafford Park Redevelopment property (hereafter SPR property). The SPR property is 370-acres in size and is located in Stafford Township, Ocean County, New Jersey (**Figure 2**). This research was funded by the developer, Walters Homes, Inc. (hereafter Walters) and overseen by the New Jersey Pinelands Commission (hereafter the Commission).

HA's involvement in this investigation started in May 2006, and terminated in December, 2013. The framework for this project was guided by the June 28, 2006 Memorandum of Agreement (hereafter MOA) which was made between Walters Homes, Ocean County, Stafford Township, and the New Jersey Pinelands Commission. This action was taken because an old unlicensed landfill was contaminating ground water and the environmental quality of nearby, Mill Creek. In accordance with the MOA, Walters closed and excavated the old unlicensed landfill on site and used the excavated materials to properly close and cap the new licensed landfill located on the SPR property.

BACKGROUND INFORMATION

The Northern Pine Snake, a "threatened" species listed by the NJDEP, occurred on, and in the vicinity of the SPR property. Considerable effort was expended by HA in surveying the SPR property site for Pine Snakes during the 2006 activity seasons. In keeping with the MOA, HA was asked to assist specifically with a Northern Pine Snake nesting survey and an egg incubation program in May, June and July of 2006. Through these intensive surveys, it was learned that the SPR property provided critical nesting and overwintering habitat for Northern Pine Snakes. The Commission determined that the Pine Snake population, and other state-listed plant and wildlife species required a management and conservation study plan. HA wrote that plan (Zappalorti and Golden 2006).

Figure 1. Northern Pine Snake.

Figure 2. A 2007 aerial photograph showing a western view of the study site and the early stages of the commercial construction on the eastern and central portions of the site. The licensed landfill is centered on the western portion of the SPR property (highlighted with white lines), and retention basin D is located in the extreme western portion of the site (highlighted in white). The three Pine Snake mitigation and management fields are due west from the edge of the site (outlined in red lines). The perimeter exclusion drift fence and trap line is also outlined with red lines which surrounded the SPR property. Source: Walters, Inc.

Walters commissioned HA and the ENSP to develop specific conservation and management plans regarding mitigation to reduce direct adverse impacts to Pine Snakes, southern gray treefrogs (*Hyla chrysoscelis* - endangered), and two rare plant species, Knieskern's Beaked Rush (*Rhynchospora knieskernii*), a federally-threatened and state-endangered sedge, and Little Ladies'-tresses (*Spiranthes tuberosa*), an orchid on the Commission's list of protected plants. Final progress reports for southern gray treefrogs and rare plants were provided to the Commission by HA in 2008. HA and Dave Golden, former Senior Zoologist with the Endangered and Nongame Species Program, designed and wrote the conservation, mitigation and management plan for northern Pine Snakes as outlined in the MOA (Zappalorti and Golden 2006).

ERECTING AND MONITORING THE PERIMETER DRIFT FENCE

The perimeter drift fence was maintained and monitored for 4-years (2007 to 2010). Snake traps were placed on both sides of the fence for two years to capture Pine Snakes that may be leaving the SPR property construction area. It was assumed that most snakes would be collected or displaced by the end of two trapping years. After 2008, traps were placed only on the outside of the fence for 2009 and 2010 to capture snakes entering the SPR property. The fence was repaired and kept functional during the 4-year on-going drift fence trapping studies. The traps were checked every 48-hours during the active season for snakes (April through October). Any new adult Pine Snakes caught in the perimeter fence traps were fitted with radio-transmitters (up to 10 snakes), and were monitored for the remainder of the investigation. Hatchlings and juveniles caught in the traps (or by random searching), were injected with Pit Tags as part of the mark and recapture program.

Drift Fence Trapping Protocol - Between 2007 and 2010, one large perimeter drift fence was installed that was approximately 13,500-feet in length. HA's specially designed snake box traps were attached to the drift fence (**Figures 3** and **4**). We started out with 134 traps for 2007 and 2008. with 67 traps placed on each side of the fence to capture snakes and other wildlife moving in both directions of the fence. In 2009 and 2010 we only trapped snake leaving the study site with 126 snake box traps. The 1,300 feet perimeter drift fence encircled approximately 90% of the 370-acre study site. The fence traversed various habitat types in an attempt to capture free-ranging Norther Pine Snakes and other reptiles and amphibians (**Figure 1**). This technique was used in conjunction with the visual sampling techniques described above to increase the chance of capturing Pine Snakes (Zappalorti and Torocco 2002). The perimeter drift fence was also meant to exclude Pine Snakes and other wildlife from entering the construction areas on the SPR property. The drift fence consisted of black nylon silt fence, three feet in height, and was supported with wooden oak stakes. Approximately five to eight inches of the fence material was buried below grade level, backfilled and tamped, thereby preventing snakes and other wildlife from crawling under the fence (Enge 1997a and 1997b, Zappalorti and Torocco 2002). A small hole (approximately four inches in diameter), was cut into the fence material at the ground surface, and a box funnel trap was connected to the hole (**Figures 5** and **6**), thus providing a place for snakes and other animals to crawl through the fence and become trapped (Dargan and Stickel 1949; Enge 1997a, 1997b; Casazza et al, 2000). Michael Zappalorti, was the person who checked all the traps and removed and released snakes and other wildlife back into the Stafford Forge WMA.

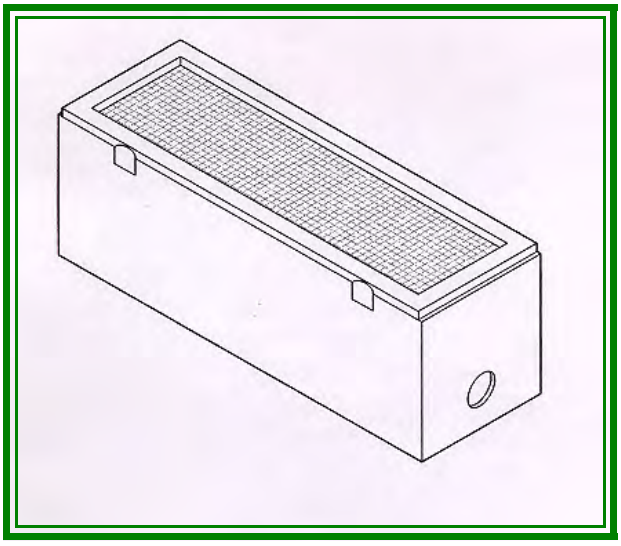
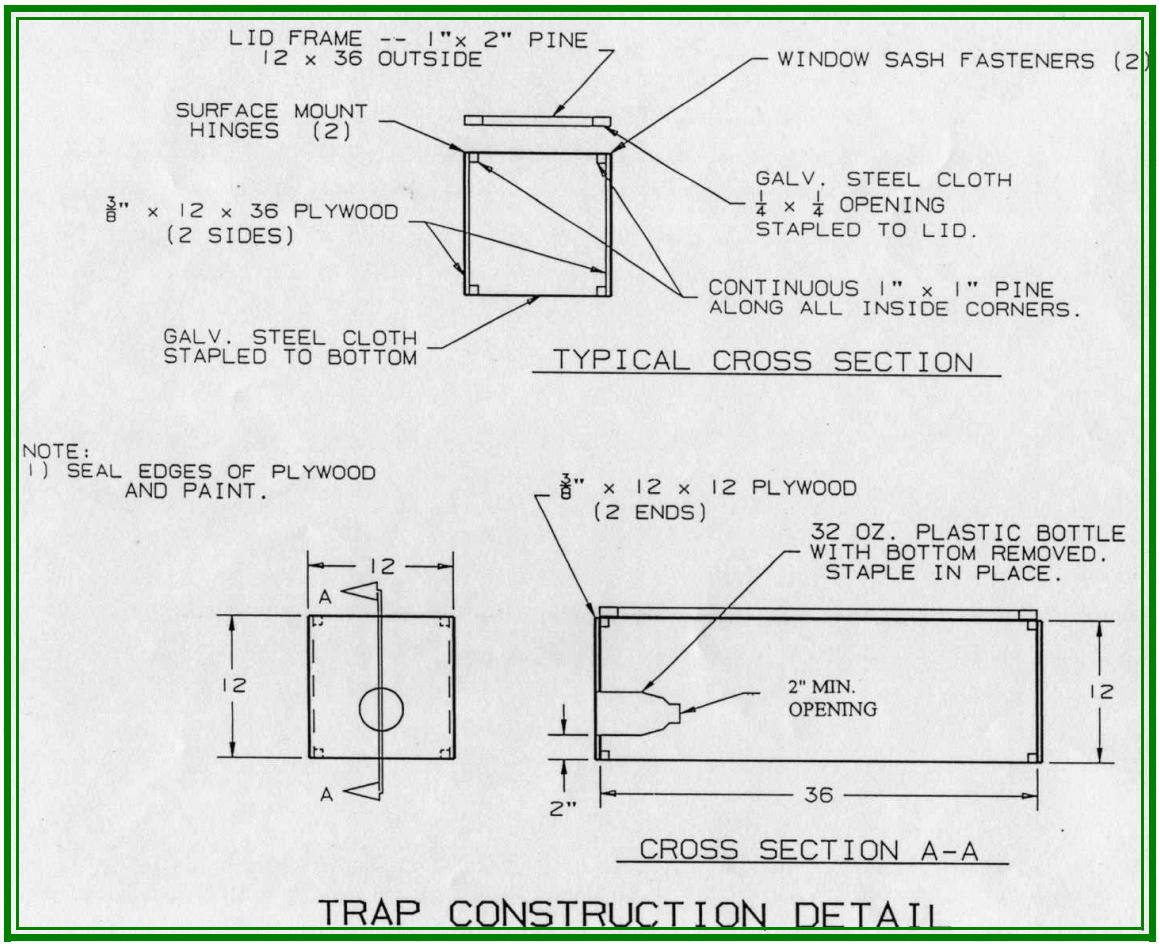
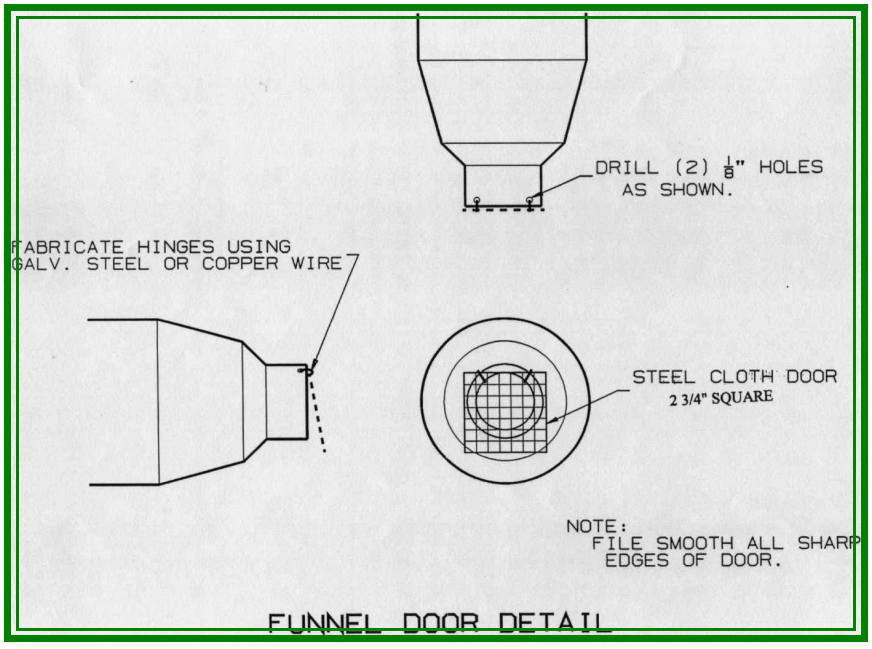


Figure 3. Diagram of HA's wooden box funnel trap to capture snakes and other wildlife.


LID FRAME -- 1"x 2" PINE
12 x 36 OUTSIDE
WINDOW SASH FASTENERS (2)
SURFACE MOUNT
HINGES (2)
GALV. STEEL CLOTH
¼ x ¼ OPENING
STAPLED TO LID.
¾" x 12 x 36 PLYWOOD
(2 SIDES)
CONTINUOUS 1" x 1" PINE
ALONG ALL INSIDE CORNERS.
GALV. STEEL CLOTH
STAPLED TO BOTTOM
TYPICAL CROSS SECTION
NOTE:
1) SEAL EDGES OF PLYWOOD
AND PAINT.
¾" x 12 x 12 PLYWOOD
(2 ENDS)
32 OZ. PLASTIC BOTTLE
WITH BOTTOM REMOVED.
STAPLE IN PLACE.
12
A
12
A
2" MIN.
OPENING
12
2"
36
CROSS SECTION A-A
TRAP CONSTRUCTION DETAIL


DRILL (2) ⅛" HOLES
AS SHOWN.
FABRICATE HINGES USING
GALV. STEEL OR COPPER WIRE
STEEL CLOTH DOOR
2 3/4" SQUARE
NOTE:
FILE SMOOTH ALL SHARP
EDGES OF DOOR.
FUNNEL DOOR DETAIL

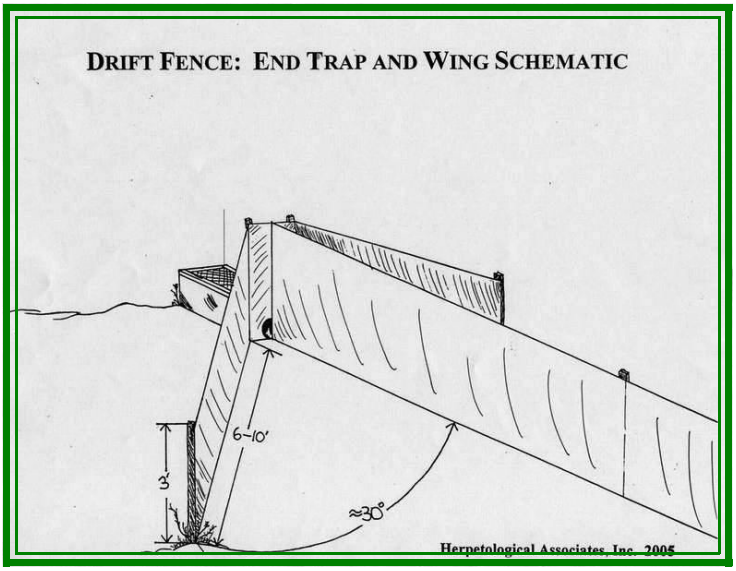


Figure 6. Illustration of the terminus of a drift fence showing the position of an end trap and the directional arms which guide snakes into the mouth of the trap. Source: Herpetological Associates, Inc.

Each box trap measured approximately three feet long, one foot high and one foot wide. The traps were constructed from treated plywood and 1/4-inch mesh galvanized hardware cloth. Each trap had one plastic funnel placed with its wide end attached to the end of the trap, and the narrow end extending into the trap. A hinged lid with latches allowed easy access to remove trapped snakes and other wildlife (Casazza et al, 2000). The snake trap works on a principle similar to that of a minnow trap, where fish (and in this case, snakes) are able to easily enter the trap, but have great difficulty in finding their way out because of the one-way door flap (**Figure 5**). Leaves were placed in each trap to provide a cool, moist retreat for trapped animals. A plywood board was placed over the top to provide shade and reduce exposure to the sun (Enge 1997a and 1997b, 1998a, 1998b and 2001). The 126 traps were removed from the drift fence and the program was terminated as planned at the end of the 2010 field season. The perimeter silt fence itself was removed in March of 2011.

Drift fences are physical barriers that direct the movement of fossorial reptiles and other animals toward a trap (Enge 1997a; Friend et al. 1989). Drift fences with pitfall traps are typically used in long-term study projects to identify the presence of reptile species, and to learn about relative abundance and habitat use (Karns 1986). Drift fences with funnel traps were used to survey herpetofauna of steephead ravines in deep sands of the Florida Panhandle (Enge 1998). Snakes and other animals encountering a drift fence generally follow along it, and are captured in a pitfall or funnel trap. Pitfall buckets are not suitable for capturing large snakes because they can crawl right over the opening without being trapped. HA does not use pitfall traps unless sampling for salamanders.

Three types of material are generally used in the construction of drift fences. These are nylon silt fence, aluminum flashing, or wire hardware cloth (Enge 1997b). The fencing is partially buried in the ground and may be supported by wooden or metal stakes. HA has found that metal stakes are better for long-term studies because they will not be eaten by termites.

PROTOCOL FOR RELEASING TRAPPED PINE SNAKES FOUND IN THE SPR PROPERTY

One of the goals of the Species Management Plan was the protection of threatened and endangered species on the SPR property from adverse impacts and direct harm during the redevelopment process. This included, but is not limited to, the reestablishment of threatened and endangered species at appropriate habitat areas designated by the Pinelands Commission and the NJDEP. Furthermore, the MOA mandates that steps were taken to preclude such species from returning to the disturbed areas of the Stafford Park Redevelopment site. Radio-tracked Pine Snakes caught in the drift fence traps or found along the perimeter drift fence were moved approximately 200 meters, into the Stafford Forge WMA forest, roughly perpendicular to their point of capture at the drift fence. Snakes new to the study were processed (weighed, measured and sexed), PIT tagged (Elbin and Burger 1994), and then released according to the same procedure followed for radio-tracked specimens.

Figure 7. An Eastern Hognose Snake captured in one of the Drift Fence Traps. Photo by Mike Zappalorti, HA Staff.

Unlike in previous years, snakes that had somehow breached the perimeter drift fence and were relocated on the SPR property, were not shifted back into Stafford Forge WMA. One of the questions in this study addresses whether Pine Snakes that were shifted in 2006 from the landfill into Stafford Forge WMA would continue to try to access the landfill in the following years, especially females during the nesting season (Burger and Zappalorti 1986 and 1991).

Since there was no more active construction occurring on the landfill after 2010, HA decided that it was important for data collection purposes to allow any Pine Snakes that chose to enter the landfill or SPR property to do so and move about unmolested. This protocol continued until the study was terminated in 2013.

Results of Trapping

2007 Trapping - Drift fence surveys began on April 16, 2007. Traps were checked along the drift fence once within every 48-hour period throughout the active field season. There were a total of 139 traps along approximately 13,000 feet of drift fence. However, on May 16, 2007 a major forest fire destroyed 10,000-acres of pine -oak forest along with a large portion (90%), of the perimeter drift fence along with 115 traps. As a result, drift fence surveys did not begin again until June 13, 2007. After reconstruction of the drift fence line 134 traps were attached. Closing of the traps for the winter season began on November 1 and concluded on November 11, 2007. Any open traps were checked every 48 hours until all were closed. The purpose of the perimeter drift fence was to prevent animals (specifically Pine Snakes) from entering the construction site and to capture any snakes trying to leave the site.

During the 2007 season, 24 species of reptiles and amphibians, 9 species of mammals, and one species of bird were captured in the drift fence traps. Eastern hognose snake, northern black racer, Fowler's toad, red-backed salamander, and green frog were the most commonly captured reptile and amphibian species. In 2007, five individual Pine Snakes were captured in the traps on six different occasions. Of the five Pine Snakes, four were adults and one was a juvenile. Only one of the captured Pine Snakes was a new previously unmarked snake. This snake was captured on August 17, 2007. It was PIT tagged and fitted with an external transmitter to enable HA to radio-track it to a natural hibernaculum. One gray tree frog was captured in a drift fence trap during the season. White-footed mice (*Peromyscus leucopus*) were the most frequently captured mammal. An ovenbird (*Seiurus aurocapillus*) was the only bird species captured.

2008 Trapping - Drift fence surveys began on April 15, 2008. Traps were checked along the drift fence once within every 48 hour time period throughout the active field season as dictated in the aforementioned management plan. There were a total of 134 snake box traps along the 13,000-feet drift fence. The drift fence traps were closed for the winter on October 31, 2008.

During the course of the 2008 field season, 22 species of reptiles and amphibians and 4 species of mammals were captured in the drift fence trapping system. Similar to the 2007 field season, eastern hognose snake, northern black racer, Fowler's toad, eastern garter snake, and green frog were the most commonly captured reptile and amphibian species. In 2008, 7 Pine Snakes were captured in the traps. Of the 7 snakes, 4 were adults, one was a 2006 juvenile, one was a 2007 juvenile, and one was a 2008 hatchling. Two of the adult Pine Snakes were new unmarked captures. One was a gravid female, the other was a male that was caught late in the season. This male was fitted with an external transmitter in order to determine where its overwintering den was located. When this snake emerged in the spring of 2009, the external transmitter was removed and the snake was released at its capture location. It was not implanted with a transmitter.

The other two snakes captured were radio-tracked animals (2006.26 and 2007.15). The 2006 juvenile was from a clutch that was hatched in HA's laboratory and released into Artificial Hibernaculum 1 on 09/22/06. The 2007 juvenile and the 2008 hatchling were both new captures. They were PIT tagged and released at their capture locations.

2009 Trapping - In 2009, HA followed the same protocol for the drift fence studies. Trapping began on April 15, 2009. Traps were checked along the drift fence once within every 48 hour time period throughout the active field season in accordance with the Pine Snake management plan. While there were some problems with rain water drainage issues, realignment of the fence and vandalism, there were still 126 snake funnel traps placed along the approximately 13,000 feet of drift fence. As in previous years of this study, the traps were closed for the winter on October 31, 2009 and opened the following spring on April 15, 2010. The perimeter drift fence helped stop and capture any species of snakes, turtles, frogs and toads trying to enter the SPR property. During the course of the 2009 field season, 24 species of reptiles and amphibians were found moving along the fence or captured in the drift fence traps.

2010 Trapping - HA followed the same protocol for the drift fence study as in prior years. Traps were opened on April 15, 2010 and were checked within a 48 hour time period throughout the active field season. There were 126 snake funnel traps placed along the approximately 13,000 feet of drift fence. As in previous years of this study, the traps were closed for the winter on October 31, 2010.

As a reminder, the purpose of the perimeter drift fence was to prevent Northern Pine Snakes (and other small wildlife), from entering the SPR property and construction areas. The perimeter drift fence also helped stop and capture any other species of snakes, turtles, frogs and toads trying to enter the SPR property. During the course of the 2010 field season, 19 species of reptiles and amphibians were found in the various drift fence traps. **Table 1** lists the confirmed species that were trapped over the four year drift fence study.

Figure 8. An adult male Northern Pine Snake that was captured in a drift fence trap. Notice the one-way swinging wire door.

In 2010, three new northern Pine Snakes were captured in the traps. Two were 2010 hatchlings and the other was a young adult (mostly likely a fourth year snake). Although not found by random searching, two eastern king snakes were captured in traps along the drift fences. Likewise, redback and northern red salamanders were not found by random searching, but only caught in the drift fence traps. In 2010, HA staff captured a significantly smaller number of reptiles and amphibians in the perimeter drift fence traps in comparison to previous years. This may be a result of the fact that the landfill habitat is no longer suitable because its conditions have been so altered from 2006. Pine Snakes may have changed their seasonal movements to a point where they no longer come in contact with the drift fence. The drop in the number of captures may also be due to the extremely hot and dry weather experienced in the summer of 2010, which resulted in less overall movement by reptiles and amphibians. A summary of all reptile and amphibian species captured in traps or moving along the drift fence are listed in **Table 1**.

Table 1. Reptile and Amphibian Species Captured or Observed along the Perimeter Drift Fence Trapping System on the SPR Property between 2007 and 2010 (see Excel spread sheets for total number of species captured) .

No. of Species	Common Name	Scientific Name
1	Eastern Box Turtle	(*Terrapene c. carolina*)
2	Spotted Turtle	(*Clemmys guttata*)
3	Eastern Painted Turtle	(*Chrysemys p. picta*)
4	Redbelly Turtle	(*Pseudemys rubriventris*)
5	Northern Fence Lizard	(*Sceloporus undulatus hyacinthinus*)
6	Northern Redbelly Snake	(*Storeria o. occipitomaculata*)
7	Eastern Garter Snake	(*Thamnophis s. sirtalis*)
8	Eastern Ribbon Snake	(*Thamnophis s. sauritus*)
9	Eastern Worm Snake	(*Carphophis a. amoenus*)
10	Rough Green Snake	(*Opheodrys aestivus*)
11	Eastern Hognose Snake	(*Heterodon platirhinos*)
12	Northern Black Racer	(*Coluber constrictor*)
13	Northern Pine Snake	(*Pituophis melanoleucus*)
14	Eastern Kingsnake	(*Lampropeltis getula*)
15	Northern Redback Salamander	(*Plethodon cinereus*)
16	Northern Red Salamander	(*Pseudotriton r ruber*)
17	Four-toed Salamander	(*Hemidactylium scutatum*)
18	Fowler's Toad	(*Anaxyrus fowleri*)
19	Eastern Spadefoot Toad	(*Scaphiopus h. holbrookii*)
20	Northern Spring Peeper	(*Pseudacris c. crucifer*)
21	Pine Barrens Treefrog	(*Hyla andersonii*)
22	Southern Gray Treefrog	(*Hyla chrysoscelis*)
23	Coastal Plain Leopard Frog	(*Lithobates utricularia*)
24	Wood Frog	(*Lithobates sylvatica*)
25	Green Frog	(*Lithobates clamitans melanota*)
26	Carpenter Frog	(*Lithobates virgatipes*)
27	Bull Frog	(*Lithobates catesbeiana*)

Figure 9. A trapped Northern Black Racer ready to strike.

Examples of Other HA Drift Fence Trapping Studies

In another long-term 10-year study of Northern Pine Snakes, that also included drift fence trapping and radio-telemetry, we captured a total of 40 individual specimens. Of the 40 Pine Snakes, 13 were caught in box traps along 2,500-feet of drift fences. We studied home ranges and maximum dispersal distance from hibernacula at a 1,417.5-hectare preserve in Cumberland County, New Jersey between 1993 and 2003. We discovered 22 different winter hibernacula that were used by this Pine Snake population. Of the 2 male and 8 female snakes monitored in hibernacula for 5-years, voluntary shifting was observed by 8 individuals. Seven snakes shifted dens between years once and one male shifted dens twice. In contrast, 2 females showed den philopatry for 5 consecutive years. Radio-tracked snakes were relocated in their habitat between 20 and 140 times.

The average Minimum Convex Polygon home range size of 27 radio-tracked Pine Snakes was 69.26-hectares (170.71-acres). The mean 100% MCP home range size of male snakes was 111.32-hectares (N = 14), whereas females had a smaller mean size of 75.72-hectares (N = 13). An adult male had the largest home range (184-hectares or 455.70-acres). The maximum distance traveled from its winter den was 1,609 meters (1.609 kilometers and/or 5,280 feet). The average maximum distance traveled by radio-tracked Pine Snakes, to and from their winter dens, was 952.9-meters (0.9529-kilometers). Of these, 50% (N=20) snakes traveled more than 1,000-meters, 20% (N=8) snakes traveled 1,100-meters, 10% (N=4) snakes traveled 1,200-meters, and 2.5% (N=1) snake moved 1,609-meters.

Some snakes were only radio-tracked for one full year, while others were tracked for 3 to 5-years. Snakes that were monitored for 2-years or more had larger home ranges than those individuals that were only radio-tracked for one year. Based upon these data, radio-tracking several adult snakes over a 3 to 5-year period is not only the most efficient method to find hibernacula locations of meta-populations, but reveals a more complete understanding of their ecology, secretive behavior and conservation needs (Zappalorti et al, 2015).

At another study site in Cumberland County, HA erected four linear drift fences (fence numbers 1, 2, 3 and 4) in the Spring (April 13, 2002) at selected habitat sites on a 1,350-acre property. Sites were chosen on the basis of habitat features and topography that were considered typical for Pine Snake use (Zappalorti et al, 1983). Their locations were selected in an attempt to maximize the area of the property sampled. All captured Pine Snakes and Black Racers that were not previously tagged were injected with an AVID ID pit tag.

From April through October, a total of 81 snakes were captured in the drift fence traps. Of the 81 snakes captured, there were 54 Black Racers (*Coluber constrictor*), 8 Northern Pine Snakes, and 19 individuals of several other species. These numbers include both initial captures and all recaptures in the traps.

Drift Fence Snake Trapping at Fort Dix

Three drift fences were erected at 3 different areas on Joint Base - McGuire, Fort Dix, Lakehurst property. The three linear fences were approximately 450-feet in length, totaling 1,350-feet. Each fence had 10 box funnel traps associated with it. The drift fence traversed various habitat types in an attempt to capture free-ranging Corn Snakes, Pine Snakes and/or Timber Rattlesnakes. This technique was used in conjunction with the visual sampling techniques to increase the chance of capturing one or more of the three target snake species. The drift fence was constructed of black nylon silt fencing, 3 feet in height, and was supported with oak stakes. Approximately 5-inches of the fence material was buried below grade level, thereby preventing snakes from crawling under the fence. A small hole (approximately 4-inches in diameter) was cut into the fence material at the ground surface, and a box funnel trap was connected to the hole, thus providing a place for snakes to crawl through the fence and become trapped (Dargan and Stickel 1949; Enge 1997a, 1997b; Casazza et al, 2000).

Each box trap measured approximately three feet long, one foot high and one foot wide. The traps were constructed from treated plywood and 1/4 inch mesh galvanized hardware cloth. Each trap had one plastic funnel placed with its wide end attached to the end of the trap, and the narrow end extending into the trap. A hinged lid with latches allowed easy access for snakes to be trapped (Casazza et al, 2000). The snake traps work on a principle similar to that of a minnow trap, where fish (and in this case, snakes) are able to enter the trap but have great difficulty in finding their way out. Leaves were placed in each trap to provide a cool, moist retreat for trapped animals. A plywood board was placed over the top to provide shade and reduce exposure to the sun (Enge 1997a and 1997b, 1998a, 1998b, 2001; Zappalorti and Torocco 2002).

Results of Drift Fence Trapping Surveys on Fort Dix - In 2010, HA's protocol for the drift fence traps followed the guidelines of the NJDEP's recommendation to check for captured wildlife every 24 to 48-hours. Trapped snakes and other reptiles and amphibians were identified, removed and released 2 meters away from the fence. After a rainfall, traps were checked along the drift fence every 24-hours, but if it was hot and dry they were checked every 48-hours. On September 1st we opened-up the three drift fences. The traps were removed from the drift fences on October 15, 2010 as per the contract. The purpose of the drift fence was to capture small wildlife (specifically Pine Snakes), on the JB-MDL property. The drift fence also helped capture other species of snakes, turtles, frogs and toads on the study site.

Results of Drift Fence Trapping and Random Searching - Between April 15 and May 30, three adult Pine Snakes were captured in drift fence traps. On June 1, we found a dead-on-road (DOR) adult female Pine Snake north of Bivouac Area 22 on Range Road. On June 12 a gravid female Pine Snake was captured hidden under plywood behind Range 86. This snake was suitable for a radio-transmitter implantation after she laid her eggs. On June 13 an adult female hognose snake was found under plywood behind Range 86. Northern fence lizards, northern black racers, eastern hognose snake, Fowler's toads and green frogs were the most commonly captured reptile and amphibian species. Random Searching also produced 6 Northern Pine Snakes in addition to the ones caught in traps. Of the 6 snakes, all were adults. Five of the of the 11 adult Pine Snakes were fitted with transmitters and radio-tracked during the 2010 field season. Any Pine Snakes captured after August 15 were not surgically implanted as per the NJDEP protocol for snake surgeries (Rudolph et al, 1998). Hatchling Pine Snakes (22), from nest sites were injected with micro-chip PIT Tags and released according to the protocol. In 2010, HA staff captured several other species of snakes including one live Corn Snake, 4 Hognose Snakes, 5 Black Racers, 2 Garter Snakes, 2 Ring-neck Snakes and 3 Worm Snakes using various other survey methods.

Results of Road Cruising - Road cruising means looking for snakes and other wildlife on paved or sand roads while driving from one location to another on Fort Dix. HA staff found both live and dead snakes (DOR) on the roads during our 2010 investigation. Many other forms of wildlife were also found DOR. We found at least one DOR northen Pine Snake every month of our survey, and in May and June 6 DOR's were observed. Three black racer snakes and two rough green snakes were found dead on Range Road between July and October. We also observed two box turtles and numerous fence lizards and Fowlers toads on Range Road and other connecting roads. While driving from one study site to another on 9-2-10, at 1500 hrs., HA staff found a road killed Corn Snake on Range Road, just south of the 539 entrance gate. It was an adult female. The snake was taken and frozen for DNA tissue samples. Two other DOR Corn Snakes were found on Route 539, one in July and the other in August. This is a good example showing that even if the target species of snakes occur on a study site they are not always easy to capture in drift fence traps. Random searching may find just as many individuals, and sometimes more than trapping efforts.

Monitoring Pine Snake Nests and Hatchlings

Female Pine Snakes often select open sandy areas, without dense trees to allow full sun penetration to their nesting sites (Burger and Zappalorti 1985). Gravid females return to their traditional nest site year after year in grassy areas. The nest site typically has some nearby cover where she can rest unobserved by predators during the hottest part of the day. The "nesting area" usually has Pennsylvania sedge grass (*Carex pennsylvaticus*), and other heat tolerant grasses with soil that is easy to excavate. Dry sugar sand is too soft and causes the tunnel and nest cavity to collapse when she is digging (or once the eggs are laid). Thus there is a delicate balance between sand soft enough for the snake to dig, but hard enough to support the roof of the tunnel. The roots of various grasses and Pennsylvania sedge provide soil stability and some slight moisture for the incubating eggs (Burger and Zappalorti 1991).

Juvenile and Hatchling Pine Snakes

A total of 22 hatchling Pine Snakes were captured at the three confirmed nest sites during the 2010 field season. Two other hatchlings were found killed on Range Road in the Fall. Hatchling snakes disperse into the forest to forage and seek shelter, but some often fall victim to mammal or bird predation (Fukada 1978; Fukada 1960; Fitch 1999). HA staff captured and PIT tagged all 22 new hatchlings, along with one juvenile Pine Snake caught in drift fence No. Two (Elbin and Burger 1994; Zappalorti et al, 1983; Burger et al, 1987).

Monitoring Pine Snake Nests and Hatchlings

Our research protocol was to locate, capture and mark any gravid Pine Snakes at a nesting area, or to capture digging females when they left their nests in the heat of the day to rest in shade. While we did not find any females excavating their nests, we did locate three nest sites in late June and early July. On August 20 and 21, we placed small silt fence corrals around the three Pine Snake nest sites discovered in June. This was done in order to capture hatchling Pine Snakes as they disperse from the nest sites.

The average clutch is nine eggs, so we were able to capture and mark 22 hatchling Pine Snakes by trapping the nest sites with corral fences. Each hatchling was injected with a micro-chip PIT Tag as part of the mark and recapture study. HA staff marked a total of 22 hatchling Pine Snakes during the 2010 field study. In this case, if one knows where a nest site is, encircling it with a drift fence will help capture all the snakes that hatch. It is important to cover the fenced area with bird netting to prevent predation of the snakes by birds of prey.

Figure 10. A circular drift fence corral around a winter hibernaculum on Joint Base McGuire, Dix, Lakehurst. Notice the metal stakes and five-feet high hardware cloth instead of using nylon silt fence material. The higher fence prevents snakes from climbing over and escaping capture.

Corralling of Natural Hibernacula - Since Pine Snakes often den communally (Burger et al 1988b; Burger and Zappalorti 2011), HA often corrals natural winter hibernacula. Natural dens are found via radio-tracking. The four dens on Fort Dix were encircled in the winter of 2010, in an attempt to capture new Pine Snakes, Corn Snakes, or other species in the Spring of 2011. We used 6-feet high metal stakes and 5-feet tall, 1/4 inch metal hardware cloth to construct the temporary circular enclosures. Four snake box traps were attached to the corrals and were checked every 48-hours during the Spring emergence period (Mid-March through Mid-May). **Figures 10** and **11** illustrate the circular den corrals used to capture 15 additional Pine Snakes. Encircling and trapping winter dens is an effective way of learning how many individual snakes may use a particular den. This type of trapping effort also demonstrates what other species of snakes share the hibernaculum. Over the past 35-years, HA has learned that several other species of snakes often use Pine Snake dens to overwinter, including Corn Snake, Hognose Snake, Coastal plain milk snake, Black Racer, Black Rat Snake, and on two occasions even Timber Rattlesnakes (Burger and Zappalorti, 2011).

Figure 11. Shows a snake box trap attached to the out side of the hardware cloth fence. Notice the sand ramp to allow easy access into the trap. As a snake returns to its den, it crawls along the base of the fence until it encounters the trap entrance hole.

DISCUSSION AND RECOMMENDATIONS

HA has provided examples of various snake drift fence trapping programs in the Pine Barrens of New Jersey over a 20-year period. Conducting mark and recapture studies requires being able to find snakes with some regularity in order to estimate population size, survivorship, growth in the wild and evidence of reproduction. Because snakes are secretive, fossorial creatures, and have the ability to remain hidden for long periods of time, they are not always observed in their habitat. That is why herpetologist sometimes use drift fence trapping systems to capture their target snake species.

Based upon research needs, deciding how to capture fossorial reptiles for short-term and/or long-term studies is always a challenge. Knowing where, when, and how to find these secretive reptiles can make a difference in the success or failure of a research project. One should learn as much as possible about the natural history of the target snake species, because many have limited yearly, seasonal, and/or daily activity patterns.

Collecting and monitoring fossorial and terrestrial reptiles presents a unique set of challenges, because so much of their life is hidden. Large gaps exist in our knowledge and understanding of the behavior and ecology of these secretive species (Mattison 1995). Sampling methods must be efficient at finding the target species while producing as little disruption in their habitat(s) as possible. 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 snake species selects on an hourly, daily, or seasonal basis is extremely important. Being able to predict when and how to search or trap for the target snake species may greatly enhance one's capture results (Zappalorti and Torocco 2002).

Selecting the Right Methods and Sampling Protocol - When drafting a plan for scientific research to investigate fossorial or terrestrial snakes, one should carefully consider what species to use as study subjects. The ideal situation is to find snakes in the wild as often as possible, and in substantial numbers. Furthermore, obtaining a large sample size is necessary for meaningful statistical data analysis. When dealing with secretive, fossorial snakes finding enough specimens on a regular basis is not always easy to achieve, or may not even be an option. Protected species listed as endangered or threatened (E&T species) are the forms most often in greatest need of ecological studies. Information gathered from field studies aids in the development of smart conservation and management programs for their continued survival. Some scientists are compelled to study E&T species because funding of research grants is most readily available from state or federal agencies. When collecting E&T species one should always obtain the necessary state or federal permits in order to legally do so. Coordination with state and/or federal agencies should always be sought before starting an investigation.

Care to minimize stress, damage, and mortality to target E&T species should be stringently taken. Guidelines such as those for the use of live snakes in field research developed concurrently by the American Society of Ichthyologists and Herpetologists, the Herpetologists' League, and the Society for the Study of Amphibians and Reptiles should be reviewed (IACUC 2001 [http://nersp.nerdc.ufl.edu/~iacuc/reptilerules.htm]). Minimal disturbance to a snake's nest or brooding site, basking site, major foraging areas, dens (hibernacula), and other key components of their habitat is an important consideration from a conservation standpoint.

Capture Success and Possible Problems - Environmental conditions such as temperature, precipitation, soil moisture, humidity, light intensity, wind, and season all have strong influences on snake activity patterns (Vogt and Hine 1982). Unsuitable weather conditions may lead to decreased terrestrial behavior, markedly reduced activity, shifts in habitat type used, and/or estivation. Complications affecting capture success may include: weather/climatic conditions, avoidance behavior by the target species, daily and seasonal activity patterns, and more important - the experience and skill of personnel conducting the field studies (Crosswhite, Fox and Thill 1999).

A reptile crossing a road or basking in an open field is easy to see, and thus easily captured by the average herpetologist. However, most snakes remain hidden for 50 to 75% of their lives and are difficult to find and capture. Just as when one views a piece of fine art work such as a painting, sculpture, or photograph, "beauty is in the eye of the beholder." Likewise, when searching for fossorial and/or terrestrial reptiles, the partially concealed reptile with it's cryptic coloration will only be seen by the eyes of the beholder. In other words, by the experienced field herpetologist. Therefore, a visual search image and basic understanding of the life history and behavior of the reptiles being sought is very important. This chapter contains instructions and suggestions on how to effectively sample secretive fossorial and terrestrial reptiles. It provides guidelines, general methods, and offers specific examples of how to help scientists successfully locate and sample hard-to-find fossorial and terrestrial reptiles.

Shelter or Cover Boards

Cover boards are plywood or metal rectangle or square sheets that are placed on cleared ground to create an inviting place for snakes and other reptiles to retreat under (Sutton, Mushinsky, and McCoy 1999, Tietje and Vreeland 1997). Warren (2000) placed 61-cm (2-feet) by 61-cm (2-feet) plywood boards atop wooden legs 5-cm (2-inches) by 5-cm (2-inches) by 10-cm (4-inches). The boards were then covered with 61-cm (2-feet) 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 although cover boards captured fewer total species than funnel traps, they did yield some species not found with other methods (Homyack and Giuliano 2000). Using cover boards in conjunction with random searching increases the number of specimens seen during a mark-recapture study, this higher sample allows an estimate of the size of a population (Catenazzi 2001).

Parmelee and Fitch (1995) conducted a long-term cover board experiment which compared the use of metal versus plywood, age of cover boards (seven years old versus new), and surface preparation (vegetation under the boards versus bare ground with vegetation removed). The investigators captured 105 snakes of eight species during their experiment, as well as two lizards (*Ophisaurus attenuatus* and *Scincella lateralis*) and one turtle (*Terrapene ornata*). There was no overall significant differences between the six shelter types, however metal shelters were avoided during the heat of mid-day because of high temperatures. The plywood boards were used during the heat of day because they did not absorb as much heat and were somewhat cooler (Parmelee and Fitch 1995). Henry Fitch used an assortment of methods to find and capture snakes at the University of Kansas' Natural History Reservation between 1948 and 1997. His best results were with the use of wire funnel traps (that he made himself) and artificial shelters (both plywood and metal) which yielded the best capture results. Eighteen different snake species were captured in his long-term (50+ years) study of a Kansas snake community (Fitch 1999).

Plastic Netting with Cover Boards

Stuart et al (2001), reported on the hazard of plastic netting as an entanglement obstacle to snakes and other wildlife. My own observation in the New Jersey Pine Barrens are similar to theirs. I have seen numerous species of snakes trapped in this inexpensive monofilament netting that is manufactured from polypropylene or polyethylene plastic. This material is widely used around private dwellings (backyards) and/or commercial gardens. Landscapers also use plastic netting to protect freshly planted grass seed that is covered with hay, so it has a chance to grow before birds eat it. A common application for netting is for the exclusion of birds, rabbits, ground hogs, white-tailed deer, and other wildlife from farm fields, orchards, vineyards, and backyard ponds. This material, often marketed as "bird netting," comes in a variety of square or rectangular mesh sizes (13-37 mm); most of the netting I have seen is made of sturdy, monofilament strands (ca. 0.25 mm thick) that are resistant to degradation from ultraviolet light. The various turtles and snakes I have seen trapped in plastic netting include box turtles (*Terrapena carolina*), spotted turtles (*Clemmys guttata*), timber rattlesnake (*Crotalus horridus*), hognose snake (*Heterodon platirhinos*), garter snake (*Thamnophis sirtalis*), water snake (*Nerodia sipedon*), black racer (*Coluber constrictor*), pine snake, and corn snake. While all the snakes I saw were seriously entangled, and some were injured with skin lacerations and swelling, none succumbed from being trapped. Had I not been called by the property owners, the snakes would have surely died from heat stroke in a day or so.

Since snakes were caught so readily in plastic netting (Reed et al, 2000), I tried using it under cover boards in areas where I knew snakes were present. I stabled 4 feet by 5 feet sections of plastic netting along the center of a 4 by 8 feet sheet of half inch plywood. The plywood was placed with the netting down, and elevated with fallen logs, so it was at least 5 to 10 inches above the ground surface. The plastic netting was arranged in layers, so that if a snake crawled under the board, it would become entangled. The plywood also acted as a shade board, so the trapped snake would not be exposed to possibly lethal rays of direct sunlight. I baited the ground under the bottom of the plywood with nesting material of white-footed mice (*Peromyscus mucosus*) and chicken feed, corn, and grain to attract small mammals. Several snakes (i.e., pine, hognose, corn, and black racer) were captured using this method. The drawback to this method is that the “sucker boards” must be checked daily for the good health and safety of the trapped snake.

Snakes are drawn to grassland habitat because of the abundant prey species they find there as HA has observed based upon similar Pine Snake and Corn Snake management and conservation studies at the Audubon Sanctuary in western Berkeley Township, Ocean County, New Jersey (Robert Zappalorti, personal observations). This current rare snake study on the JB-MDL property is similar to other snake studies published in the literature such as Kauffeld (1957), Zappalorti et al, (1985), Burger and Zappalorti (1986, 1987, 1988, 1989, 1991 and 1992), Burger et al, (2000), Burger et al, (2007), Himes et al, (2006), Gerald, Bailey and Holmes (2006a and 2006b), and Golden et al, (2009), and this study will compliment and enhance our knowledge of these secretive snake species.

Do Drift Fences with Funnel Traps Work?

Gibbons (1983) thinks drift fences with pitfall traps capture more kinds of reptiles than any other method of trapping technique used by herpetologists. For example, the rainbow snake (*Farancia erytrogramma*) is seldom seen in the wild, even by experienced herpetologists. It spends most of its time underground, or in or near water (Conant and Collins 1998). Gibbons' South Carolina study featured a 30-inch high aluminum flashing drift fence (one mile long, encircling a Carolina Bay wetland) with a 5-gallon bucket pitfall traps every thirty feet. This drift fence caught 28 rainbow snakes in a single day in 1975 (Gibbons 1983). Crosswhite, Fox and Thill (1999) found drift fence arrays to be the most effective method of sampling snake populations. Shewchuk et al. (1998) found the most effective combination for catching snakes was drift fences with funnel traps.

Drift fences with pitfalls and funnel traps sampled herpetofauna at five study sites in five Chicago region counties (Mierzwa 1993). One to four drift fences were used per site, resulting in 1,935 captures of 20 species. Mierzwa (1993) found that drift fences are more effective and less biased than other collecting methods for amphibians and reptiles, echoing Campbell and Christman (1982) and Rudis (1984), and provide easily quantified data.

Enge (1998) designed a drift fence array with funnel traps to identify and compare herpetofaunal communities of steephead ravines in two river drainages in Florida. Each drift fence array (modified from that of Jones 1986) had three arms radiating outward at 120 degree angles and was constructed of 30.5 m long and 92 cm wide silt fencing. Arrays were erected adjacent to streams, and some intersected streams, and some of the arms had end traps in the water. Four funnel traps (86 cm long) of aluminum window screening fastened with staples were used per arm. Both single-opening and double-opening funnel traps were used. Funnel traps were shaded with masonite and provided with moistened sponges to minimize desiccation. Six arrays in Apalachicola ravines had 1,233 captures of 34 species of reptiles and amphibians, and six drift fence arrays in Ochlockonee ravines had 2,283 of 31 species in 216 total trapping days. Fifteen snake species, three lizard species, three skink species, and three turtle species were captured, marked and released on the opposite side of the fence. Twenty-one species of anurans and salamanders were also captured (Enge 1998).

Restraints and Drawbacks of Trapping Snakes

The first drawback to erecting drift fences and trapping snakes is the cost of material to build the snake traps (**Figures 3** to **6**). Each trap costs approximately $30.00 for material and labor. The second downside is the cost of fence material. Nylon silt fence costs $2.00 a foot, and wire hardware cloth cost $125.00 for a 50-feet roll. Once the material is gathered, then one has to select suitable locations in the snakes habitat to install and erect the fence and set the traps properly. Depending upon the habitat type, vegetation has to be cleared and tree limbs cut away to keep snakes from climbing over the fence. The final drawback is the labor of checking the traps on a daily basis, or every 48-hours depending on weather conditions and the permit requirements of state regulations.

CONCLUSIONS

Understanding the life history and ecology of fossorial and terrestrial snakes will greatly enhance scientific research. Once one knows how, when, and where to capture these secretive reptiles, better capture results should and can be achieved. By considering and perhaps combining some of the methods suggested in this report, such as: Visual Encounter Surveys, Random Opportunistic Sampling, Time Constrained Searches, Road Cruising, Cover Boards, Drift Fences with Funnel Traps, Radio-tracking, and Marking with PIT Tags, one's chances are greatly increased to capture and better study these secretive reptiles.

Learning about the biology of these fossorial and terrestrial reptiles, such as the importance of foraging ecology, basking and thermoregulation behavior, types of hibernacula selected, and activity periods and home-ranges, one can utilize this knowledge and thus increase the chances of capturing study specimens. Likewise careful planning should lead to a successful study. Opinions vary as to the effectiveness of different techniques and combinations of techniques. It is difficult to generalize as each snake group being studied will have to be tailor-made to the habitat situation the serpents occupy. The above examples should be considered to see if your study could incorporate some, or all of the techniques discussed. Refer to their sources in the bibliography for more detailed information.

When designing a sampling program that involves the capture of fossorial or terrestrial snakes, one should plan their investigation using the following information:

❀ Description of the natural history, behavior and habitat needs of the target snake species;

❀ Conduct a habitat evaluation as to the likelihood of it being suitable for one or more of the target reptile species;

❀ Develop methodologies for conducting an intensive survey to determine whether any of the target snake species are present in the study area;

❀ Select the specific techniques that must be used, and the best season(s) or time period(s) over which such surveys should be conducted;

❀ Determine if the site is critical habitat for the target species (i.e., birthing rookery, shedding station, winter hibernacula, important basking or foraging area);

❀ Prepare the manner in which data should be recorded in the field and presented in a final report; and

❀ Conduct a literature search and provide references to scientific publications for sources of

information about the target snake species being studied and any other relevant survey methods.

In addition, there is room to be creative in devising new and better sampling methods for fossorial and terrestrial snakes. New techniques for sampling, such as designing better trapping methods, or improved radio-tracking devices and technology, will enhance our knowledge of wild fossorial and terrestrial reptile populations. Modifications and improvements to traditional methods will yield more captures, more frequently, and provide sufficient data sets.

Many of the citations and sampling examples provided in the literature cited section of this protocol are not specifically from studies performed on fossorial and terrestrial snakes, but the techniques and information are of value nevertheless. The techniques suggested in this report will help one to find, observe, survey, and capture snakes in difficult-to-sample habitats, and in many cases these methods can be directly applied to finding and capturing them in sufficient numbers for meaningful statistical analysis.

Respectfully submitted,

Herpetological Associates, Inc.

Figure 12. A nylon drift fence erected in a field habitat.

Figure 13. Measuring and injecting a Pit Tag in a juvenile Pine Snake caught in a drift fence trap.

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Northern Pinesnake (*Pituophis melanoleucus*)

Herpetological Associates, Inc.
405 Magnolia Road, Pemberton, New Jersey 08068

Mobile: 609-618-0314

Visit our web site at: HerpetologicalAssociates.com