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# *2009 Annual Northern Pine Snake Monitoring and Radio-tracking Report, at the Stafford Business Park, Stafford Township, Ocean County, New Jersey*

***Submitted October 13, 2010***

***To***


**Mr. Joseph Del Duca, Partner and General Counsel**

***The Walters Group***

**500 Barnegat Blvd. North - Building 100**
**Barnegat, New Jersey 08005**

***By***

**Robert T. Zappalorti, Matthew P. McCort and David W. Burkett**

***Herpetological Associates, Inc.***

***Environmental Consultants - Plant and Wildlife Specialists***
***575 Toms River Road Jackson, New Jersey 08527***

***and***

**Dave Golden, Senior Zoologist**

***Division of Fish and Wildlife***

***Endangered and Nongame Species Program***
***New Jersey Department of Environmental Protection***
***Trenton, New Jersey 08625***

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## INTRODUCTION

This is the third annual northern pine snake (*Pituophis m. melanoleucus*) progress report with respect to the on-going commercial and residential development known as Stafford Park Redevelopment property (hereafter SPR property) in Stafford Township, Ocean County, New Jersey (**Figure 1**). The SPR property is 370-acres in size. Providing a framework for this project, is the June 28, 2006 Memorandum of Agreement (hereafter MOA) which was made between Walters Homes, Inc. (hereafter Walters), Stafford Township, and the New Jersey Pinelands Commission (hereafter the Commission). As part of its responsibilities for this development, Walters has built a new legal landfill on the redevelopment site to replace the old one that was contaminated. The new landfill has been sealed and capped, and planted with warm season grasses. Walters has created three pine snake habitat management fields, containing six artificial overwintering hibernacula (hereafter dens); shifted a portion of the population of pine snakes; and initiated a seven-year pine snake monitoring program. Walters has also constructed a large commercial (retail) section of the proposed development and began residential development (apartment buildings) in 2009.

## BACKGROUND INFORMATION

Threatened and endangered species surveys commenced at the SPR property in April 2004. These surveys, which were conducted by EcolSciences, Inc., revealed the presence of three (3) state-listed species, including the northern pine snake. The northern pine snake is listed as a state-threatened species in New Jersey by the NJDEP, and it occurs on, and in the vicinity of the SPR property. Considerable effort was put forth surveying the SPR property site for pine snakes during the 2004, 2005 and 2006 activity seasons. In May of 2006, Herpetological Associates, Inc. (hereafter HA) was asked to assist with the ongoing research. Through these intensive surveys, it was found that the SPR property was providing critical foraging, nesting, and overwintering habitat for northern pine snakes. It was determined that pine snakes on the SPR property required a long-term management and conservation study plan.

Walters was permitted to proceed with the SPR project provided that specific conditions were met regarding the mitigation of potential impacts to pine snakes, as well as other threatened and endangered plant and wildlife species. A progress report for rare plants was provided by HA under a separate cover. HA and Dave Golden, Senior Zoologist with the New Jersey Department of Environmental Protection's Endangered and Nongame Species Program (hereafter the Department), were asked to design and write a Conservation, Mitigation and Management Plan for pine snakes on the SPR property site. These conditions were outlined in the June 28, 2006 MOA. In accordance with the MOA, all funding for the conservation plan is provided by Walters Homes. This plan consists of two parts, a Relocation and Management Plan - **Part I** and a Radio-tracking and Monitoring Plan - **Part II**.

On December 4, 2006, HA submitted the final pine snake relocation and monitoring plan entitled: "Northern Pine Snake Management and Conservation Plan, and Radio-tracking and Monitoring Plan for Stafford Business Park and Stafford Forge WMA," to the Commission (Zappalorti and Golden 2006).


**Figure 1**. 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 licenced landfill is centered on the western portion of the SPR property (highlighted with white lines), Retention Basin D is located at the extreme west of the site (highlighted in white), the three pine snake mitigation and management fields are due west of the site (outlined in red lines), and the perimeter exclusion drift fence that surrounds the SPR property (is also outlined with red lines). Source: Walters, Inc.

The seven-year, long-term monitoring program will evaluate whether the pine snakes shifted from the old landfill at the Stafford Business Park will use and exploit the newly created artificial dens and management fields. Habitat manipulation and the management fields were provided as an alternative to replace the lost landfill habitat within the Stafford Business Park Redevelopment site.

According to Zappalorti and Golden (2006), the long-term field studies and radio-tracking monitoring program will address and may possibly answer the following six research questions:

**1.** Can adult and hatchling northern pine snakes establish themselves and overwinter successfully in constructed artificial hibernacula after being shifted to a different area within their known activity range?

**2**. Will non-shifted northern pine snakes (or other snake species) from the existing Stafford Forge Wildlife Management Area population begin to use the artificial hibernacula constructed at the three management fields on their own?

**3**. How do the spatial movements and other behaviors (*e.g.*, habitat use, foraging, mating, nesting, and denning) of the shifted pine snakes differ from the non-shifted pine snakes?

**4**. Do pine snakes from this population (both those shifted to the management fields and others) attempt to move back onto the redevelopment area of Stafford Township Business Park during the construction period, and if so, does this tendency diminish over time?

**5**. Will a higher percentage of northern pine snakes (adults and juveniles) return to, and overwinter in, the artificial hibernacula when they are kept in an enclosed area around the hibernacula and fed for two winters versus only a single winter?

**6**. Will shifted and non-shifted gravid (carrying developing eggs) female northern pine snakes from this population begin using the three management fields as nesting habitat in future years?

## MATERIALS AND METHODS

### HA Staff and Researchers

There were numerous tasks to be performed during the 2009 field season at the SPR property. The following HA staff assisted with these jobs or were present during some, or all of the plant and wildlife surveys: David Burkett, Robert Hamilton, William Callaghan, Joe Embrey, Raymond Farrell, Robert Fengya, Ted Gordon, Zigmund Leszczynski, Matthew McCort, Pete Mooney, David Schneider, Michael Zappalorti and Robert Zappalorti. Additionally, Dave Golden (Division of Fish and Wildlife, NJDEP), also advised and assisted with various tasks throughout the 2009 field season.

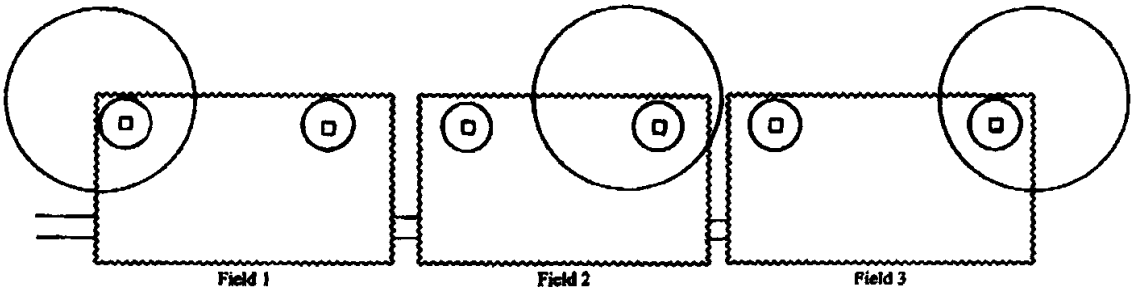
### CREATION OF MANAGEMENT FIELDS AND ARTIFICIAL DENS

The relocation and management phase of the conservation plan included habitat manipulation for pine snakes that were collected and shifted from the SPR property. HA and the Division supervised the creation of three pine snake management fields (hereafter MF 1 through 3), at preselected suitable sites within Stafford Forge WMA. Each cleared field measures approximately 300 feet by 800 feet in size (or a total of 5.5-acres, see **Figure 2**). These three 5.5-acre fields were meant to replace the open grassland habitat that was lost on the SPR site (e.g., the foraging habitat and nesting areas on the old unlicensed landfill). Two snake dens (artificial hibernacula), were constructed on each management field, approximately 350 feet from one another (Gillingham and Carpenter 1978, Frier and Zappalorti 1983). Each hibernaculum was encircled with a one-acre fence to keep the snakes within the den enclosures. The circular fences stood 5 feet in height. Three of the dens (AH 1, 4, and 6) had a larger, 3-acre perimeter fence for holding the pine snakes over a twenty month period (1.5 years). A total of 95 pine snakes were released into the dens in the fall of 2006 (20 adults, 4 sub-adults and 71 hatchlings).

These snakes were randomly selected for distribution into Treatments A and B (A = one-winter treatment and B = two-winter treatment). The third treatment, Treatment C (the lab treatment) was not originally planned, but was created out of necessity after it was determined that 8 of the pine snakes were not healthy enough to be released in the fall of 2006.

Unlike Treatments A and B, snakes were not randomly assigned to Treatment C and were held in HA's laboratory for one winter. All 8 snakes placed in Treatment C were determined to be healthy enough to be released into the two-winter treatments in the spring of 2007, and were monitored via radio-telemetry through the 2007, 2008 and 2009 activity seasons.

**Figure 2.** Original layout of the Northern Pine Snake Management Fields, showing the artificial hibernacula and former location of the corral fences at Stafford Forge WMA, in 2006-2007. In 2008 corral walls were removed from around all artificial hibernacula. Only the fields and artificial dens remain in 2009.




**Legend**: □ = Artificial Hibernaculum, ❍ = Small Winter Fence, ◯ = Large Summer Holding Corral.

**Note**: Diagrammatic drawing is not to scale. See description in section above for size details titled "Creation of Management Fields and Artificial Dens."

After emerging from the artificial dens, snakes in the two-winter treatments were all released into the 3-acre corrals. On May 16, 2007, a severe forest fire devastated the entire pine snake study area and the three management fields, burning all the fabric off the fences and all the vegetative cover in the forest. Due to complications from hawk predation and damage related to the May 16, 2007 forest fire, these three, 3-acre perimeter fences could no longer be used. Two-winter treatment snakes were instead held within the 1-acre corrals for the twenty month period mentioned above. After one winter of hibernation, snakes emerging from dens 2, 3, and 5 (the one-winter treatments) were allowed to disperse into the surrounding Stafford Forge WMA forest habitat.

Another portion of the relocation and management phase of the conservation plan involved habitat enhancement for pine snakes. This included the construction of 6 foot high earthen berms along the edges of the three 3 fields and large earthen and wood debris piles within the center of the fields. These earthen berms were constructed out of A-horizon sand, stumps, logs and brush. The fields provide pine snakes with forest-edge type habitat suitable for basking and resting. The fields also allow for open, sandy areas that provide potential nesting habitat for female pine snakes. As part of the habitat enhancement, HA and the Department planted grasses on the fields to replicate the lost landfill field habitat. Open grassy fields have been shown to be good nesting and foraging habitat for northern pine snakes (Burger and Zappalorti 1986 and 1991). For greater detail on the success of the habitat enhancement, please refer to the discussion section of this report.

## ONSITE MONITORING

One of our tasks was to act as environmental monitors during various construction activities on the SPR site. During any habitat alteration, a qualified HA staff member was present to examine the area for any reptiles or amphibians that may have been present within the habitat. Any animals found during these activities were collected, documented and released in the nearest section of protected Stafford Forge WMA forest. The clearing of the forest within the SPR property boundaries was mostly completed in 2006 and 2007. Pertinent data with respect to environmental monitoring is further explained in the results section of this report.

## HABITAT EVALUATION

HA has three criteria for judging the potential value of the available habitat and its existing conditions for endangered, threatened or rare species (ETR species). These are:

**1. Structure of Available Habitat:** Both the biotic and abiotic components are considered. These are good indicators for the possible occurrence of particular ETR species within a specific study area (Burger and Zappalorti, 1986; Reinert and Zappalorti, 1988a and 1988b; and Heyer et al., 1994).

**2. Historic Evidence:** Known sightings of the target ETR species in the State Natural Heritage Program database, and historic records on or in the vicinity of a study site, are important to the overall evaluation of a site as habitat for ETR species (Zappalorti and Johnson, 1982, Golden and Jenkins 2003, Golden et al. 2009).

**3. Indicator Species:** The presence of plant and animal species that are often found in association with a target ETR species is highly informative when evaluating the suitability of a study site. Such indicator species may include food/prey organisms, or species that typically occur in similar or identical habitats as the target ETR species. The presence of associated or indicator species demonstrates the ecological value of the habitat within a particular study site (Frier and Zappalorti 1983, Brown 1993, Kingsbury and Gibson 2002).

## REPTILE AND AMPHIBIAN SURVEY TECHNIQUES

Reptiles and amphibians are often difficult to census due to their highly secretive nature and ability to remain hidden for long periods of time. Environmental conditions such as ambient temperature, precipitation, soil moisture, relative humidity, light intensity, wind, and season have strong influences on reptile and amphibian activity patterns (Vogt and Hine, 1982). Unsuitable weather conditions may lead to increased fossorial behavior (burrowing), markedly reduced activity, shifts in habitat usage, and/or estivation (dormancy during hot and dry conditions). Therefore, the use of several sampling techniques which take into account the various aspects of an animal's biology will often result in the best assessment of the target species' relative abundance (Zappalorti and Torocco 2002). The following visual search methods were performed.

### *Random Opportunistic Sampling (ROS)*

A simple method used by the trained herpetologist, ROS was employed in conjunction with other sampling techniques on the study site. Habitat that showed potential for target species were searched. This search method is not constrained or standardized in time transects, but instead relied on the experience and professional judgement of the investigators. This method is effective if there are no time constraints, however detailed surveys will be performed as a follow-up (Campbell and Christman 1982; Karns 1986). Qualitative impressions were determined as to the relative abundance and habitat use of certain species during ROS. All wildlife encountered was recorded to supplement the species list generated by other field methods.

### *Time-constrained Searching (TCS)*

A specific habitat (e.g., oak/pine forest, pine/oak forest, wetland corridor) was selected, and all potential hiding places for reptiles and amphibians were searched. Fallen logs, stones, leaf-litter, artificial cover objects (discarded sheets of wood or metal, rugs, and furniture), were overturned. Open, sunny areas were searched for surface active or basking snakes. Spatial boundaries for each search were limited to the selected habitat. Time limits ensured that each habitat was adequately, but not excessively, examined. When target species congregate in particular habitats (e.g., nesting area, hibernacula) for important life history events, TCS is highly productive and superior to other types of surveys methods (Campbell and Christman 1982; Karns 1986).

### *Diurnal and Nocturnal Road Cruising*

Roads which border potential habitat often yield both living and "road-killed" (referred to as DOR, "Dead On Road") reptiles, amphibians, and other animals. Identification of species found while "road cruising" can provide useful information on migration routes, activity patterns, and habitat utilization/partitioning. The basic presence or absence of a species in a particular area can also be determined by the identification of their remains alone. Road cruising was used passively, such as while driving to and from the site or while driving/walking to and from areas on the site, or it was initiated as a specific surveying technique. This method involved driving a vehicle at slow speed along sand trails and paved roads at various times of the day and/or night. Road cruising is often highly productive on warm, humid or rainy spring nights, or during other periods of high activity. Animals moving across roads and those killed were collected and/or identified (Campbell and Christman, 1982; Karns, 1986; Zappalorti and Torocco 2002).

### *Pine Snake Nest Survey*

Surveys for pine snake nests were conducted visually. Typical pine snake nesting habitat consists of sandy uplands with few shrubs or tree cover and characteristic plants such as Pennsylvania sedge (*Carex pennsylvanica*) and golden heather (*Hudsonia* sp. - Burger and Zappalorti, 1986). Pine snake nests can be located by the characteristic sand dump pile left by the nesting female after nesting (Burger and Zappalorti, 1991). Additionally, pine snake nesting areas can be found by locating the hatchlings (or their fresh shed skins) in early September when the effects of weather makes the sand dump piles difficult to find (Zappalorti, personal observations). The primary goal of these surveys was to delineate critical pine snake nesting habitat. All potential pine snake nesting habitat was carefully walked using 10 foot parallel transects. Surveys were conducted during the nesting period (late June-early July), as well as in early September. In 2009, nest searching efforts were concentrated within Stafford Forge WMA, with the main emphasis placed on the management fields created in 2006. HA staff observed several potential pine snake nests within the management fields. Some of these were already identified as actual nests via observations of radio-tracked females. Not as much time was spent on the landfill and SPR property itself, as was in the past, due to all known nesting areas on the landfill having been destroyed. HA staff did conduct occasional surveys of the landfill and SPR property with no pine snake nests being noted.

### *Drift Fence Trapping*

One large perimeter drift fence, totaling approximately 13,000 feet, has 126 box funnel traps associated with it, was erected around 90% of the study site and has been in operation since April 15, 2006. The fence traverses various habitat types in an attempt to capture free-ranging pine snakes. This technique was used in conjunction with the visual sampling techniques described above to increase the chance of capturing pine snakes. The perimeter drift fence is also meant to exclude pine snakes and other species from entering the SPR property. The drift fence was constructed of black nylon silt fence, 3 feet in height, and was supported with oak stakes. Approximately 5 inches of the fence material is 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 measures 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 has 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 allows easy access to trapped snakes (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 and 2001).

### *Protocol for Releasing Trapped Pine Snakes Found Within the SPR Property*

As stated on Page 10, and Attachment "B" Page 1, of the MOA, one of the goals of the Species Management Plan is the protection of threatened and endangered species on the SPR site from adverse impacts and direct harm during the redevelopment process. This includes, but is not limited to, the reestablishment of threatened and endangered species at appropriate areas designated by the Pinelands Commission and the NJDEP, and to take measures to preclude such species from returning to the disturbed 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 (656 feet), 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), and PIT tagged, then released according to the same procedure followed for radio-tracked specimens. Snakes that were found within the SPR property, who either traveled down the management field access road or otherwise breached the perimeter drift fence, were moved about 200 meters into the forest adjacent to the point of capture, outside the perimeter drift fence. This was the procedure we followed for all snakes in the traps or found within the SPR in 2007, 2008 and 2009. As a result, some snakes were shifted and released on the edge of the management fields, including some gravid females who were trying to go to their traditional nesting site on the SPR property.

### RADIO-TELEMETRY

Radio-tracking is a method used to monitor the movements, habitat use and behavior of free-ranging pine snakes. Advanced Telemetry Systems, Inc. R1535 or R1520 transmitter units were used. Transmitters were designed so that their mass represents less than 5% of the snake's body weight. The typical reception range of the transmitters was 400 to 1000 meters. Transmitters were surgically implanted in the coelomic cavity following the general procedure of Reinert and Cundall (1982), with improvements and modifications (Mech 1983, Reinert 1992). All snakes captured prior to 2007 were surgically implanted by a veterinarian hired by EcolSciences, Inc. All surgeries performed on snakes captured in 2007, 2008 and 2009 were conducted by qualified HA staff members in HA's laboratory in Jackson, New Jersey. Any future surgical implantation of study snakes will be conducted by a qualified HA staff member (e.g., Zappalorti, Torocco, McCort and/or Schneider).

Pine snakes with transmitter implants were located in the field once every 48 hour period using a Wildlife Materials International (Model TRX-2000S) receiver, unless weather conditions forced changes to the tracking schedule interval. Equipment problems (either transmitter or receiver) also affected the radio-tracking frequency intervals, but that aside, attempts to locate each snake were made every 48 hours (Mech 1983). Each snake re-location was recorded in the field using a Trimble GeoExplorer 3 GPS unit along with all weather and habitat use data.

### *Transmitter Surgeries in 2009*

All snake surgeries were done before August 15, 2009 (Rudolph et al, 1998). Non-shifted snakes that were captured and implanted with transmitters in 2007 had their old transmitters removed and replaced in 2009. Nine snakes were systematically collected from the field for the surgical procedure. After transmitter removal, HA staff assessed the overall health of each snake. Time frames for re-implantation and eventual release varied with the condition of each specimen. Authorized HA staff conducted all transmitter removal and implantation surgeries. Eight of the 9 snakes successfully had their old transmitters removed and replaced. One male (Field Number 2007.03) was deemed to be in poor health due to low body weight and was not in suitable condition for transmitter removal surgery. Instead, it was rehabilitated in HA's laboratory. It has since gained back sufficient body mass and will have its transmitter removed and be retired from the study.

### *Activity Range Analysis*

Radio-telemetry and GPS plotted points provided the data necessary for the calculation of activity ranges for all radio-tracked monitored pine snakes. Activity range is defined as the area each snake used for all life history activities over the course of a season, which includes emergence from hibernation until winter ingress back into its den (Gregory et al, 1987). Two methods were used to arrive at the activity range for each snake: 100% Minimum Convex Polygon and Kernel Activity Range (Samuel et al, 1985; Tiebout and Carey 1987; Tufto et al, 1996; Seaman and Powell1996).

### *Minimum Convex Polygon Activity Range*

The Minimum Convex Polygon (MCP) method of activity range analysis has historic prominence in the literature due to its relative ease of use. This MCP method uses the outer most points plotted on a map which includes 100% of the relocation points to calculate activity ranges for each snake. The outermost points on the map are connected to form a polygon. The area of the polygon is then calculated to arrive at the MCP activity range. Activity ranges maps were produced using ArcView 3.2 (Environmental Systems Research Institute, ESRI, Inc., 1992-1999) and activity range maps/calculations were done with the Animal Movement Program 2.0 (Hooge et al. 1997, USGS, Alaska Biological Science Center).

### *Kernel Activity Range*

Kernel Activity Range is calculated via a fixed kernel activity range utilization distribution (Worton, 1989) as a grid coverage using least squares cross validation (Silverman, 1986) for the smoothing parameter (H). The bivariate normal density kernel is used as suggested by Worton (1989). Kernel Activity Range uses non-parametric statistical procedures to calculate probabilities of an animal being in various locations in two-dimensional space and adjusts the activity range boundaries for local variation in frequency. Two different measures of activity range were calculated at 90% and 50% respectively. Each percentage is displayed on a base map of the study site as an area, representing the probability (90% and 50%) of each study animal occurring in that area at any given time based on the existing 2009 radio-telemetry data.

## RESULTS OF THE 2009 INVESTIGATION

### Description of Existing Conditions and Habitats

The 370-acre SPR property consists of a mixture of habitats, comprised mostly of upland pine forest and disturbed open field. The property is bordered to the west and the south by the Division's Stafford Forge Wildlife Management Area and the north and east by Route 72 and the Garden State Parkway, respectively (**Figures 1** and **2**). The northern portion of the property is comprised of three areas. The buffer zone for the Mill Creek wetland corridor, Ocean County facilities (public works, maintenance, mulching center, etc.), and the capped licensed landfill. A variety of wetland habitats exist within the Mill Creek wetland corridor, such as Atlantic white cedar (*Chamaecyparis thyoides*) swamp, deciduous hardwood swamp, and emergent wetland. The ecotone or transition area to the upland oak/pine forest, and the oak/pine forest itself, still partially exists and will remain intact, as a good portion is protected within the wetland buffer. The southern portion of the site was formally a large tract of upland pine forest. This forest was cleared and graded to the property line in 2007. The western portion of the site consists mainly of the licensed, capped landfill and an area temporarily stabilized with vegetation awaiting residential development. Storm water basins and Ocean County municipal property comprise the remainder. The eastern portion of the site is now a new shopping center with chain stores such as Dick's, Best Buy, Pet Smart, Costco and Target. There are two storm water basins and an irrigation pond associated with the shopping mall.

The center of the site was cleared and otherwise prepared for commercial and residential development in October and November 2008. In 2009, low-income residential housing was completed on the center portion of the site, opened to the public and is now mostly occupied. In addition to the habitat alteration that has occurred on the SPR site, the NJ Forest Fire Service initiated an extensive tree-thinning effort within the Stafford Forge WMA (which borders a majority of the SPR site) in 2009. This was in response to the forest fire that raged throughout Stafford Forge WMA in May of 2007. In hopes of reducing damage caused by unexpected forest fires in the future, the fire service began to selectively cut trees within prescribed areas of forest. This forestry procedure is a method used to reduce the risk of accelerated canopy burn during an uncontrolled forest fire. It is unknown what effects (if any) the tree clearing process will have upon the local pine snake population, but HA believes there will be no adverse impact. In fact, the tree thinning will most likely benefit the pine snakes by increasing rodent populations and providing more basking opportunities.

**Figure 3**. A female pine snake basking in a scrub oak tree about one-meter above the ground. Photo by Robert Hamilton, HA Staff.

## REPTILE AND AMPHIBIAN SURVEYS

### *Visual Survey Results for 2009*

Visual surveys resulted in the capture and identification of 24 reptile and amphibian species in and around the SPR property and the adjacent Stafford Forge WMA. The 24 confirmed species are:

1. eastern box turtle (*Terrapene c. carolina*)
2. spotted turtle (*Clemmys guttata*)
3. eastern painted turtle (*Chrysemys p. picta*)
4. common snapping turtle (*Chelydra s. serpentina*)
5. redbelly turtle (*Pseudemys rubriventris*)
6. northern fence lizard (*Sceloporus undulatus hyacinthinus*)
7. northern water snake (*Nerodia s. sipedon*)
8. eastern garter snake (*Thamnophis s. sirtalis*)
9. eastern ribbon snake (*Thamnophis s. sauritus*)
10. coastal plain milk snake (*Lampropeltis t. triangulum x elapsoides*)
11. rough green snake (*Opheodrys aestivus*)
12. eastern hognose snake (*Heterodon platirhinos*)
13. northern black racer (*Coluber c. constrictor*)
14. northern pine snake (*Pituophis m. melanoleucus*) (state-threatened species)
15. redback salamander (*Plethodon cinereus*)
16. northern red salamander (*Pseudotriton r. ruber*)
17. Fowler's toad (*Bufo woodhousii fowleri*)
18. northern spring peeper (*Pseudacris c. crucifer*)
19. Pine Barrens treefrog (*Hyla andersonii*) (state-threatened species)
20. southern gray treefrog (*Hyla chrysoscelis*) (state-endangered species)
21. southern leopard frog (*Rana utricularia*)
22. green frog (*Rana clamitans melanota*)
23. bullfrog (*Rana catesbeiana*)
24. carpenter frog (*Rana virgatipes*)

### *Drift Fence Survey Results for 2009*

In 2009, HA followed the same protocol for the drift fence studies. Michael Zappalorti was the person who checked the traps and removed and released snakes and other wildlife back into the Stafford Forge WMA. 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. Because 8 of the traps were built by EcolSciences and lacked the one way swinging doors, these 8 traps were removed from the drift fence in 2009. 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 purpose of the perimeter drift fence is to prevent small wildlife (specifically pine snakes), 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 2009 field season, 24 species of reptiles and amphibians were found captured in the drift fence traps. The 24 confirmed species are:

1. eastern box turtle (*Terrapene c. carolina*)
2. eastern painted turtle (*Chrysemys p. picta*)
3. common snapping turtle (*Chelydra s. serpentina*)
5. northern fence lizard (*Sceloporus undulatus hyacinthinus*)
6. northern water snake (*Nerodia s. sipedon*)
7. redbelly snake (*Storeria o. occipitomaculata*)
8. eastern garter snake (*Thamnophis s. sirtalis*)
9. eastern ribbon snake (*Thamnophis s. sauritus*)
10. eastern worm snake (*Carphophis a. amoenus*)
11. rough green snake (*Opheodrys aestivus*)
12. eastern hognose snake (*Heterodon platirhinos*)
13. northern black racer (*Coluber c. constrictor*)
14. northern pine snake (*Pituophis m. melanoleucus*) (state-threatened species)
15. eastern kingsnake (*Lampropeltis g. getula*)
16. redback salamander (*Plethodon cinereus*)
17. northern red salamander (*Pseudotriton r. ruber*)
18. Fowler's toad (*Bufo woodhousii fowleri*)
19. northern spring peeper (*Pseudacris c. crucifer*)
20. southern gray treefrog (*Hyla chrysoscelis*) (state-endangered species)
21. southern leopard frog (*Rana utricularia*)
22. green frog (*Rana clamitans melanota*)
23. wood frog (*Rana sylvatica*)
24. eastern spadefoot toad (*Scaphiopus h. holbrookii*)

Similar to the 2008 field season, eastern hognose snake, northern black racer, Fowler's toad, eastern garter snake, redback salamander and green frog were the most commonly captured reptile and amphibian species in the drift fence traps. In 2009, 6 northern pine snakes were captured in the traps. Of the six snakes, 5 were adults (all recaptures) and one was a new hatchling.

Three of the adult pine snakes (Field Numbers 2006.08, 2007.07 and 2007.15) were radio-tracked snakes. Another adult was a gravid female (Field Number 2008.13), which also was captured in a drift fence trap while gravid in 2008. The other adult was a new captured male (Field Number 2009.13). This male was fitted with an internal transmitter to compensate for mortalities suffered by study snakes at the start of the field season. The hatchling pine snake was PIT tagged and released according to the protocol. In 2009, besides the 6 pine snakes caught in traps, HA staff captured an additional 42 unmarked pine snakes using the various survey methods detailed above in this report. All pine snakes were PIT tagged and released at their original capture locations as part of the mark and recapture study.

### *Radio-tracking*

In 2009, HA continued the radio-tracking study at the Stafford Business Park site, with a total of 25 pine snakes being monitored throughout the active field season (April through October). However, there was a period of time when several of the study animals were pulled from the field for transmitter replacement (Lutterschmidt 1994). As previously mentioned, one new pine snake, a male (Field Number 2009.13) was implanted with a transmitter. This was done to compensate for mortalities suffered by study snakes in the beginning of the year (for details please refer to the Individual Snake Synopses). Of the 13 shifted radio-tracked adult pine snakes tracked by HA at the start of 2009, 9 snakes (3 males and 6 females) remain alive and healthy, 3 are deceased (2 males and 1 female), and one male never egressed from its den in the spring. Of the12 non-shifted snakes radio-tracked from the beginning of 2009, 9 are alive and healthy (6 males and 3 females), two females are deceased, and one male is currently being rehabilitated in HA's lab (please refer to the Individual Snake Synopses).

### *Artificial and Natural Den Designations*

During our intensive field studies, HA has identified several natural pine snake dens which were located by radio-telemetry in the 2007, 2008 and 2009 field seasons. In order to prevent confusion, all artificial dens in the management fields are referred to as "Artificial Hibernacula" (AH 1 through 6). All natural dens located in 2007 are hereby identified as "Natural Hibernacula" (NH A through P). All natural dens located in 2008 are hereby identified as NH (Q through AA). Whereas all new natural dens located in 2009 are hereby identified as NH (B B through II). **Appendix I** shows each individually designated hibernacula and the corresponding snakes that utilized them in the 2007, 2008 and 2009 field seasons. The 2007 - 2008 winter was the last winter that snakes were forcibly held within the two-winter treatments (AH 1, AH 4, and AH 6), thus completing the experimental habitat imprinting portion of the study. Since Spring 2008, all study snakes have been free-roaming. Therefore, all overwintering sites used by radio-tracked snakes in the 2009 - 2010 winter season were selected by the snakes, without any influence, as they had unrestricted access to their natural winter den locations.

### *Results of Radio-telemetry Monitoring*

**Figures 6, 7** and **8** show a comparison of the average home ranges of the shifted and non-shifted snakes, using both Minimum Convex Polygon and Kernel home range methods of analysis (Samuel et al, 1985; Tiebout and Carey 1987; Seaman and Powell1996). **Table 1** shows the Minimum Convex Polygon home range area in acres and hectares for each individual snake radio-tracked during the 2009 field season. A brief synopsis of every adult pine snake involved in the radio-telemetry aspect of this project in 2009, currently alive or deceased, is detailed below.

Dave Golden, Senior Zoologist, of the Department has provided home range analysis maps of radio-tracked pine snakes in the 2009 active season. These maps are included within the synopsis for each snake. Please refer to the maps for information on each individual pine snake's activity range size during the season. In addition, **Appendix II** provides a brief synopsis of each snake that was deceased before the 2009 radio-telemetry season.

**Table 1. Minimum Convex Polygon (MCP) Home Range Size in Acres and Hectares of 20 Radio-tracked Northern Pine Snakes in 2009.**

| HA Snake Field ID Number | Sex | Number of Relocations | MCP Area in Acres | MCP Area in Hectares |
|---|---|---|---|---|
| 2006.08 | F | 79 | 160.854 | 65.095 |
| 2006.09 | F | 65 | 338.557 | 137.009 |
| 2006.16 | M | 73 | 194.626 | 78.763 |
| 2006.19 | F | 80 | 71.511 | 28.940 |
| 2006.21 | F | 59 | 114.193 | 46.212 |
| 2006.26 | M | 74 | 626.697 | 253.615 |
| 2006.28 | F | 76 | 235.691 | 95.381 |
| 2006.32 | F | 60 | 93.829 | 37.971 |
| 2006.34 | M | 75 | 416.565 | 168.578 |
| 2007.04 | F | 49 | 337.686 | 136.675 |
| 2007.05 | F | 69 | 295.130 | 119.435 |
| 2007.07 | F | 62 | 652.502 | 264.058 |
| 2007.09 | M | 53 | 895.526 | 362.406 |
| 2007.10 | M | 60 | 967.250 | 391.432 |
| 2007.11 | M | 73 | 335.93 | 135.971 |
| 2007.14 | M | 69 | 419.683 | 169.840 |
| 2007.15 | F | 75 | 582.051 | 235.548 |
| 2008.02 | F | 64 | 158.417 | 64.109 |
| 2008.03 | M | 74 | 786.697 | 318.365 |
| 2009.13 | M | 45 | 175.125 | 70.871 |

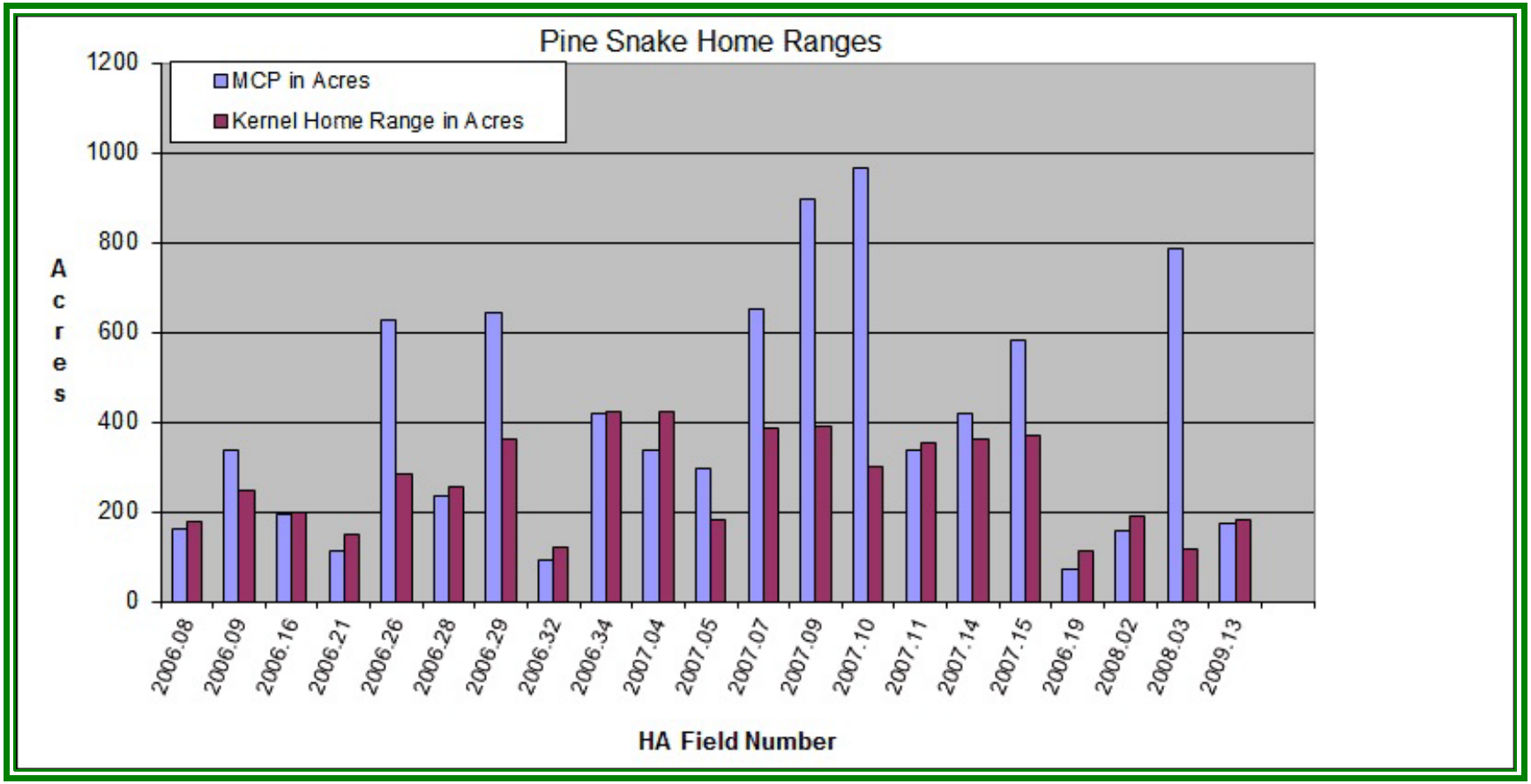



**Figure 4.** Combined Minimum Convex Polygon and Kernel Home Range analysis for all shifted and non-shifted pine snakes radio-tracked at the Stafford Park Redevelopment property during the 2009 study period. Source: Herpetological Associates and the Endangered and Nongame Species Program, NJDEP.

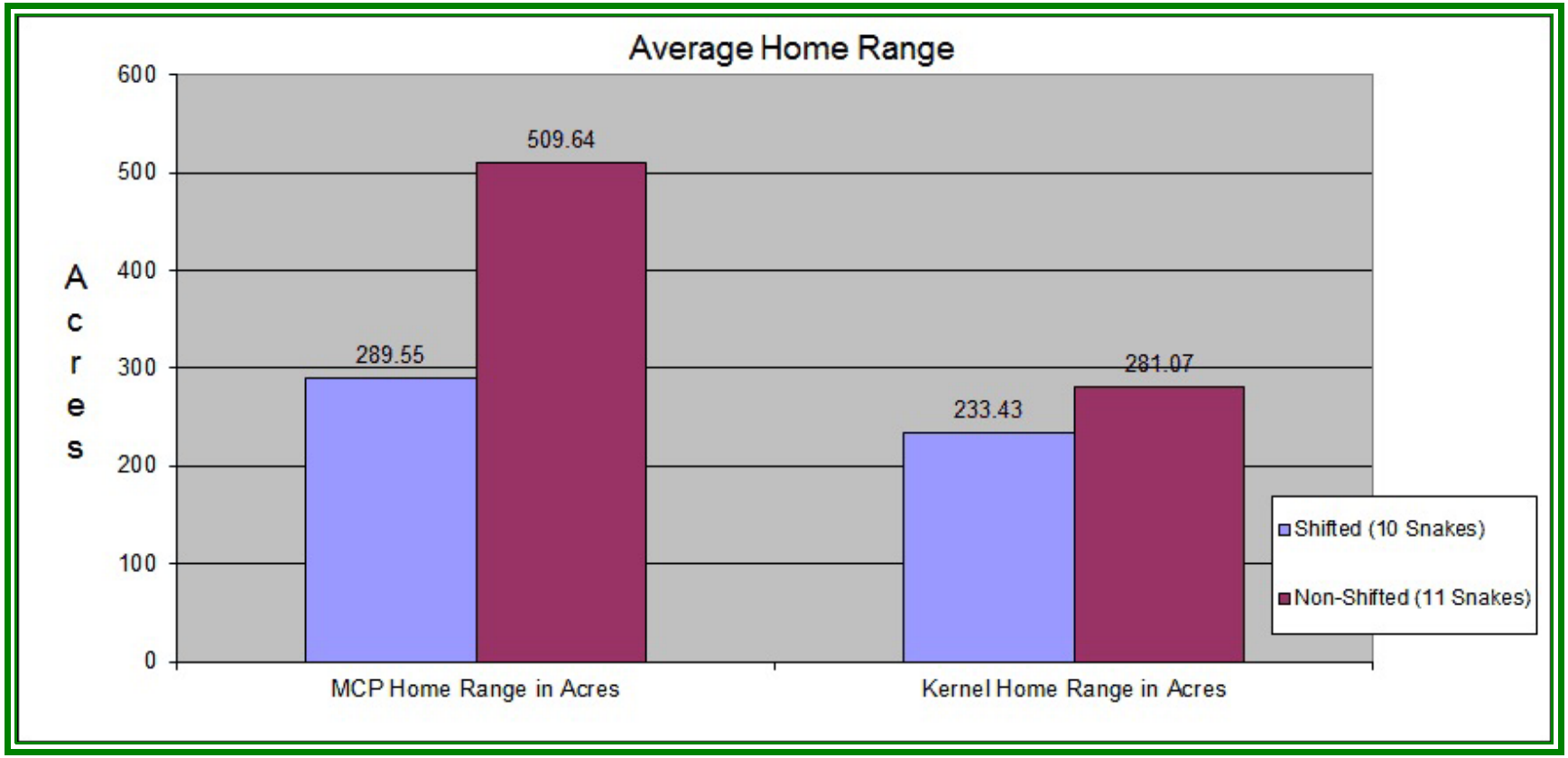



**Figure 5**. Comparison of the average Home Range of shifted (10 snakes), and non-shifted (11 snakes), radio-tracked pine snakes at the Stafford Park Redevelopment property study area in 2009. Source: Herpetological Associates and the Endangered and Nongame Species Program, NJDEP.

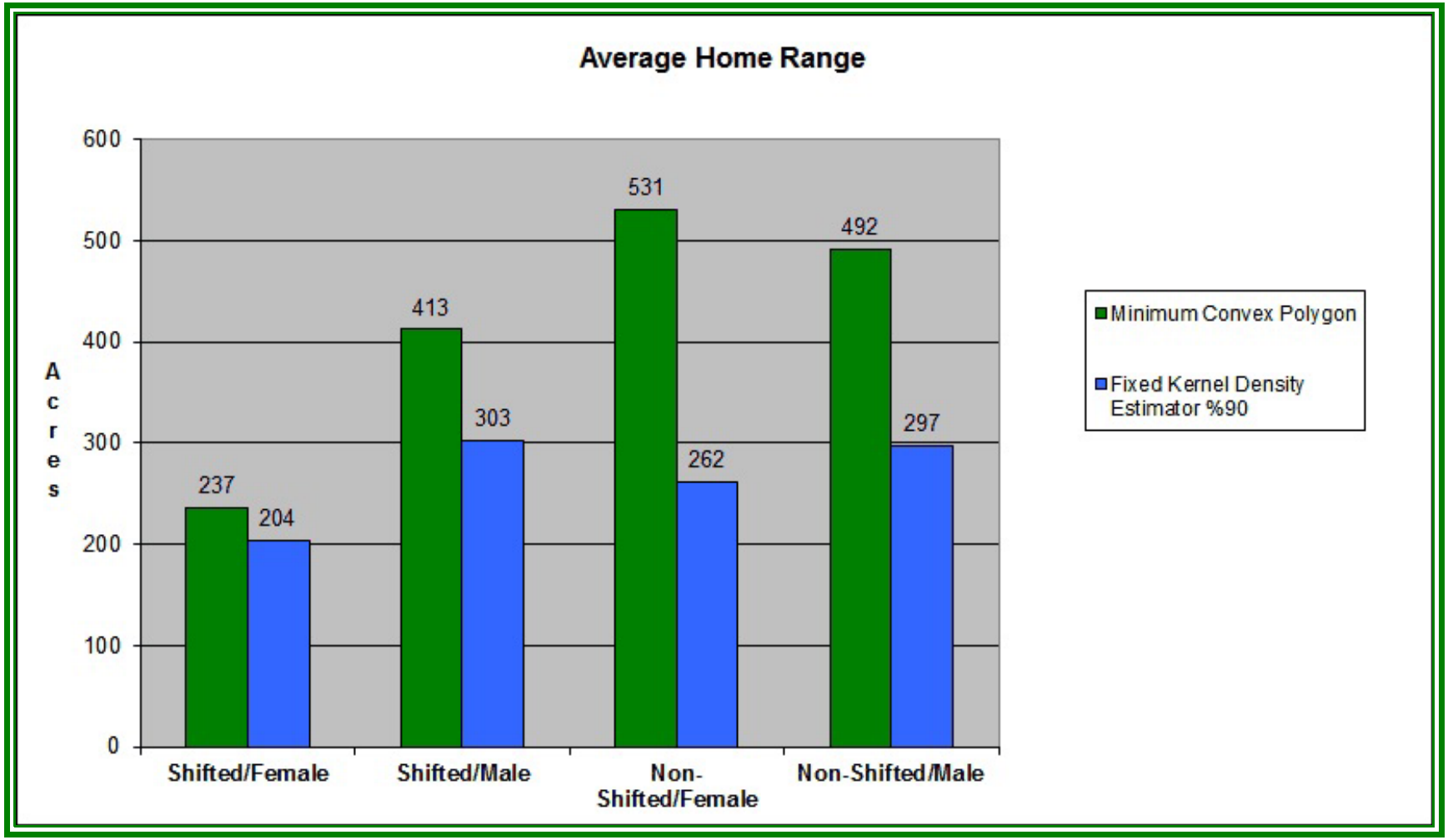



**Figure 6**. Comparison of the average activity home range sizes in acres for male and female shifted and non-shifted radio-tracked pine snakes at the Stafford Park Redevelopment property in 2009 at the study Area. The numbers at the top of the bars represent relocations of those snakes in that cohort. Source: Herpetological Associates and the Endangered and Nongame Species Program, NJDEP.

## INDIVIDUAL SNAKE SYNOPSES AND HOME RANGE MAPS

***N. Pine Snake No. 2006.08*** (♀). (Shifted Snake, Treatment C/Lab) Current status = Alive and healthy. This snake was initially captured near the landfill by EcolSciences, Inc. on 05/05/06.

**2008:** A transmitter reimplantation surgery was conducted on 06/01/08 and the snake was released on 07/11/08. It was relocated 48 times in 2008. For the remainder of the activity season this snake frequented the upland pine forest west of the management fields. In October, the snake made a move back to the edge of the management fields and overwintered in NH B, an abandoned mammal burrow located approximately 30 meters from AH 6. Pine Snakes 2006.17 and 2007.03 also overwintered with 2006.08 at this location.

**2009:** This snake egressed from NH B on 04/27/09, and was relocated 79 times throughout the 2009 field season. Similar to its behavior in the 2008 season, it was often relocated in the upland pine forest west of the management fields and less frequently north of Hay Road. It was twice found in traps bordering the landfill (on 06/17/09 and 07/02/09). While these attempts to access the SPR occurred during nesting season, this snake was neither observed engaged in any mating behavior, nor did it appear to be gravid. Movement back to NH B occurred by 10/12/09, where it spent the winter of 2009 - 2010.

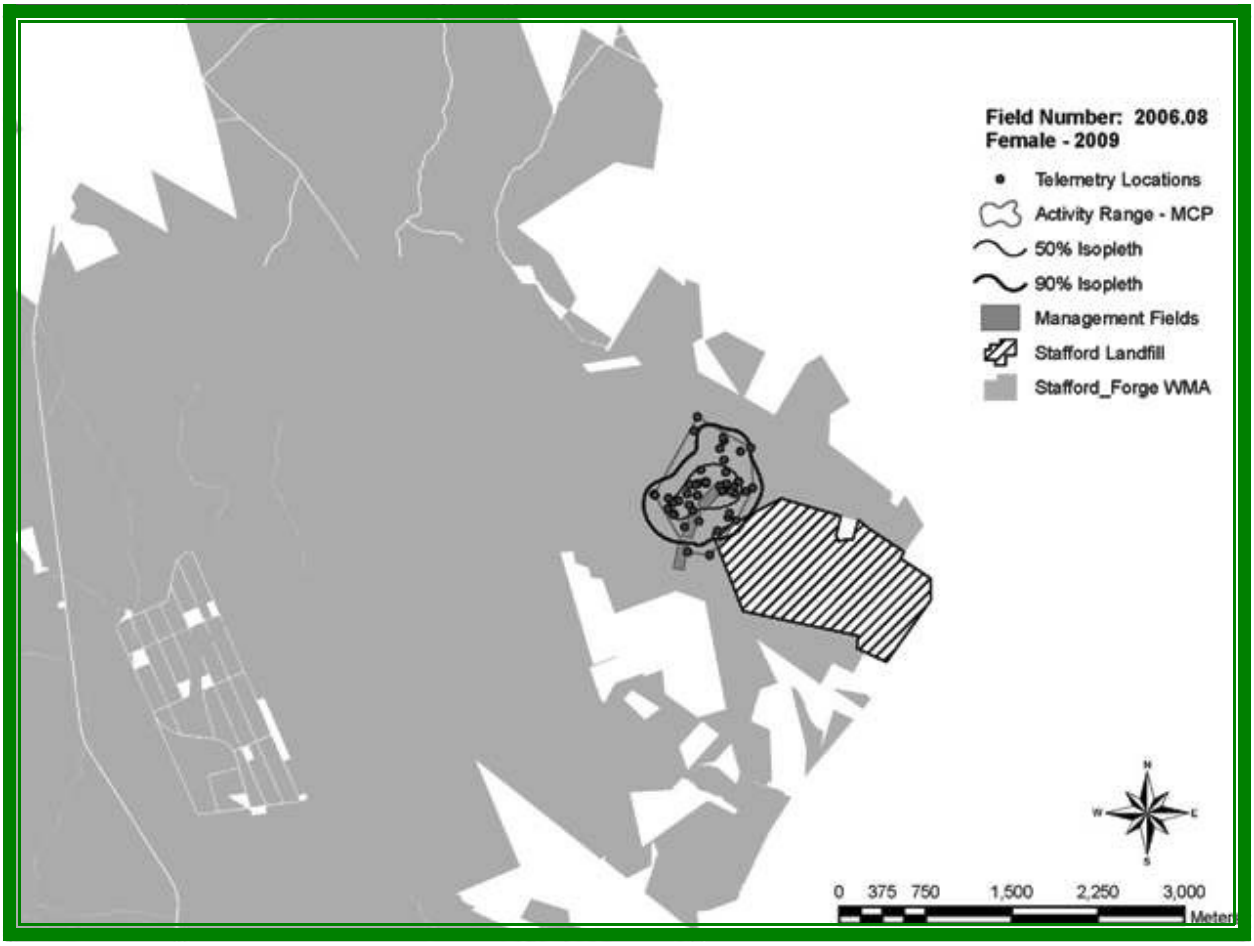



**Figure 7.** Radio-telemetry relocations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis), for a female northern pine snake number **2006.08**. The complete forest habitat area size used during the 2009 field season was 160.8-acres (65.5-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**N. Pine Snake No. 2006.09** (♀). (Shifted Snake, Treatment A/1 winter) Current status = Likely Deceased.

This snake was originally captured during a presence/absence survey conducted by EcolSciences, Inc. in 2004.

**2008:** The snake egressed from NH I on April 23, 2008. In May, two different male pine snakes on two separate occasions were captured within close proximity to this snake, suggesting that this female had mated. After completion of transmitter reimplantation surgery on 07/16/08, the snake was released into the forest at its previous relocation. The snake spent the remainder of the season in a tract of oak/pine forest north of the SPR property. The snake was located in August frequenting red squirrel (*Tamiasciurus hudsonicus*) feeding stations and burrows. Based on the amount of time spent at these locations, this suggests potentially successful foraging behavior. In October, this snake crossed a small wetland SSW of the oak/pine forest and entered the same hibernaculum (NH I) it utilized the previous winter season.

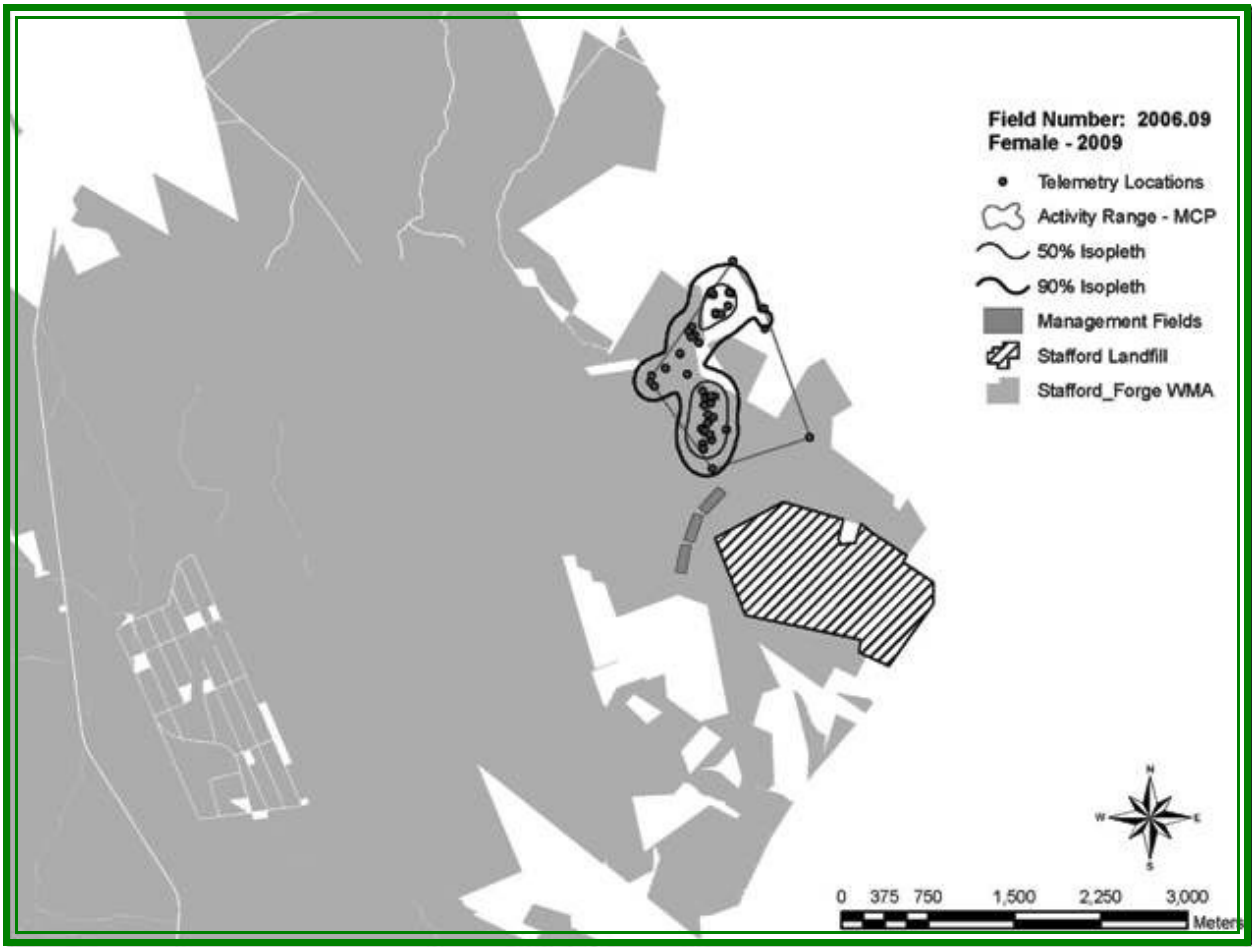



**Figure 8.** Radio-telemetry relocations and activity range size (minimum convex polygon and 50% and 90% isopleth from Kernal analysis) for pine snake number **2006.09**. The complete forest habitat area used while being radio-tracked in 2009 was 338.5-acres (137.9-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009**: This snake emerged from NH I on 04/27/09, and was relocated 65 times during the 2009 radio-tracking field season. In May, the snake made a series of small moves to the south, eventually crossing the Mill Creek wetland corridor (see **Appendix IV**). In behavior similar to that of 2008, the snake was frequently relocated utilizing red squirrel feeding stations/burrows in the vicinity of a transitional (lowland to upland) pine/oak ridge between Hay Road and the wetland. The snake made extensive use of the wetland for the next several weeks, and on one occasion was observed swimming across Mill Creek. The snake continued to move between the aforementioned pine/oak ridge and the vicinity of its hibernaculum until early August, when it made a substantial move to the east. It then began to frequent a section of open canopied, disturbed oak/pine forest several hundred meters west of Route 72, where it was often relocated beneath discarded brush and leaf piles as well as other human-generated debris. In early fall, the snake began to make a series of small moves to the southwest towards its previous winter den, NH I. On 11/04/09, this snake was observed basking near a stump hole approximately 20 meters north of NH I. The snake was observed to be alert and was actively tongue flicking despite the cool ambient temperature (13.6 degrees C). It was assumed that it would once again overwinter within NH I. When HA staff later attempted to confirm that the snake was actually within NH I, no signal could be detected in the immediate vicinity. A concerted effort was made to locate the snake from several points within its known home range, and despite the use of three receiver boxes, no signal was received and the snake was not found. It is thought that the snake was carried off by a hawk or mammal predator since no transmitter signal was ever again detected, and no carcass was found.

***N. Pine Snake No. 2006.11*** (♂). (Shifted Snake, Treatment A/1 winter) Current status = Deceased. This snake was originally caught by EcolSciences, Inc. on the landfill access road on 05/17/06.

**2008:** This snake egressed from NH A in April 2008. Until early October, this snake remained within 100 meters of the management fields. During that time it mainly utilized man-made berms along the edge of the management field access road. It then made series of large moves to the southeast. The snake overwintered in a section of pine/oak forest, near the Garden State Parkway, south of the SPR property in a new location (NH Q). No obvious entrance holes or signs of digging into underground refugia were noted in the snake's general location. Leaf litter may have covered the entrance hole.

**2009:** This snake was relocated 15 times during the 2009 field season. It had already egressed from NH Q by the time radio-tracking commenced on 04/26/09. In early May, this snake moved into an area of pine forest often frequented by two other study snakes (Field Numbers 2006.34 and 2007.11). This location was approximately 640 meters southwest of its denning site. On 05/20/08 this snake was found killed by an unknown predator along the edge of a wetland corridor west of its previous relocation. The snake had been decapitated and a portion of the upper body was missing. Based on the condition of the carcass (i.e., the cleanly severed backbone and tissue at the wound, rather than stripping of the flesh) suggest mammalian predation. It appeared to have been a recent mortality, since there was no odor emanating from the carcass and rigor mortis had not set in yet. It is possible that the predator that was responsible was scared off by the approach of HA staff before it could finish eating the snake. Because there were just 15 relocations for this snake in 2009, a home range map is not shown.

***N. Pine Snake No. 2006.15*** (♂). (Shifted Snake, Treatment C/Lab) Current status = Undetermined. This snake was captured in trap 24 along the perimeter drift fence by EcolSciences, Inc. on 05/17/06.

**2008:** On 06/11/08 this snake was recaptured within the AH 4 corral. The snake was collected for transmitter removal. Upon examination, the snake was determined to be of poor body weight, so it was retained in HA's laboratory and put on a feeding schedule in order to improve its overall body mass and health. By 10/03/08 the snake was determined to be healthy enough to undergo the removal surgery. As it was too late in the season for re-implantation, the snake was fitted with an external transmitter and released back into AH 4.

It was concealed within an earthen berm along the western edge of MF 2 for approximately one month before moving to an artificially created earth mound located in the center of the same field. On two separate occasions, HA staff identified and photographed snake tracks created by a snake with a bulge on its right side (external transmitter) crossing a sand path near AH 4. This suggests that the snake may have been using the berm for shelter, but emerging for behavioral reasons, such as foraging, basking or searching for a more suitable overwintering location. The snake eventually overwintered in the mound in MF 2 as described above.

**2009:** According to the transmitter signal, pine snake 2006.15 never egressed from the large earthen mound in MF 2 where it hibernated during the 2008 - 2009 winter. Whether this snake failed to successfully overwinter, or the radio-transmitter fell off is not known. This snake was fitted with an external transmitter towards the end of the 2008 field season and it is possible that the radio-transmitter may have slipped-off during the winter or during spring egress. Attempts by HA staff to dig-up and unearth this transmitter were unsuccessful. Because there were just 15 relocations in 2009 for this snake, a home range map is not shown.

**Figure 9**. A male pine snake holding a female by the neck during courtship and mating behavior. Photo taken in May 2009 by Bob Hamilton, HA Staff.

***N. Pine Snake No. 2006.16*** (♂). (Shifted Snake, Treatment C/Lab) Current status = Alive and healthy. This snake was originally captured by EcolSciences, Inc. in trap number 27 along the perimeter drift fence on 05/18/06.

**2008:** This snake egressed from AH 1 on 05/10/08. The old transmitter was removed on 06/01/08 and the new transmitter was implanted on 07/29/08. This snake was relocated 46 times in 2008. After its release, the snake traveled through habitat west and south of MF 1. It spent the entire month of August concealed within the perimeter berm of MF 1 before returning to AH 1 where it overwintered alongside pine snake 2006.19.

**2009**: This snake's active season began on 04/27/09, when it was located in a den trap attached to AH 1. It was relocated a total of 73 times in the 2009 field season, during which time it routinely made a series of large, abrupt moves. Radio-tracking efforts provided evidence that this snake's active period was spent almost exclusively between two distinct areas. As in the previous season it was frequently relocated in the pine/oak habitat south and west of MF 1, where it was observed foraging on multiple occasions.

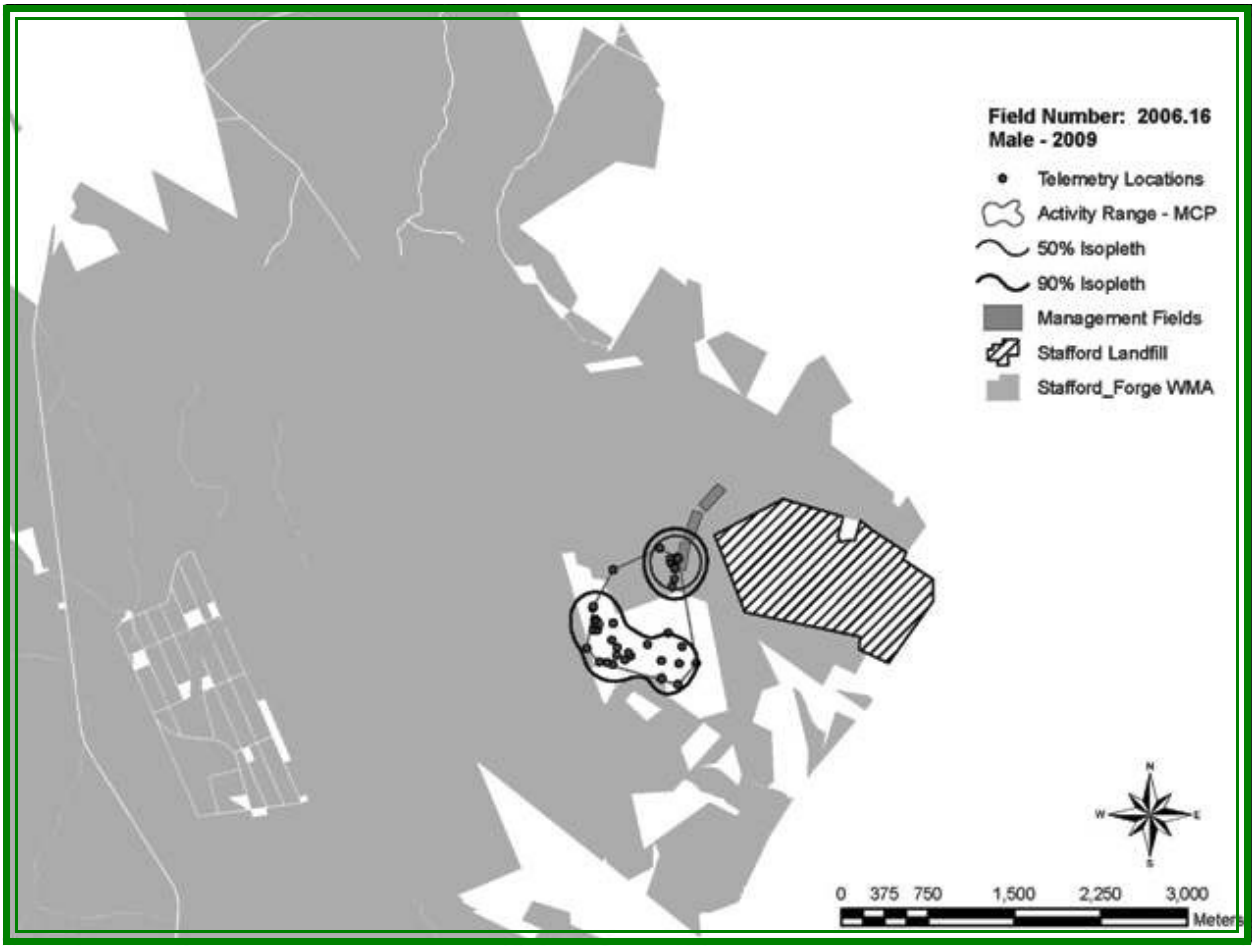



**Figure 10.** Radio-telemetry relocations and activity range size (minimum convex polygon and 50% and 90% isopleth from Kernal analysis) for northern pine snake number **2006.16**. The complete forest habitat area used while being radio-tracked in 2009 was 194.6-acres (78.7-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

Interspersed throughout these relocations, this snake often utilized cavities within the berm structure in the southwest corner of MF 1, or was found in transit between these substantially distanced areas. During its time within the MF 1 berms, this snake was almost completely inactive for a number of successive relocations. It was infrequently visible adjacent to its berm, and was observed to be in an opaque (pre-shed) condition at these times. In a behavioral parallel to the 2008 season, this snake spent the entire month of September in a sand mound on the southwest perimeter of MF 1. This snake returned to its hibernaculum on 10/06/09, immediately following its month-long concealment within the sand mound. It once again overwintered in AH 1 alongside pine snake 2006.19, suggesting that these two snakes have learned it is a suitable hibernaculum and imprinted to the artificial den they were forced to use for two winters.

***N. Pine Snake No. 2006.17*** (♂). (Treatment C/Lab) Current status = Deceased. This snake was captured by EcolSciences, Inc. on 05/21/06 in trap eighteen (18) along the perimeter drift fence.

**2008:** The snake egressed from AH 6 in April, 2008. The old transmitter was removed on 07/08/08 and a new one was implanted on 08/04/08. This snake was relocated 37 times in 2008. After surgery, the snake was released outside of the corral along the forest edge west of AH 6. This snake spent the remainder of the season in the upland pine forest west of the management fields, occasionally returning to the perimeter berms. On 10/14/08 the snake was located in the same stump hole as pine snake 2007.03, approximately 200 meters northwest of MF 3. It then returned to the western edge of MF 3 and overwintered in NH B (30 meters west of MF 3). Pine snakes 2006.08 and 2007.03 also overwintered at this natural den location.

**Figure 11**. Northern pine snake number **2006.17**, was found dead on the road, flipped onto the rumble strip of the southbound lane of the Garden State Parkway. It was hit numerous times as evidenced in the picture. It received serious physical trauma by repeated hits of the wheels of vehicular traffic. The radio-transmitter can be seen popped out of its body. Photograph by Robert J. Hamilton, Herpetological Associates, Inc., 2009.

**2009:** On 04/27/09, this snake egressed from NH B, and was relocated a total of 14 times during the 2009 field season. On 05/18/09, it was found to have scent-trailed study female 2007.15 to an area near the Garden State Parkway, and was relocated in the immediate vicinity of this female. On the following relocation day (05/20/09), this snake was found dead on the road (DOR), on the edge of the Garden State Parkway's southbound lane (see **Figure 11**). The dead pine snake was seen by an HA staff member in a passing vehicle. He went back to inspect the snake and found its non-functional transmitter popped-out of the body, thus confirming its identity.

***N. Pine Snake No. 2006.19*** (♀). (Shifted Snake, Treatment C/Lab) Current status = Alive and healthy. This snake was originally captured by EcolSciences, Inc. on 05/24/06 in the NW corner of the former Stafford Township Police firearms shooting range, which no longer exist.

**2008:** HA implanted a transmitter in this snake on 07/17/08. It was relocated 45 times during the 2008 field season. After release, this snake primarily utilized habitat south and west of the management fields. This snake used the man-made berms extensively along the access road, the outer corral paths and on the management fields prior to returning to AH 1 where the snake overwintered. Pine snake 2006.16 hibernated in this location as well.

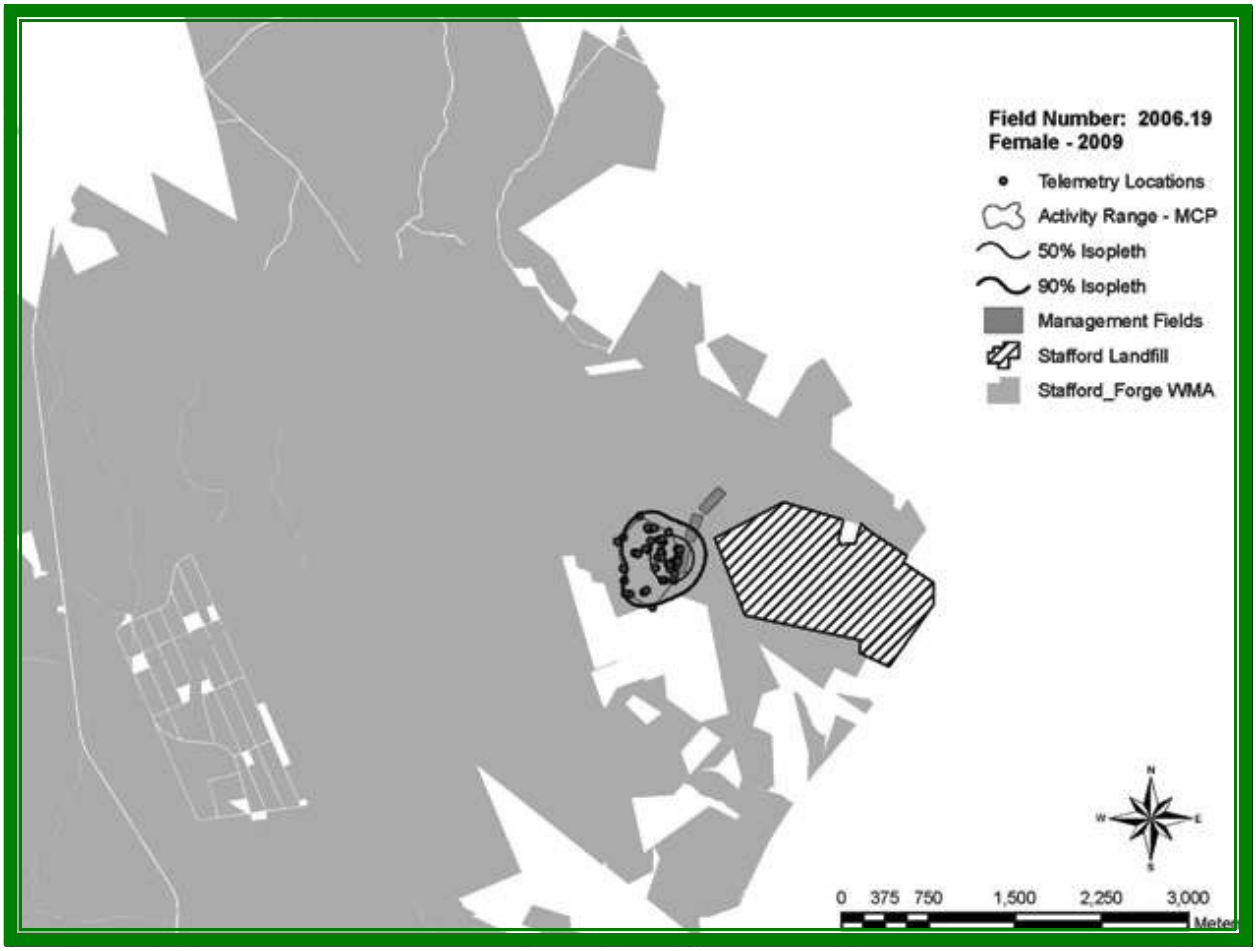



**Figure 12.** Radio-telemetry relocations and activity range size (minimum convex polygon and 50% and 90% isopleth from Kernal analysis) for northern pine snake number **2006.19**. The complete forest habitat area size used while being radio-tracked in 2009 was 71.5-acres (28.9-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009:** This snake emerged from AH 1 on 04/18/09, and was relocated 80 times throughout the field season. It repeated similar behavior to what it had done in 2008, and was often relocated within pine/oak forest south of the management fields, as well as the upland pine forest to the west. This snake continued to make use of the multiple man-made berms and mounds along the perimeter of the management fields and outer corral paths; in many cases found in the same locations as in 2008. During mid-October this snake returned to den AH 1, where it spent the winter alongside pine snake 2006.16. It once again overwintered in AH 1 with pine snake 2006.16, suggesting that these two snakes may have been imprinted to the artificial den.

***N. Pine Snake No. 2006.21*** (♀). (Treatment A/1 winter) Current status = Deceased. This snake was originally captured in trap 95 along the perimeter drift fence by EcolSciences, Inc. on 05/27/06.

**2008:** A new, two-year transmitter was implanted in this snake on 07/29/08. This snake spent the majority of the 2008 season in the same habitat it favored in 2007. This area consists of a tract of upland oak/pine forest on privately owned property between Mill Creek and Route 72 approximately 2.4 kilometers N/NW of the management fields. This snake selected a different overwintering location in 2008 (NH R), 1.15 kilometers N/NW from where it hibernated in 2007. The only noticeable entrance to this particular hibernaculum was a small, round hole in the forest floor.

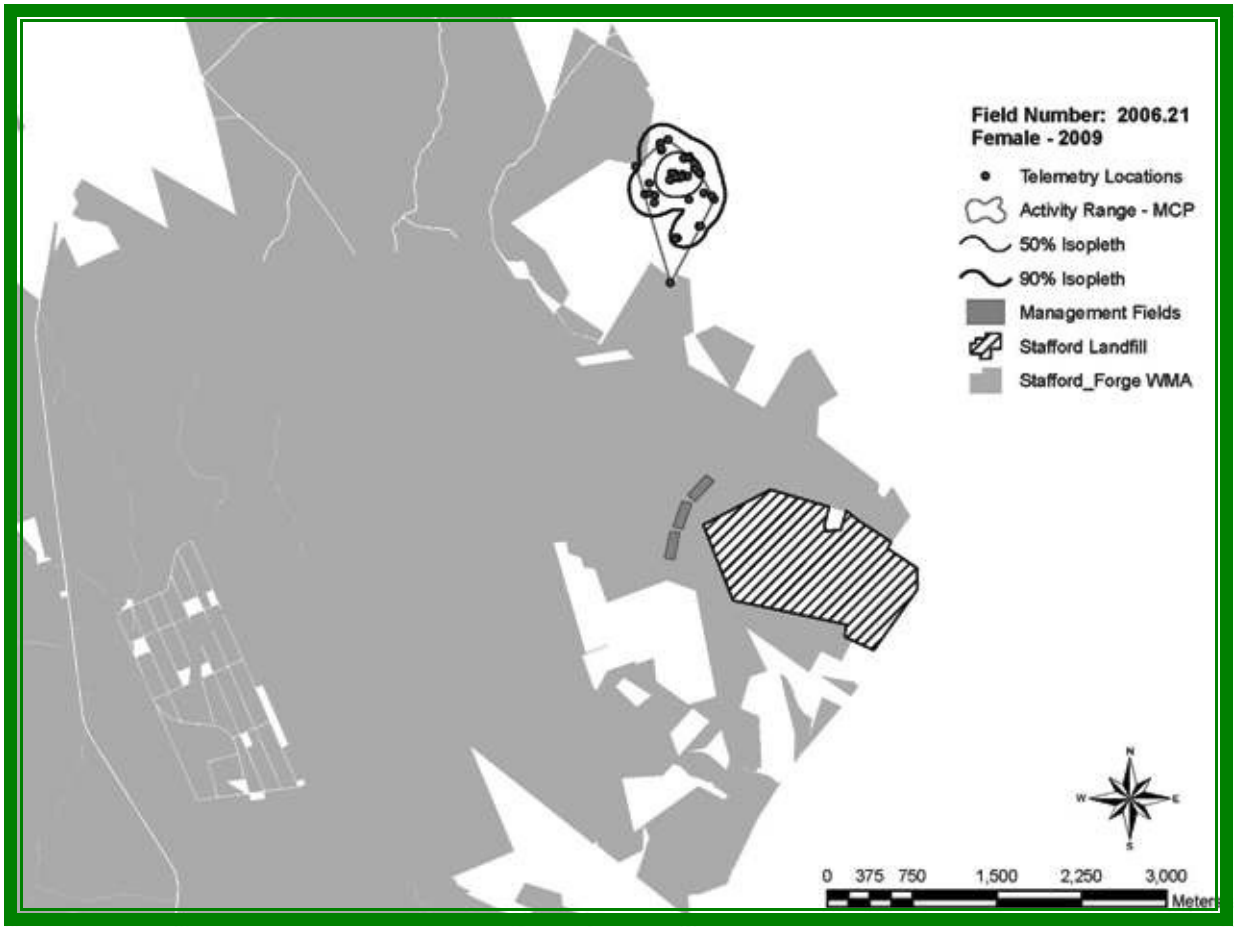



**Figure 13.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for northern pine snake **2006.21**. The complete forest area size used while being radio-tracked in 2009 was 114.1-acres (46.2-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009:** This snake egressed from NH R in early April 2009, and was relocated 59 times during the 2009 field season. On 04/23/09, this snake was discovered in an active defensive posture (coiled in a striking position and hissing) and bleeding profusely from its eye and snout. An active red squirrel (*Tamiasciurus hudsonicus*) feeding station and burrow was noted within 1 meter of the snake. It is likely that the snake was attempting to shelter in the burrow, as the ambient temperature was 14.5 degrees C. It is probable that the snake was too cool to feed or defend itself adequately and received a serious bite from the red squirrel. Though outwardly healthy and in good body weight upon egress from hibernation, the snake went into a slow decline after suffering this serious facial injury. Pine snake 2006.21 moved a few hundred meters southeast from its location on 4/23/09 into upland oak/pine forest approximately 180 meters SW of Route 72, and remained in this general area throughout the season. This snake eventually became blind in its right eye, developed a mouth infection, and continued to lose weight as the season progressed. On 10/21/09, the snake was found killed by an unknown small predator, possibly a fox or raccoon. The snake's head and neck were missing, and the posterior third of the body was eviscerated with the transmitter exposed. The carcass was collected and frozen by HA staff.

***N. Pine Snake No. 2006.26*** (♂). (Shifted Snake, Treatment A/1 winter) Current status = Alive and healthy. This snake was originally captured by EcolSciences, Inc. during the summer of 2006.

**2008:** In April, 2008 the snake egressed from NH A. This snake was relocated 63 times during the 2008 field season. The snake remained concealed in the berm on the east side of MF 3 for nearly a month before traveling south along the berm. In October, this snake was captured twice in the perimeter drift fence trap line. Near the end of the field season, it began to utilize habitat south of the Stafford Park property and overwintered in NH N, a natural den identified through radio-telemetry in 2007.

**2009:** This snake egressed from NH N on 04/25/09, and was relocated 74 times during the course of the 2009 season. This snake extensively used areas in and around the management fields (most frequently being found within the perimeter berms), interspersed with shorter forays into the pine/oak habitat south and west of the management fields. During mating season, this snake was observed making erratic moves, most often associated with attempts to access the landfill. On one such occasion, this snake breached the perimeter drift fence line and concealed itself within a landfill drainage structure for several days consecutively. On 10/02/09 this snake was relocated back at NH N, where it successfully spent the winter of 2009 - 2010. Its activity home range map is shown on the next page (**Figure 14**).

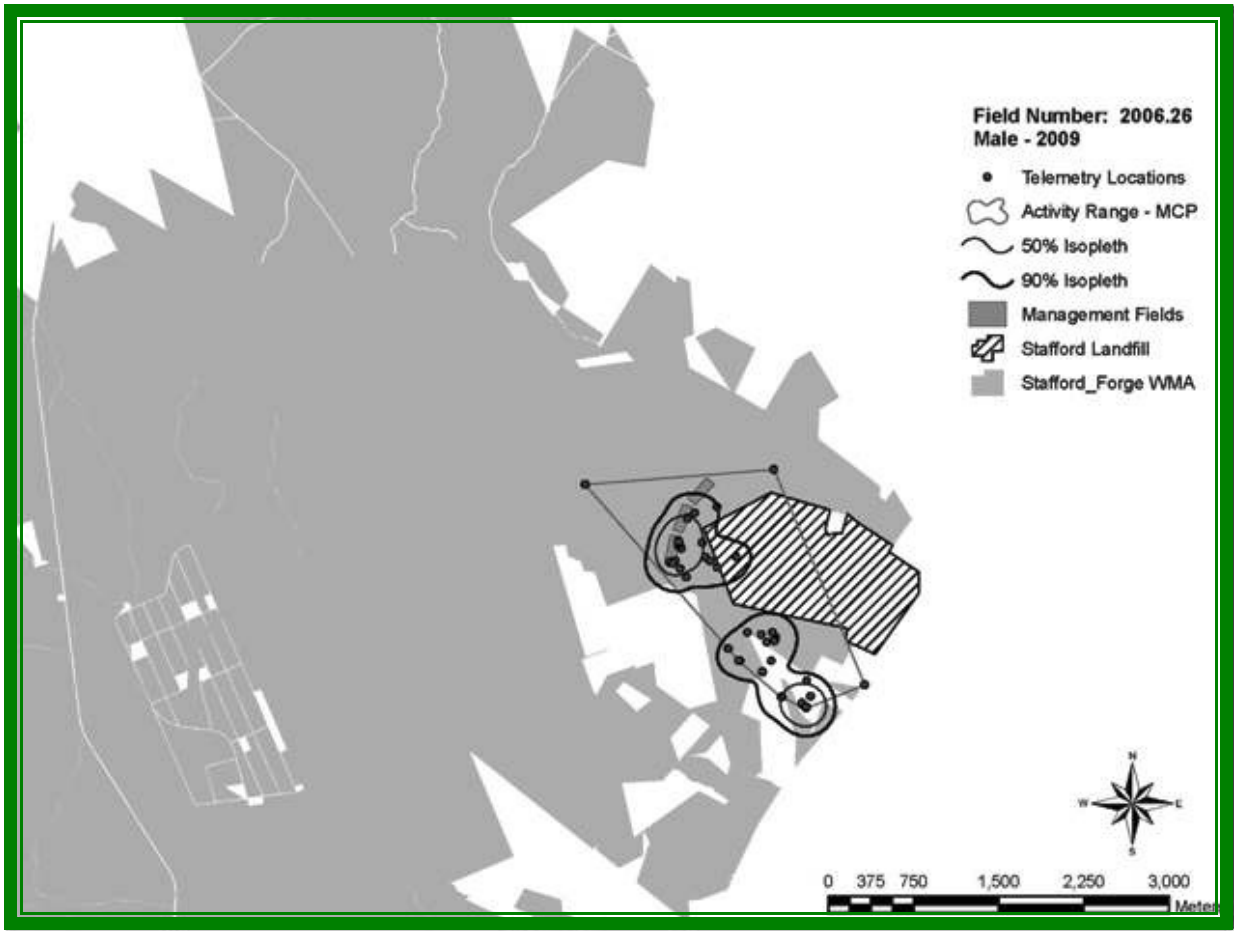



**Figure 14.** Radio-telemetry locations and activity range sizes (minimum convex polygon and 50% and 90% isopleth from Kernal analysis) for northern pine snake number **2006.26**. The complete forest area size used while being radio-tracked in 2009 was 626.6-acres (253.6-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

***N. Pine Snake No. 2006.28*** (♀). (Shifted Snake, Treatment C/Lab) Current status = Alive and healthy. This snake was initially captured by HA on the landfill on 06/23/06.

**2008:** This snake egressed from AH 1 on 05/09/08 and traveled into oak/pine forest southwest of the management fields. During 2008 this snake used different habitats south of the SPR site, including several relocations within a forested wetland. On 10/05/08 it moved to a newly discovered natural den (NH S) where it spent the winter. No obvious entrance hole was detected near this new overwintering location.

**2009**: This snake was relocated 76 times during the 2009 field season. The snake emerged from NH S on 04/23/09. Over the next several relocations the snake continually moved east into habitat established as its home range by radio-tracking in 2008. Throughout the majority of the 2009 field season, this snake was consistently relocated in a tract of upland pine and pine/oak forest between Micaja Road and the Cedar Run wetland corridor to the south. The snake was also found within the wetland corridor on several relocations, often in an opaque condition. This female was never observed mating and did not appear gravid in 2009, despite appearing outwardly healthy and of good body weight. Interestingly, this snake was observed to have excavated a small nest-like cavity.

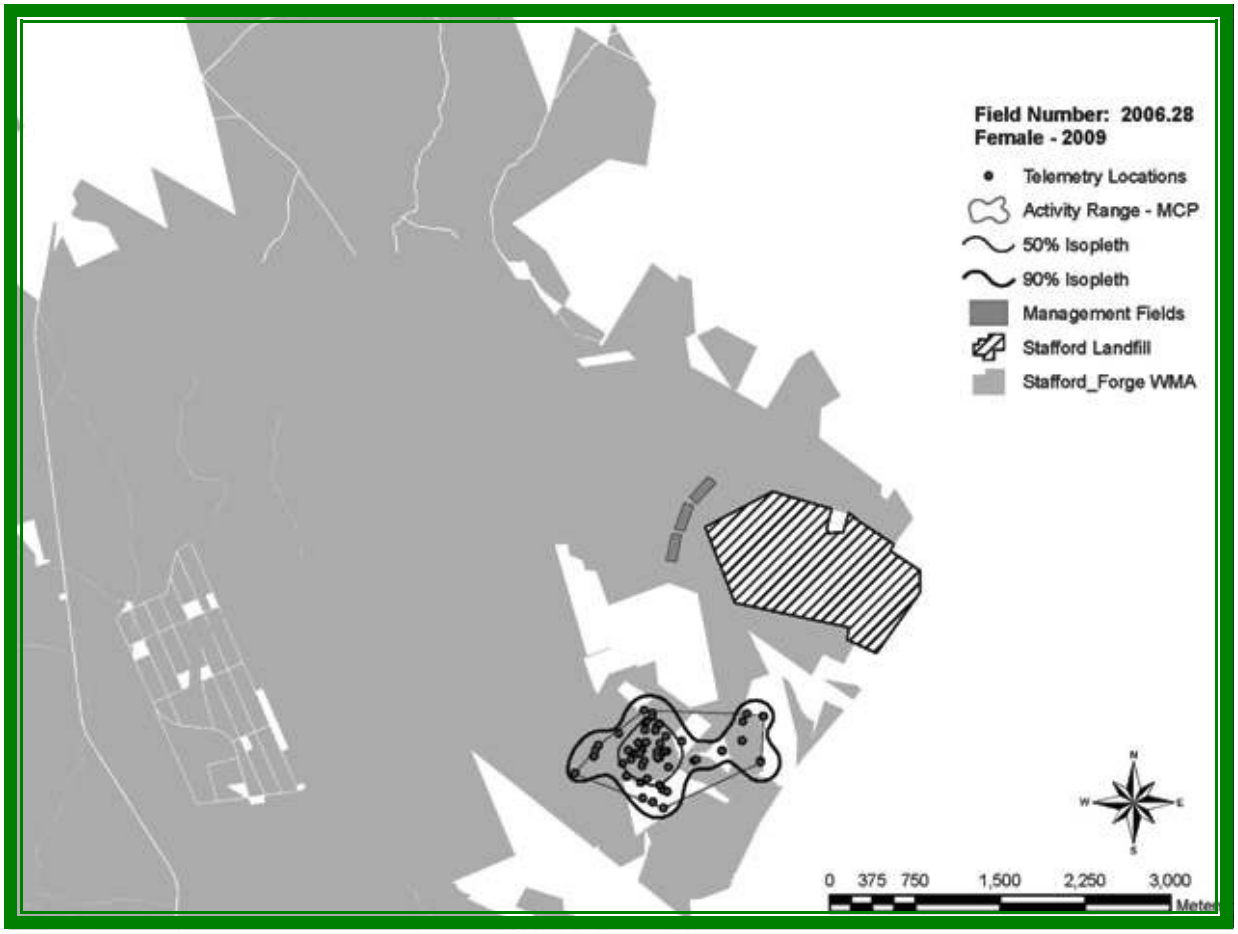



**Figure 15**. Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for northern pine snake number **2006.28**. The size of the area used while being radio-tracked in 2009 was 235.6-acres (95.3-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009** *Continued*: The snake went into a small mammal burrow with the probable intent of feeding on the mammal resident. Similar behavior was observed during a relocation of another snake (Field Number 2007.11 in 2008). On 09/24/09, pine snake 2006.28 moved to the east side of the Cedar Run wetland corridor and was relocated near the landmark known as the "glass pile" (see **Appendix IV**). This snake was rarely observed east of Cedar Run prior to this date. Following 09/24/09 this snake consistently traveled to the east until it finally hibernated. The den location was a nondescript hole in an upland pine/oak forest. This newly discovered hibernaculum was designated as NH DD.

***N. Pine Snake No. 2006.29*** (♀). (Shifted Snake, Treatment B/2 winters) Current status = Alive and healthy. This snake was captured on 06/26/06 in trap 97 of the perimeter drift fence by EcolSciences.

**2008:** This snake was collected from AH 6 fence enclosure on 05/19/08. The old transmitter was removed on 06/01/08 and a new, two-year transmitter was implanted on 07/16/08. The snake was released on 07/21/08 along the western edge of MF 3. This snake was relocated 45 times in 2008. It spent the majority of the season in upland pine forest west of the Stafford Park property. This snake overwintered in a section of upland pine forest in a newly discovered natural den (NH T).

**2009:** This snake emerged from NH T on 04/23/09, and was relocated a total of 78 times during the 2009 field season. The early portion of its activity period was spent in a section of severely burned upland pine forest in the vicinity of its hibernaculum. It was in this same area that pine snake 2006.29 was courted by and mated with male 2007.10 on 05/13/09. These two snakes were relocated together a total of three times, out of which one additional mating observation was made on 05/22/09. After mating, this snake continued to use the same section of forest, specifically frequenting an old red squirrel feeding station and borrow that it also used in 2008. On 06/24/09 it was found freshly shed (for the first time since mating) and immediately crawled towards the SPR property for nesting. On June 26, 2009, it was found inside the SPR, near the landfill, but it had became trapped in a drainage corral in the process. The gravid snake was moved approximately 200 meters (656 feet), into the Stafford Forge WMA forest, behind the perimeter drift fence. This was done according to our protocol, and more importantly because the snake was trapped in full sun exposure with no available cover. It was determined that the pine snake's life was in imminent danger of overheating and death. On 06/30/09, it was determined that this female had nested in a large soil/stump mound at the far (northeast) end of MF 3. It spent the remainder of the season less predictably, moving through a variety of habitats within its home range. It was relocated several times in the unburned lowland forest north of Hay Road, as well as north of the Mill Creek wetland corridor. This snake once again overwintered in NH T, a destination it had reached on 10/25/09.

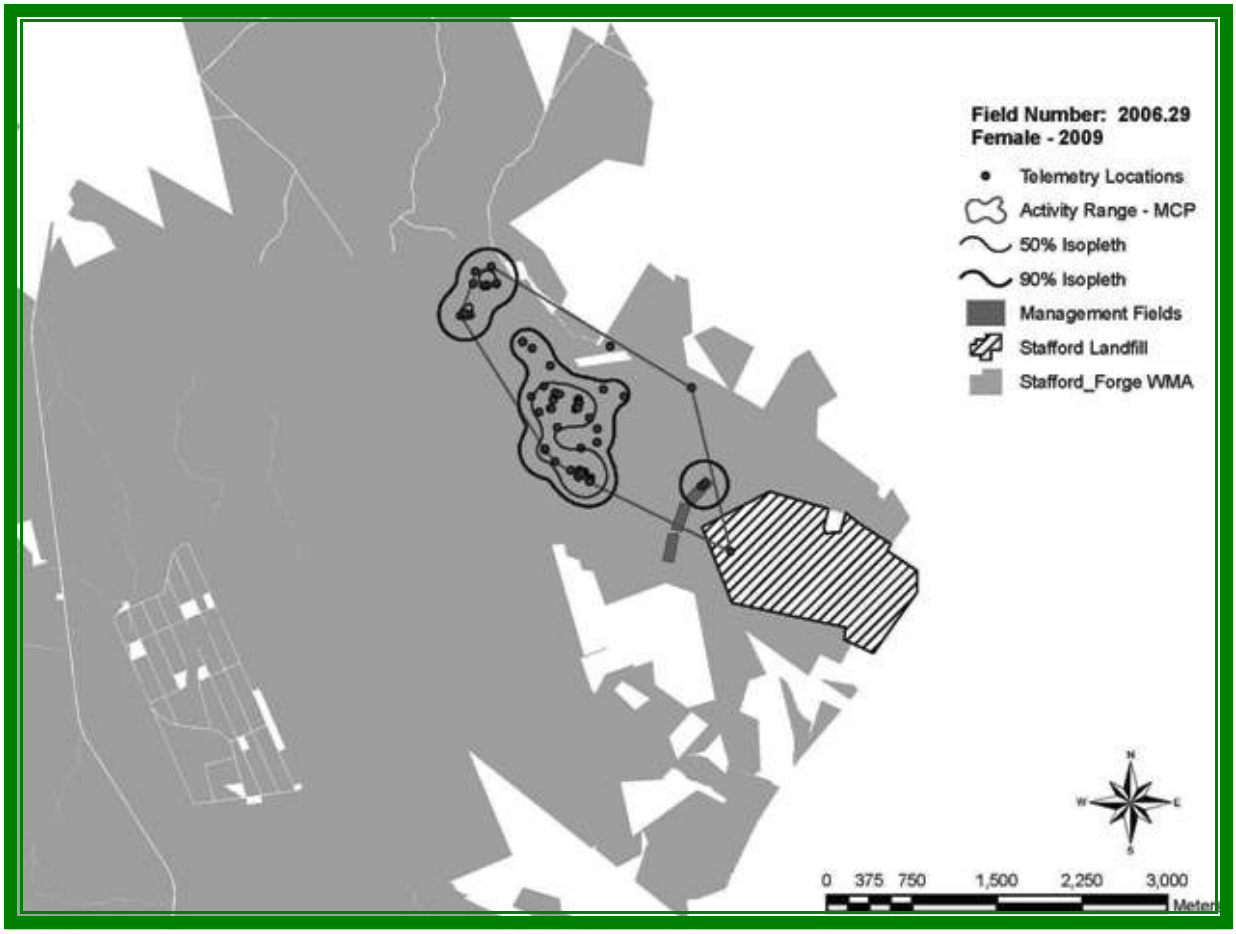



**Figure 16.** Radio-telemetry locations and activity range sizes (Minimum Convex Polygon and 50% and 90% isopleth from the Kernal Analysis) for pine snake number **2006.29**. The various forest area size used while being radio-tracked in 2009 was 642.9-acres (260.1-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

***N. Pine Snake No. 2006.32*** (♀). (Shifted Snake, Treatment A/1 winter) Current status = Alive, but in poor body weight. This snake was originally captured in trap 61 along the perimeter drift fence on 07/08/06.

**2008:** The snake egressed from NH D on 05/03/08 and was observed to have extensive hibernation sores on its head and neck. By mid-November 2008, this snake was overwintering in a stump hole in the same general vicinity as in 2007. However, during a mid-winter check on the snake's location in January of 2009, it made a large move of approximately 200 meters southeast. The snake crossed to the north side of Hay Road into an unburned upland oak/pine forest. No obvious entrance to this new hibernaculum was noted, due to the large amount of leaf litter on the forest floor. This natural den location was designated NH W.

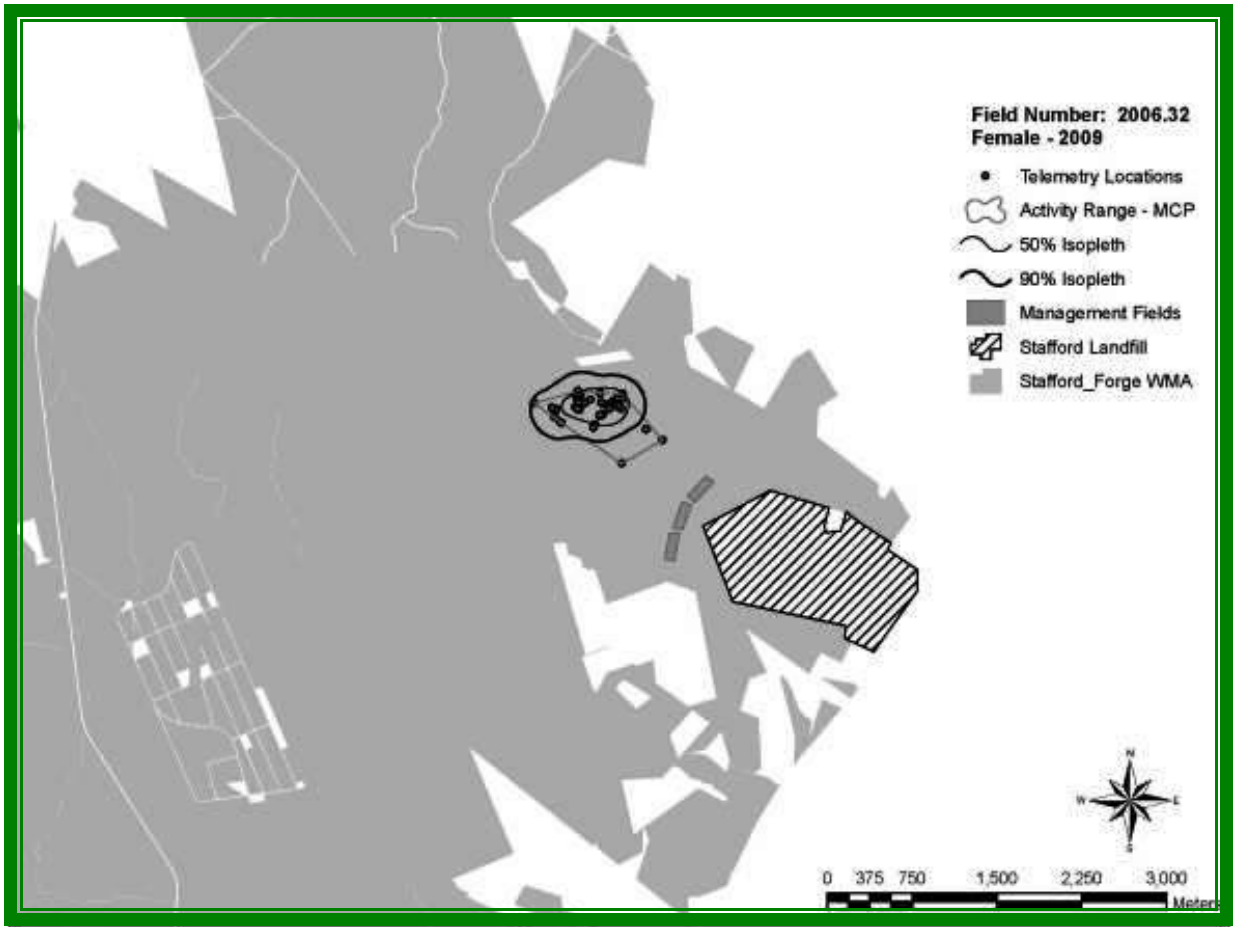



**Figure 17.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2006.32**. The complete forest area size used while being radio-tracked in 2009 was 93.8-acres (37.9-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009**: This snake egressed from NH W on 04/23/09, and was relocated 60 times during the 2009 field season. Following emergence, it sheltered within an active red squirrel feeding station approximately 20 meters northwest of its hibernaculum and remained there for 8 relocations. The snake made a series of small moves through this area until mid-May, when it went opaque. The snake then left the dense, unburned pine/oak forest by its hibernaculum and moved west across Hay Road. It made a small move north into transitional lowland/upland oak/pine forest in the vicinity of its 2007 hibernaculum (NH D). Another study snake (Field Number 2008.02, a male), was repeatedly located within this same general area, but no courtship or mating was observed, and pine snake 2006.32 was not gravid. Throughout the remainder of the season, this snake utilized a relatively small portion of its home range. It was most consistently relocated in a section of dense, unburned pine/oak forest east of Hay Road and west of the Mill Creek wetland corridor. On a few relocations, the snake was found to have returned to the transitional oak/pine forest that it had frequented during the early part of the season (vicinity of NH D). In October 2009, HA staff noted that this snake had lost a substantial amount of body weight due to unknown causes. This snake did not return to any of its previously selected hibernacula in 2009, but instead chose to overwinter in a small, nondescript hole between an upland pine ridge and a narrow forested wetland located within the southeastern portion of its home range. This new den site has been designated as NH FF.

**Figure 18**. When confronted, pine snakes will often face the intruder, coil in a strike position, and hiss loudly. While some individuals may occasionally bite, they are a calm and docile harmless species of snake. Photo by R. T. Zappalorti.

***N. Pine Snake No. 2006.34*** (♂)**.** (Shifted Snake, Treatment A/1 winter) Current status = Alive and healthy. This snake was originally caught in trap 85 of the perimeter drift fence by EcolSciences, Inc. on 08/31/06.

**2008:** The snake egressed from NH O on 04/17/08. This snake spent the majority of late April and May in a forested wetland south of the Stafford Park property. On 06/10/08, the snake was relocated 50 cm away from a hole in which an ovulating female (Field Number 2007.05), was concealed. No courtship or mating attempts were observed, but it is likely that this behavior occurred. This snake continued to utilize the aforementioned forested wetland and the adjacent oak/pine forest for the remainder of the 2008 field season. Throughout 2008, this snake was relocated within the same home range identified via radio-telemetry in 2007. It overwintered in a natural den (NH V), 3 meters from one of its relocation points observed in 2007.

**2009:** This snake was relocated 75 times in the 2009 field season. It had already egressed from its den prior to the commencement of radio-tracking efforts on 04/16/09. When it was relocated on 04/23/09, the snake had made a fairly large move to the north from its previous location near its hibernaculum. On 05/09/09 this snake was observed mating with pine snake number 2007.05, approximately one kilometer northeast of its winter den (NH V). This male was again observed in courtship with the aforementioned female on 05/18/09, however, actual copulation was not observed (please refer to the Breeding and Nesting Observation section).

This snake had an activity range of 416.5-acres (168.5-hectares), one of the largest home ranges of any radio-tracked pine snake in 2009. It was relocated within 15 meters of the SPR perimeter drift fence, as well as approximately 2.65 kilometers S/SW of the SPR property. In 2009 this snake frequented the same habitat areas that it used during the prior seasons within its home range. However, it was also relocated in new sections of forest it had never been observed in previous years. During the past two seasons this snake was one of the first study snakes to enter hibernation. In contrast to its previous behavior, this snake was not found in the vicinity of a suitable hibernaculum until 10/23/09. It chose to overwinter within a small nondescript mammal burrow in pine/oak forest south of the SPR site. This previously unknown hibernaculum is designated NH HH.

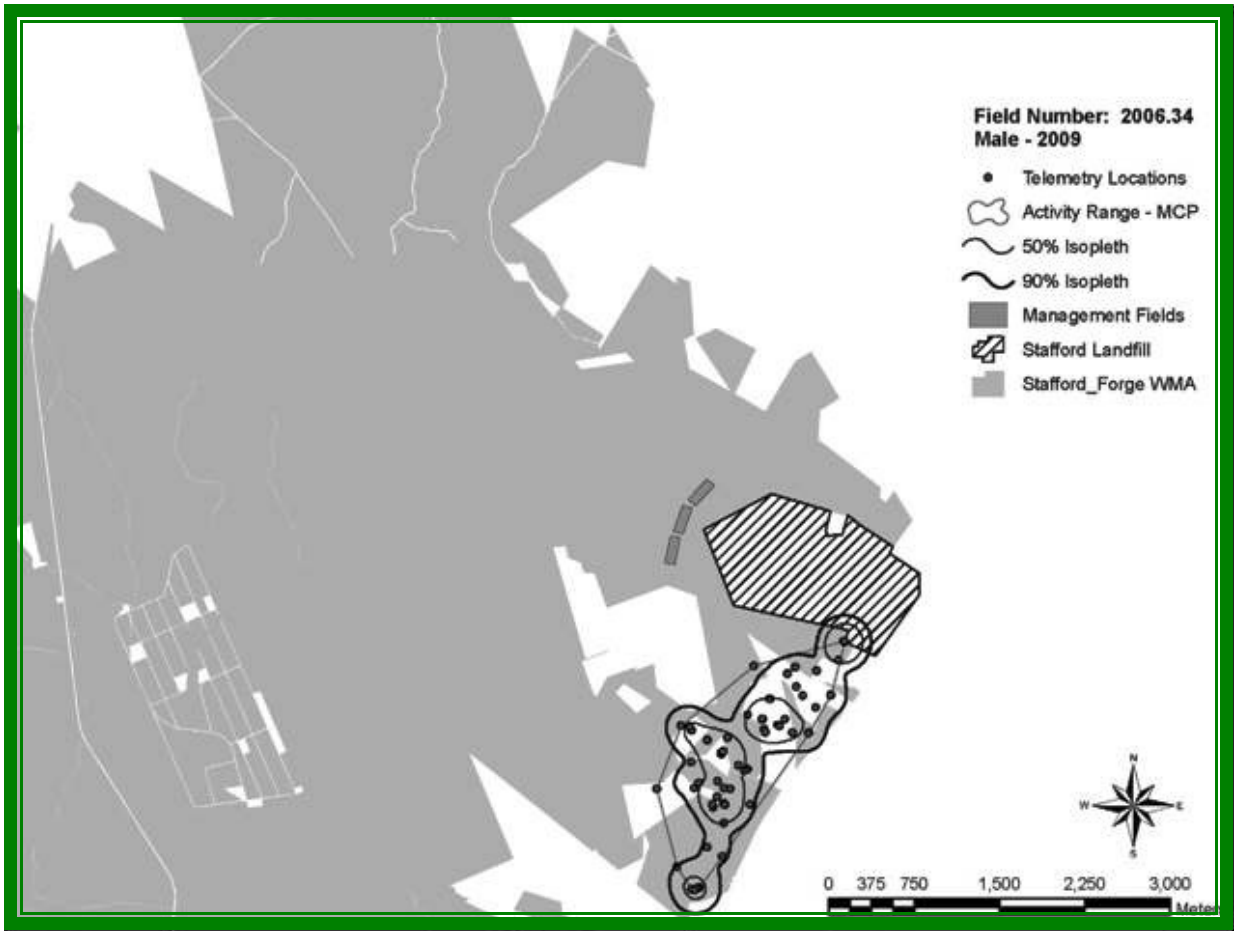



**Figure 19.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2006.34**. The complete forest area size used while being radio-tracked in 2009 was 416.5-acres (168.5-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**NON-SHIFTED SNAKES**

***N. Pine Snake No. 2007.03*** (♂). Current status = Alive, but has low body weight. This snake was originally captured by HA staff on 05/24/07 in a heavily burned area of the upland pine forest west of the management field number three.

**2008:** This snake was first observed on the surface at the entrance of NH B on 04/17/08, but did not egress from NH B until 05/07/08. This snake was relocated 87 times in 2008, and traveled W/NW into the same habitat it used in 2007. It was opaque (pre-shed) from 05/28/08 to 06/06/08. In July, the snake moved back to the forest immediately west of MF 3 and used the perimeter berm for shelter prior to making a large move into a section of the Mill Creek wetland corridor located north of Hay Road. On 08/11/08 the snake was again located near the perimeter berm of MF 3.

On 09/25/08, it was located in NH C, a natural den located near the Hay Road pond (see **Appendix IV**). It made a late season move in the direction of the management fields, and had returned to NH B by early November. During the two previous seasons, this snake has been the last study snake to enter a permanent overwintering station. Throughout the entire 2008 active field season this particular snake appeared thin and had lost body weight. There was little evidence of this snake successfully feeding during the entire season.

**2009:** This snake was relocated a total of 9 times during the 2009 season. It had egressed from NH B on 04/30/09, several days following the other study snakes (Field Number 2006.08 and 2006.17) who also used the same natural den. Between 04/30/09 and 05/07/09, it was relocated within a mound along the AH 6 outer corral path. When first relocated above ground, this snake was collected from the field for transmitter replacement surgery. Upon further inspection, it was determined that its overall low body mass and poor health would compromise its ability to survive transmitter removal surgery. This snake is currently being held in HA's laboratory and has since regained sufficient body weight to enable HA staff to eventually remove its radio-transmitter. It will be retired from the study and released in its natural den in the spring of 2011. Because it was removed from the field in mid-season of 2009 and held in the laboratory, this snake does not have an activity home range map.

***N. Pine Snake No. 2007.04*** (♀)**.** Current status = Deceased. This snake was originally captured by HA staff on 05/25/07 in an isolated section of disturbed pine/oak forest on the east side of the Stafford Park construction site.

**2008:** On 04/17/08 this snake was located 100 meters from its winter den (NH L), indicating that egress had occurred prior to that date. This snake was relocated 86 times in 2008. On 06/26/08 it was observed actively raiding the nest of an eastern cottontail rabbit (*Sylvilagus floridana*). HA staff observed the snake constricting and eating five neonate rabbits. The snake spent the next few weeks concealed within a forested wetland before making a large move towards MF 3 on 07/21/08. Over the course of the next month, this snake repeatedly used the berm along the management field edge, between forays into the surrounding upland pine forest. At the end of the 2008 active radio-tracking season, this snake was underground in a lowland oak/pine forest 150 meters west of Route 72. When HA staff went to check on this snake in January of 2009, it had made a move of approximately 300 meters north to the vicinity of where it hibernated during the previous winter. The snake was in a stump hole on a small upland rise located within pine/oak forest. This new denning location has been designated NH U.

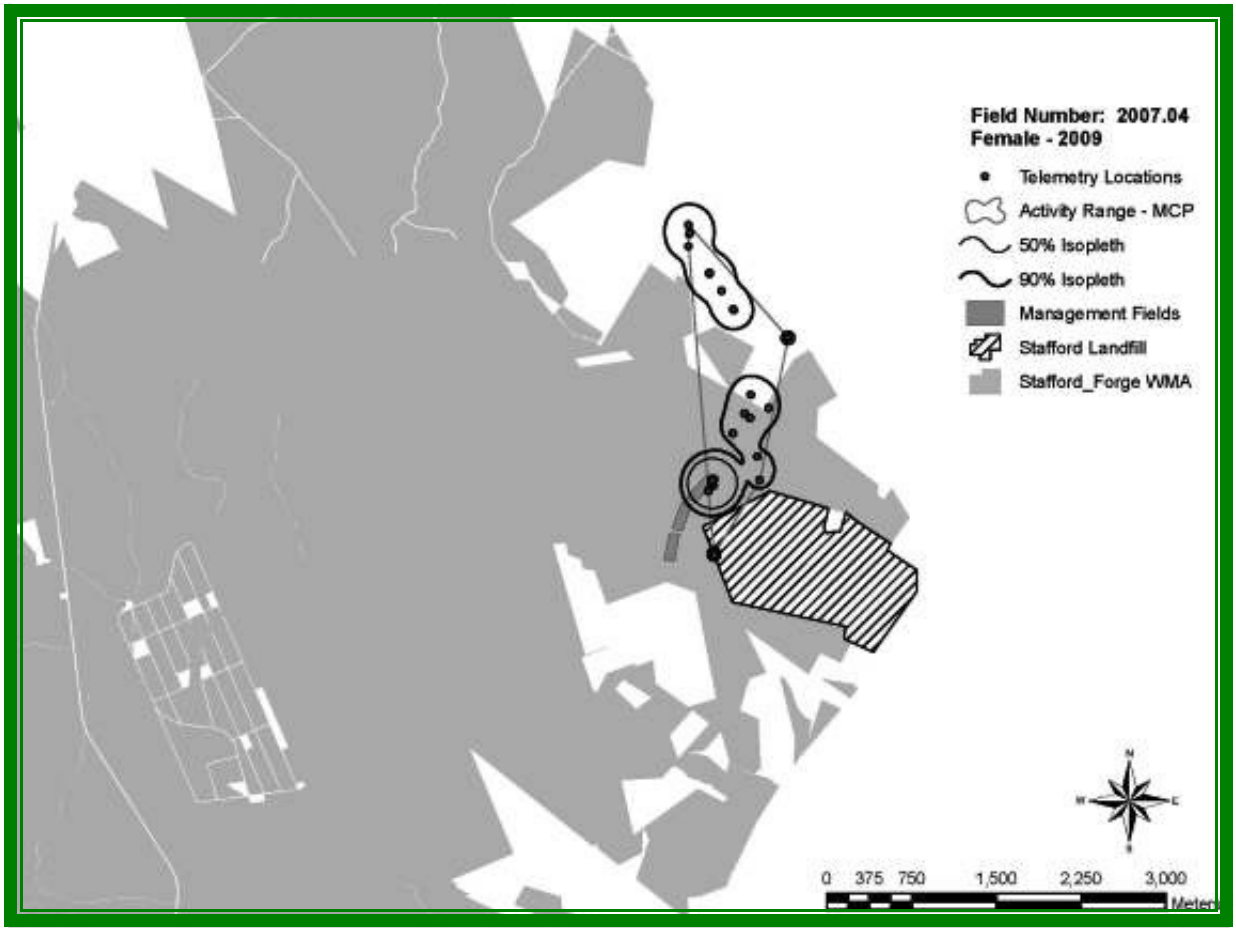



**Figure 20.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.04**. The complete forest area size used while being radio-tracked in 2009 was 337.6-acres (136.6-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009:** This snake egressed from its den on 04/23/09, and was relocated 49 times in 2009. On 05/18/09, this female was followed by a new, unknown male pine snake. To prevent disturbing any potential mating, this male was not removed from the field for processing. It was determined that this new male could be identified in the future by its distinctive markings (a series of three connected dorsal blotches at mid-body). Similar to mating behavior in 2008 (but dissimilar in time), it was found using the same forested wetland on 06/01/09. She had moved to management field 3 by 06/07/09. The snake used the northeast corner of MF 3 for refuge and nesting. It was relocated in this vicinity until 08/14/09, when HA staff discovered the partially eaten body. It was a few meters in the forest, killed by an unknown predator. Upon recovery of the transmitter, HA staff observed that the antenna wire was ripped from the transmitter casing and was twisted and damage. This was probably the result of a raptor who tore and peeled strips of flesh from the snake's body in typical bird-of-prey fashion. As additional evidence that a hawk killed the snake, there was a quantity of "whitewash" (white uric acid from a bird) on the trunk of a pine tree and nearby shrubs. Based upon past observations HA suspects a red-tailed hawk was the predator.

***N Pine Snake 2007.05*** (♀). Current status = Alive and healthy. This snake was originally captured by HA staff on 05/28/07 emerging from a stump hole next to pine snake 2006.34, during a radio-tracking relocation south of the construction site.

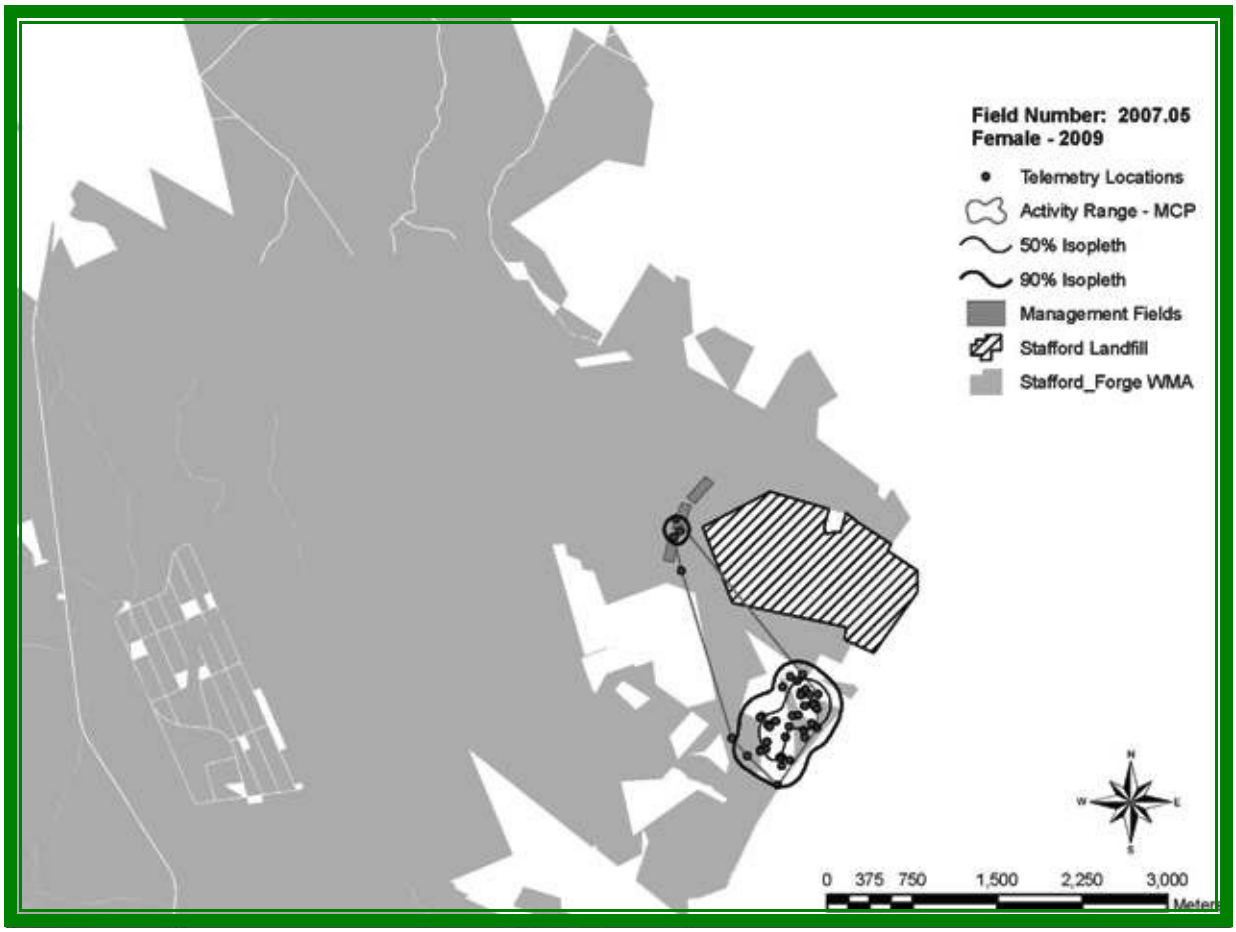



**Figure 21.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.05**. The various forested area size used while being radio-tracked in 2009 was 295.1-acres (119.4-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2008:** For the majority of the 2008 field season, this snake traveled within the home range identified via radiotelemetry in 2007. This female ovulated and was observed mating with a small male pine snake, which was new to the study on 05/21/08. During nesting season she was observed excavating and occupying a nest burrow in the earthen berm that borders the western edge of MF 2. Post egg deposition the snake made a large move S/SE, back into the habitat she had previously utilized prior to nesting. The snake overwintered in NH N again with pine snake 2006.26.

**2009:** This snake was relocated 69 times in 2009. It egressed from NH H on 04/25/09. During the first two weeks of the activity season this snake was consistently located in the forest immediately adjacent to its den site. On 05/09/09, it was relocated mating with male pine snake 2006.34. This female was again observed in courtship with the same male on 05/18/09, although copulation was not actually seen (please refer to the Breeding and Nesting Observations section below). During the breeding season, this snake was observed in close proximity to the same young male pine snake it was mating with in 2008. Mating was not observed between these two snakes in 2009, and it is not known if the female copulated with multiple males during the breeding season. This snake was noticeably gravid and eventually nested in MF 2, within 5 meters of the nest site it excavated in the 2008 season. After the nesting season, it made a large move south into the oak/pine and pine/oak forest that had been established as her main activity range during prior field seasons. This snake was observed in an interesting feeding behavior in 2009. On 05/22/09 it was relocated just below the duff layer (an accumulation of leaf litter and humus on the forest floor) in a section of upland pine/oak forest. As HA staff approached, the snake emerged from the leaf litter with an eastern mole (*Scalopus aquaticus*) held in its jaws. It took the snake approximately 15 minutes to subdue, constrict and consume the mole. This snake overwintered in a previously unknown natural den (NH DD) in a pine/oak forest near the landmark known as the "glass pile."

***N. Pine Snake No. 2007.07*** (♀). Current status = Alive and healthy. This snake was originally captured on 06/03/07 by HA staff as it was crossing Hay Road.

**2008:** This snake overwintered in a large mammal burrow complex south of the Hay Road pond, designated NH C. Immediately after emergence, this snake moved into the heavily burnt upland pine forest northwest of its hibernaculum. It stayed in this same general tract of pine forest until mid-June, when it proceeded to make a large move to the E/NE. The snake crossed Hay Road and the Mill Creek wetland corridor and was relocated in privately owned upland oak/pine habitat northeast of Mill Creek. This particular section of forest was never used by this snake during the 2007 active field season. However, during both the 2007 and 2008 field seasons another study snake (Field Number 2007.10), was frequently relocated in and around this same area. For the remainder of 2008 this snake was consistently relocated in this tract of oak/pine forest. On 10/15/08 it returned to the vicinity of NH C and subsequently overwintered for the second time at this location.

**2009:** This snake egressed from NH C on 04/18/09, and was relocated 62 times during the 2009 field season. Shortly after emergence, the snake moved east across Hay Road and was relocated in an old disturbed area frequented by another study snake (Field Number 2008.02). It remained in this general vicinity until mid-May, when it crossed the Mill Creek wetland corridor back to the privately owned upland oak/pine habitat it had favored during the previous 2008 season. This area (in the vicinity of an old power cut), is often utilized by another study snake (male Field Number 2007.10).

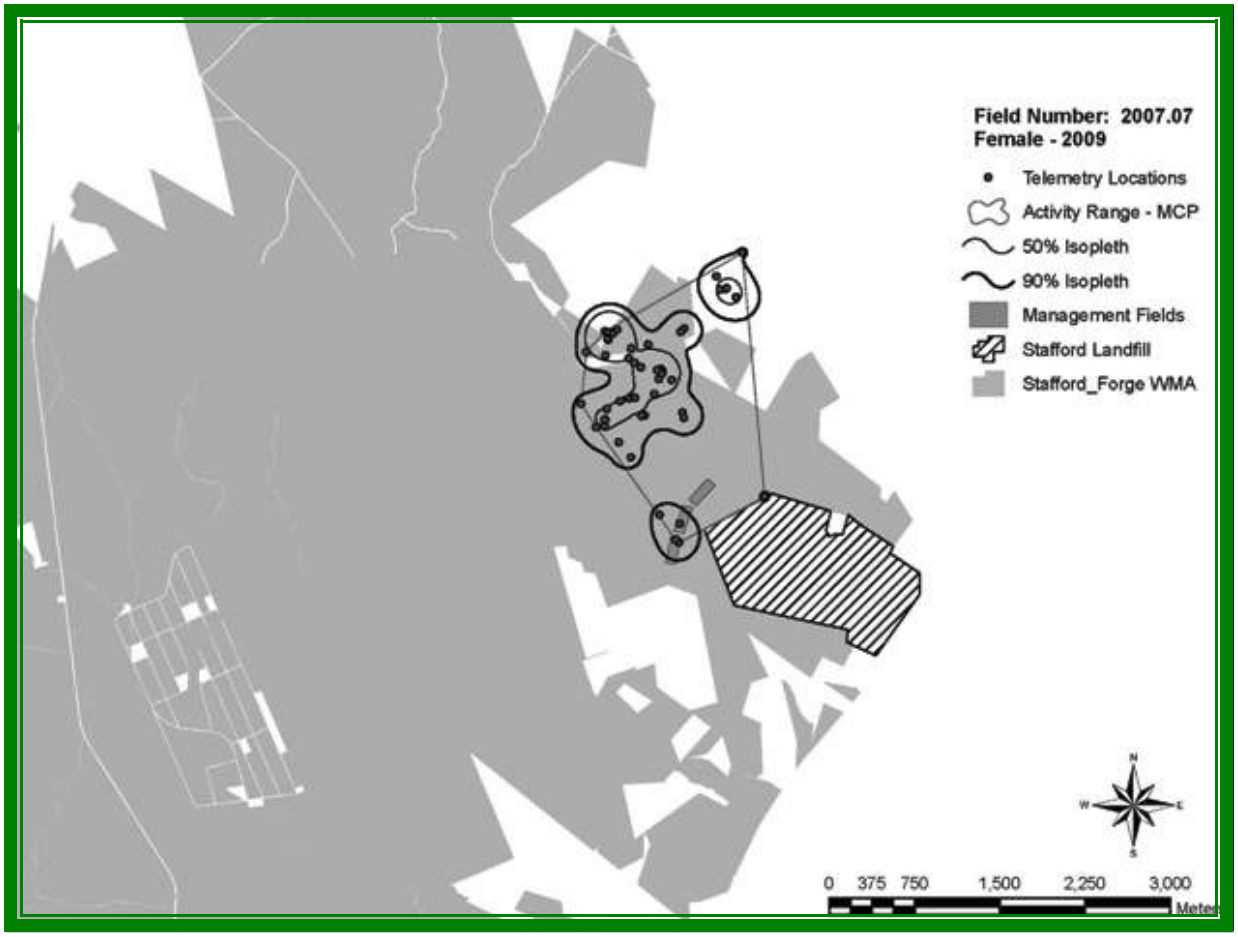



**Figure 22.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.07**. The complete forest habitat area size used while being radio-tracked in 2009 was 652.5-acres (264.5-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009**: Though no mating behavior was observed, the increased body girth and bulging eggs confirmed that this snake was indeed gravid by 06/03/09. On 06/19/09, the snake moved southwest across the Mill Creek wetland corridor and Hay Road, and was caught in the perimeter drift fence trap number 90 on 06/24/09. The snake was released several hundred meters into the surrounding forest, in accordance with the established protocol, which placed it in the upland pine forest between management field two and the perimeter drift fence.

The snake was then relocated underground in two different locations (eastern berm and large central mound) within MF 1, which left its actual nesting site undetermined. The snake was relocated traveling east away from MF 3 on 07/02/09, and at that time it was no longer gravid (evidenced by posterior skin folds). It then traveled northeast across the Mill Creek wetland corridor and spent the remainder of the month back in the upland oak/pine forest it had favored earlier in the season. The snake made one more move southwest across the wetland towards the vicinity of Hay Road before returning to its favored habitat northeast of the wetland.

This area comprises a large portion of the home range of another study snake (male Field Number 2007.10). These two snakes were found in close proximity on several occasions in late summer through early fall, for reasons undetermined. On 09/30/09 this snake made a large move of one kilometer to the northeast into a tract of cut over oak/pine forest where it had never been relocated previously. It selected a site 300 meters west of Route 72 as a new hibernaculum, designated NH GG. The entrance to this den is a series of three small holes on the forest floor, near the base of a large mountain-laurel (*Kalmia latifolia*) bush.

***N. Pine Snake No. 2007.09*** (♂). Current status = Alive and healthy. This snake was originally captured by HA staff on 06/04/07, found concealed within a trash pile.

**2008:** This snake had the largest home range of any pine snake tracked throughout the 2008 season (over 1,041-acres). It spent the majority of the field season in a large tract of heavily burned upland pine forest between Grays Road, Micaja Road and Three Foot Branch Road in the southwestern portion of Stafford Forge WMA. In September 2008, this snake made an extremely large move to the northeast and selected an abandoned mammal burrow which turned out to be a new hibernaculum (NH Y). This new den was located on a tract of privately owned land, just south of the Brighton Homes residential development.

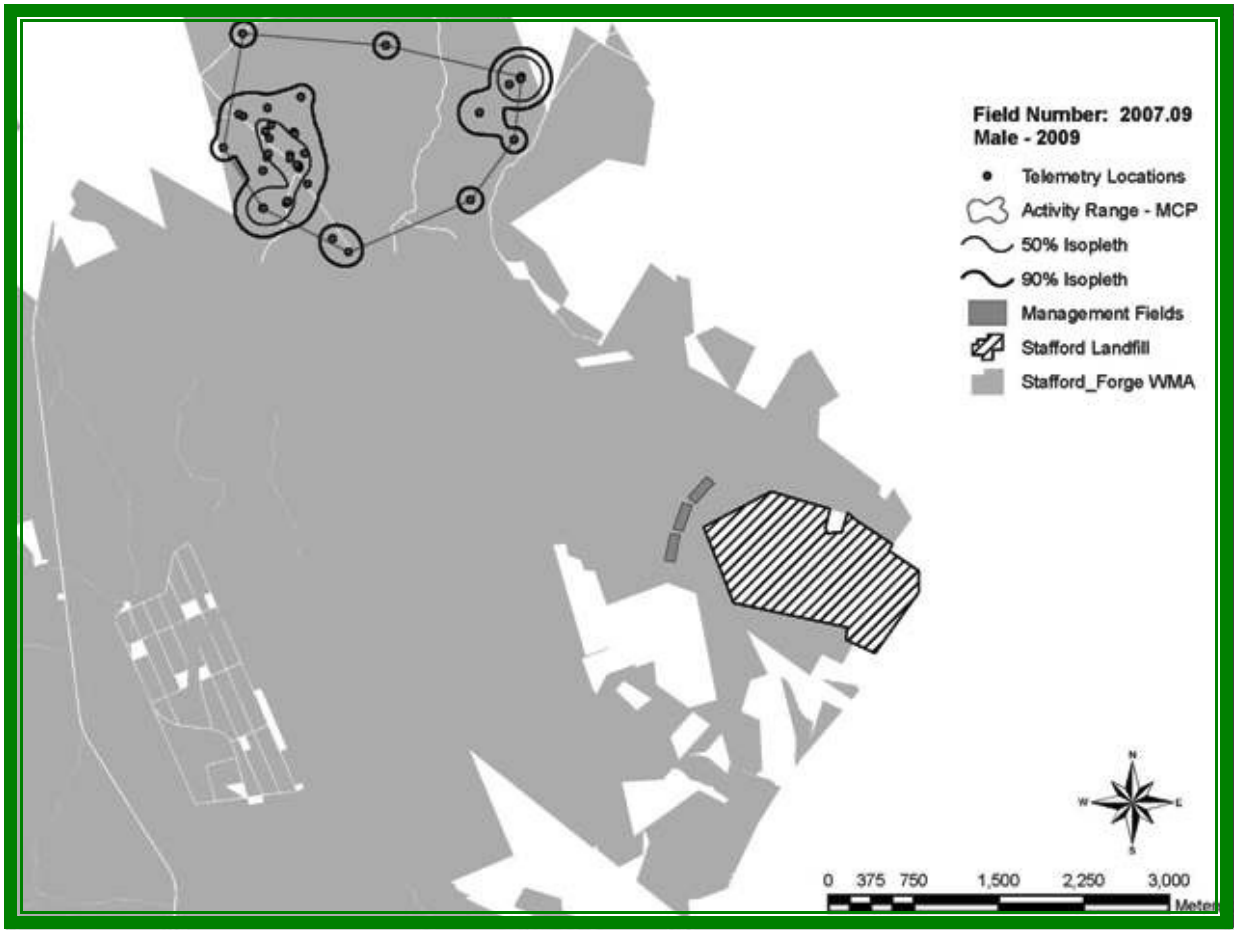



**Figure 23.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.09**. The habitat area size used by this snake while being radio-tracked in 2009 was 895.5-acres (362.4-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009**: This snake egressed from NH Y on 05/02/09, and was relocated 53 times during the 2009 field season. It spent the first two weeks after its emergence in the vicinity of its winter den, making only small moves between stump holes, fallen logs and concealed in mole tunnels. The snake then made an extremely large move west towards severely burned upland pine forest along the western edge of Grays Road. This snake was located on three occasions beneath a burnt, discarded rubber truck tire that it had utilized as a shedding station in 2008. In behavior similar to the previous season, this snake was frequently relocated in the vicinity of red squirrel feeding stations, possibly indicative of a successful foraging strategy. In contrast to the previous season, this snake never returned to the heavily burned upland pine forest between Grays Road, Micaja Road and Three Foot Branch Road that it had frequented in 2008. In 2009, the majority of its relocations were concentrated within the upland pine/oak forest east of Grays Road in the vicinity of its intersection with Pancoast Road. In early October this snake began to slowly move northeast in the direction of its 2008 hibernaculum. The snake returned to the immediate vicinity of NH Y by 10/25/09, and was not seen above ground again after10/30/09, where it spent the winter.

***N. Pine Snake No. 2007.10*** (♂). Current status = Alive and healthy. This snake was originally captured by HA staff on 06/05/07 traveling near the radio tower along the northern portion of the SPR construction site.

**2008:** This snake left its hibernaculum (NH J) on approximately 04/17/08, and remained in the general vicinity of its den until mid-May. It then made a large movement to the upland pine forest immediately west of MF 1. The snake then returned to habitat north of the Mill Creek wetland corridor, where it spent the majority of the field season in oak/pine forest in the vicinity of an old power cut (see **Appendix IV**). On 10/15/08 this snake was relocated in a small nondescript hole at the base of a large scrub oak, and selected this site as its new hibernaculum. This additional natural den has been designated NH Z.

**2009:** This snake egressed from NH Z on 04/23/09, and was relocated 60 times during the 2009 field season. The snake remained in the upland oak/pine forest in the general area of its winter den until early May, when it made a large move west across the Mill Creek wetland corridor. The snake continued to move west across Hay Road towards a sparsely canopied upland pine ridge north of the Hay Road pond. This area was within the home range of an ovulating study female (Field Number 2006.29). Pine snake 2007.10, was observed by HA staff mating with this female on two separate occasions, once on 05/13/09 and again on 05/22/09. Within five days of the last mating observation, the snake made a large move east back to the upland oak/pine forest it had used throughout the previous field season. On 06/23/09, this snake was collected for transmitter replacement surgery. It was released after the successful replacement of its transmitter on 07/06/09. After its release, the snake remained largely within its favored tract of oak/pine habitat, often traveling a few hundred meters up and down an old power cut. This snake was often relocated sheltering within two hollow pine logs in the area, one of which was elevated more than 60 cm above the forest floor. In late October 2009, this snake moved a short distance east and selected a new hibernaculum approximately 200 meters northeast of the power cut. This new natural den, a small pitch pine stump hole, was designated as NH II. This snake's home range map is on page 41. However, it is important to note, that the south eastern most point shown in **Figure 24** is erroneous and over estimates the snake's 2009 home range.

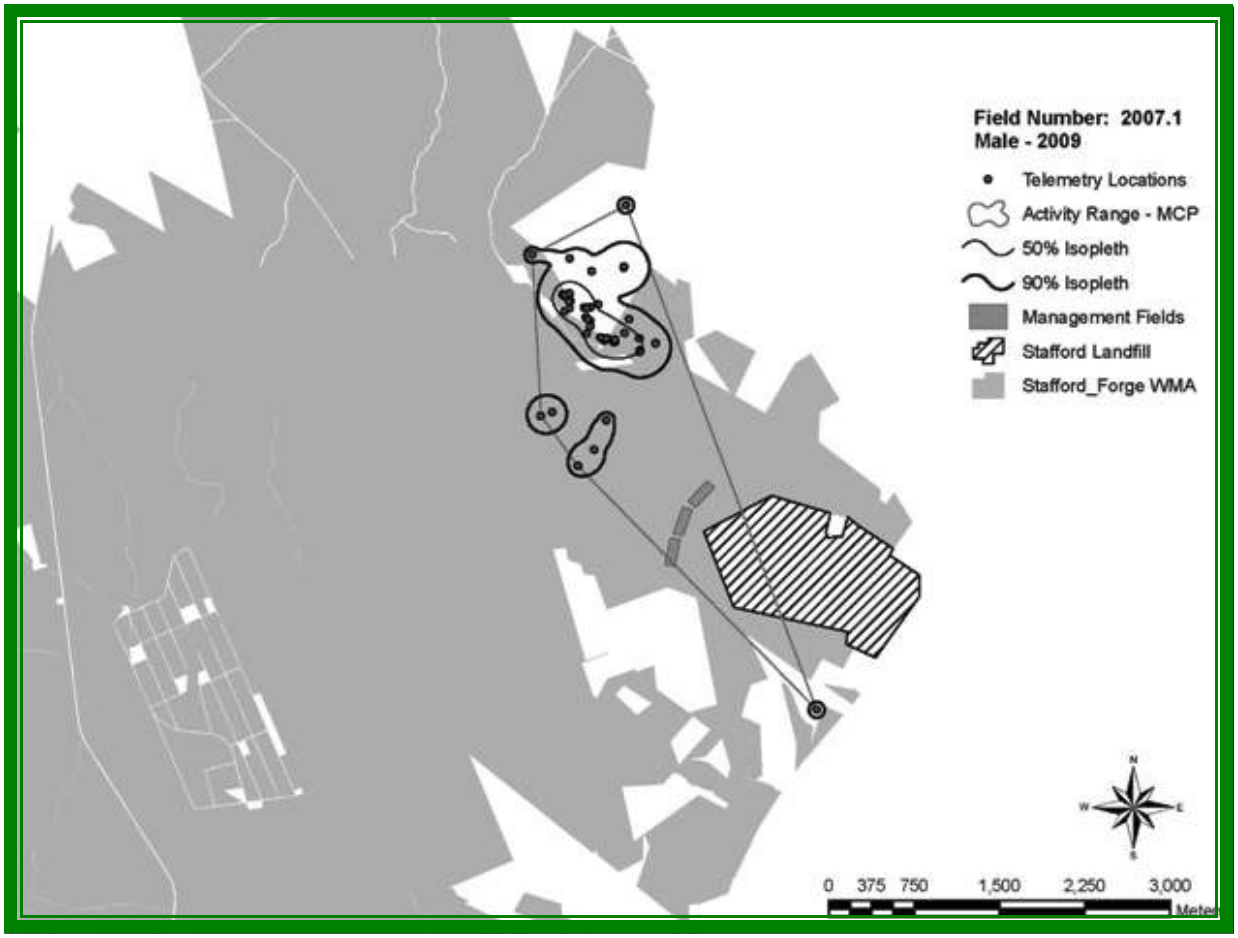



**Figure 24.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.10**. The various forested habitat size used while being radio-tracked in 2009 was 967.2-acres (391.4-hectares). It is important to note, that the south eastern most point shown is erroneous and over estimates the snake's 2009 home range size. Source: HA and the Endangered and Nongame Species Program, NJDEP.

***N. Pine Snake No. 2007.11*** (♂)**.** Current status = Alive and healthy. This snake was captured by HA staff on 06/15/07 while radio-tracking pine snake 2006.34.

**2008:** This snake had already egressed from its late season denning site by 04/17/08, prior to the start of the active 2008 radio-tracking season. During the 2008 activity season, it was observed using a variety of habitats within the same home range identified via radio-telemetry in 2007. On 08/27/08, the snake returned to its 2007 and 2008 overwintering location (NH H), where HA staff observed empty pine snake eggshells and several hatchlings. The snake remained in the general vicinity of NH H, sheltering in the various man-made berms which are prevalent at this old disturbed site before returning to NH H to overwinter.

**2009:** On 04/18/09 this snake was found in a trap attached to the corral enclosing NH H during the spring egress (please refer to the Corralling of Natural Hibernacula section below). It was relocated 73 times during 2009. For the majority of the 2009 activity period, this snake was relocated within the same general home range revealed by radio-tracking efforts in 2007 and 2008.

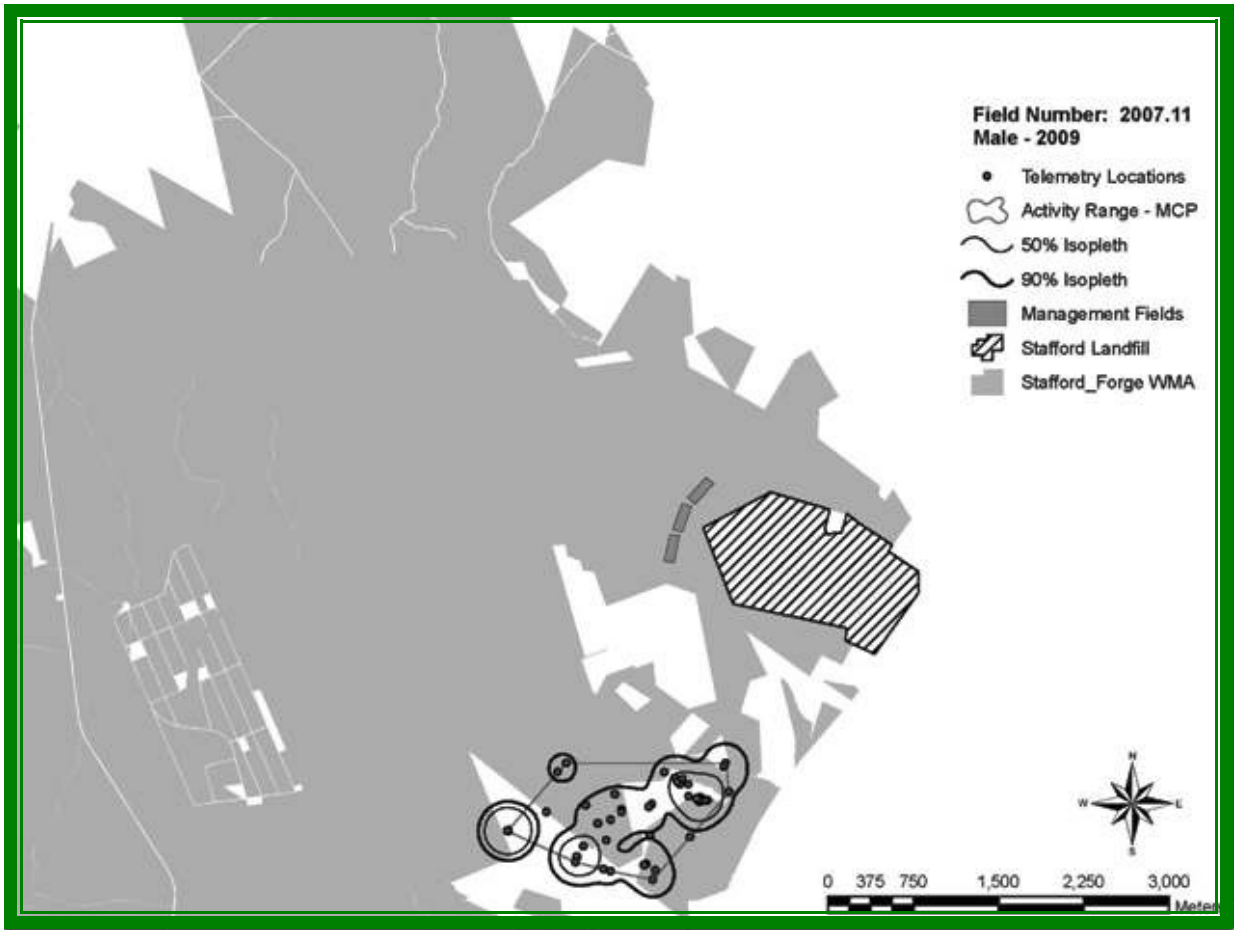



**Figure 25.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.11**. The various forested habitat area size used while being radio-tracked in 2009 was 335.9-acres (135.9-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

However, in 2009 this snake used wetlands more frequently than in previous seasons. On one wetland relocation, this snake was observed approximately 5 meters above ground in a burnt pitch pine tree. The snake was observed realigning its jaws and appeared to have a bulge at mid-body, suggesting that the snake had recently fed upon an unknown prey item, possibly a red squirrel or bird. In 2009 this snake was not observed in any courtship or mating behavior. On 09/28/09 this snake was relocated at its previous overwintering location (NH H) and was not observed above ground for the remainder of the Fall season. This snake has consistently been the first study individual to enter hibernation for three-years consecutively. It had an activity range of 335.9-acres (135.9-hectares) during its active season in 2009.

***N. Pine Snake 2007.14*** (♂)**.** Current status = Alive and healthy. This snake was originally captured on 08/11/07 near the landmark known as "the glass pile," located south of the SPR property.

**2008:** This snake emerged from NH G on 04/25/08 and immediately traveled northeast towards a portion of its home range it had frequented in 2007. On a number of relocations, it was found within close proximity to pine snake 2006.34. It was observed to be opaque while hidden in an old metal gas tank on 07/16/08. This same gas tank was used by pine snake number 2006.34 on 07/08/08. HA

staff also noted a large black racer (*Coluber c. constrictor*), shed just outside of and along the exterior of the metal gas tank. These observations suggest that this location may serve as a shedding station for multiple snake species.

Snake number 2007.14 concealed itself in a stump hole within a forested wetland from 08/21/08 through 09/07/08, and was rarely seen above ground during this time period. On 10/03/08 both this snake, and pine snake 2006.34, were relocated in the same hole near the landmark known as the "glass pile," where pine snake 2006.34 eventually overwintered. However, pine snake 2007.14 was found at this site for only one relocation, then moved approximately 1.6 km to the northeast. It selected a previously unknown mammal burrow dug into the side of a large hunter's pit, in which it overwintered. This new natural den has been designated NH AA.

**2009:** This snake was relocated 69 times during the 2009 field season. After emergence from NH AA, the snake moved into the pine forest and pine/oak habitat that it had frequented during previous field seasons. On 05/20/09 it was observed copulating with a previously unidentified female. No other interesting behaviors were observed during relocations of this snake throughout the remainder of the 2009 field season. During the majority of the activity season it was relocated within the home range revealed through radio-tracking efforts in prior years. This snake chose to hibernate in a previously unidentified natural den in upland pitch pine forest, west of Micaja Road. This den is a

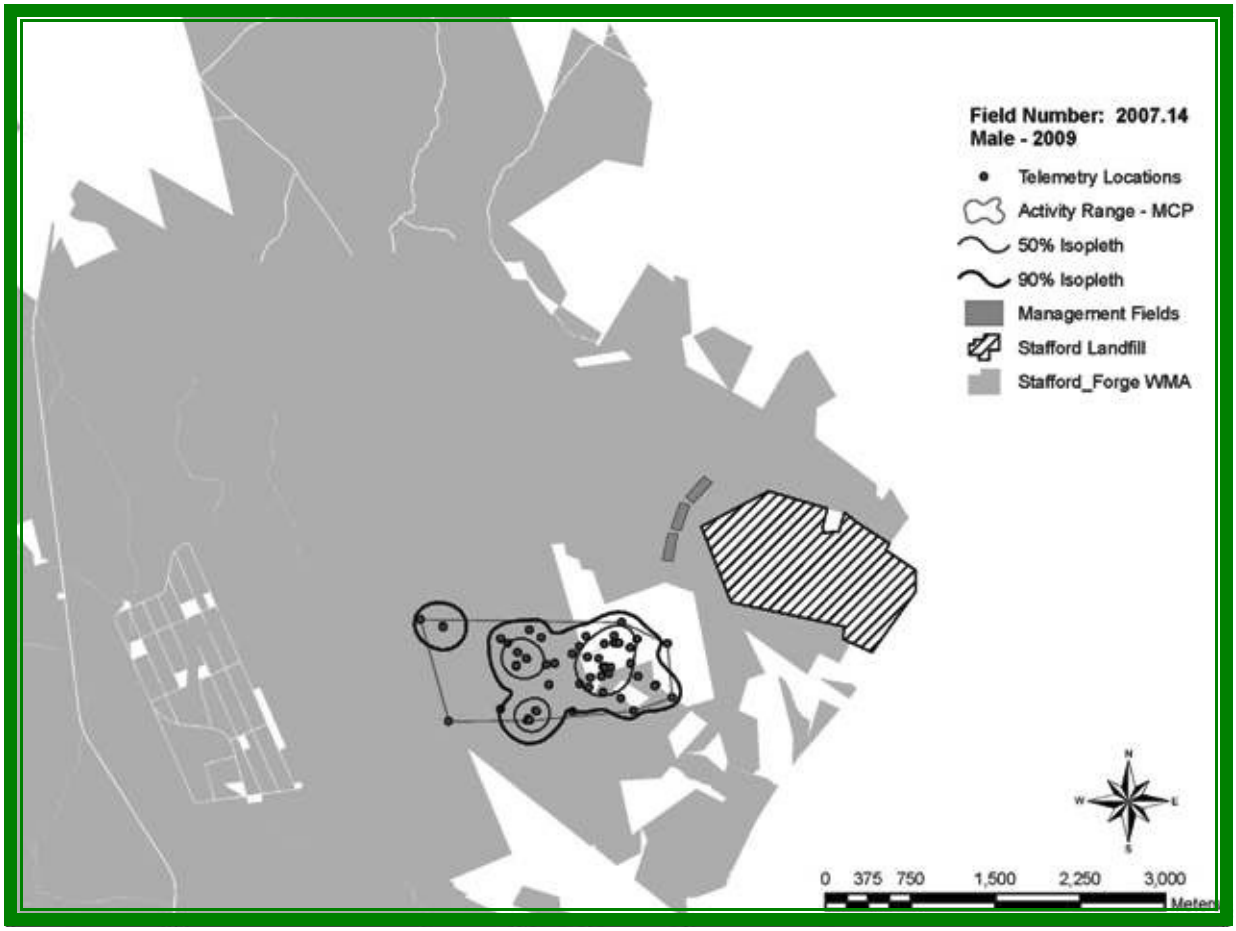



**Figure 26.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.14**. The complete habitat area used while being radio-tracked in 2009 was 419.6-acres (169.8-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

large mammal burrow, possibly abandoned by a coyote (*Canis latrans*). This new overwintering station has been designated NH CC. Pine snake 2007.14 had an activity range of 419.6-acres (169.8-hectares) during its seasonal movement period in 2009.

***N. Pine Snake 2007.15*** (♀). Current status = Deceased. This snake was originally captured in trap 8 on 08/17/07 along the perimeter drift fence on the south side of the SPR property.

**2008:** This snake egressed from NH M on 04/23/08, and seemed to favor the pine/oak habitat directly south of the eastern portion of the SPR property. It was often relocated within 10 meters of the perimeter drift fence line. On a number of occasions this snake was located in the narrow strip of existing forest between the SPR property and the Garden State Parkway (between Costco and the Parkway), and on one relocation was discovered in an arrested crawl position on the shoulder of the southbound lanes of the Garden State Parkway. This snake exhibited two interesting behaviors during the 2008 active season. It was observed both climbing and resting up in trees on two relocations. It was also relocated multiple times inside mole tunnels, suggesting a possible prey preference or foraging strategy. On 10/09/08, this snake was located underground near two old relocation flags approximately 3 meters from the entrance to an abandoned mammal burrow. The snake overwintered at this location, which was designated as NH X.


**Figure 27.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2007.15**. The complete forested habitat area size used while being radio-tracked in 2009 was 582.5-acres (235.5-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009:** This snake was relocated 75 times during the 2009 field season. It emerged from NH X on 04/27/09. During the first two weeks of its activity season this snake was relocated within close proximity to its hibernaculum. On 05/11/09 it was found within the same narrow strip of forest (between Dick's Sporting Goods store and the southbound lanes of the Garden State Parkway) as it was on several relocations in 2008. On 05/18/09 this snake was relocated in disturbed habitat within 15 meters of the Parkway near Costco. A male pine snake (Field Number 2006.17), was relocated within a few meters of this female during the same time period. Although no courtship behavior or copulation was observed between the two snakes, female pine snake 2007.15 was determined to be gravid following this encounter. On three separate occasions (06/03/09, 06/07/09, 06/26/09), this snake was caught in traps along the perimeter drift fence, while gravid, likely attempting to access the old landfill to excavate her nest. After being caught in a trap for the third time, she was relocated into the upland pitch pine forest in the vicinity of management field two. Eventually this snake nested in a large earth mound at the north end of MF 3, where pine snake 2006.29 also nested. Following egg deposition this snake spent the majority of its time in and around the management fields. On 09/22/09 it began to slowly move SE towards the area where it had overwintered during the past two seasons. Once again, this snake was captured in a perimeter drift fence trap on 10/06/09. On 10/21/09 this snake's transmitter was found on the forest floor approximately 260 meters northwest of its 2008 overwintering location. The markings on the transmitter wire suggested that the snake was likely killed by a raptor because the wire had tare marks in it. Additional evidence that a hawk killed the snake was observed in the form of a quantity of "whitewash" (white uric acid from a raptor) on the trunk of a pine tree and shrubs. No additional remains of this snake were recovered by HA staff, with the exception of the above mentioned transmitter. During its seasonal movements in 2009, snake number 2007.15 used 582.5-acres (235.5-hectares).

***N. Pine Snake 2008.02*** (♂). Current status = Alive and healthy. This snake was originally captured by HA staff while emerging from NH C on 04/16/08.

**2008:** This snake was fitted with an internal two-year transmitter and released on 05/21/08. In mid-July this snake made a long distance move to the northeast, crossing Hay Road into a disturbed area characterized by junk piles and other human-generated debris. This site was located on an upland pine/oak ridge immediately west of the Mill Creek wetland corridor. This snake was found repeatedly within a debris pile in the area, often in an opaque condition. This suggests that this snake was utilizing this particular debris pile as a shedding station. In late summer the snake made a large move south, across Hay Road and back into the heavily burned upland pine forest where it had spent the majority of the early field season. On 09/25/08 this snake made another large move back to NH C where it overwintered with a female pine snake (Field Number 2007.07).

**Figure 28**. A red-tailed hawk killing and eating a pine snake.

**2009:** This snake left the immediate vicinity of NH C on 05/02/09, and was relocated 64 times during the 2009 field season. It began to utilize a sparsely canopied, heavily burned tract of upland pine forest northwest of the Hay Road Pond throughout May into mid-June. In behavior similar to that of 2008, the snake then made a large move northeast across Hay Road back to the pine/oak ridge immediately west of the Mill Creek wetland corridor. Pine snake 2008.02 went opaque in the vicinity of the debris pile (pre-shed condition), that it had used as a shedding station in 2008 until 06/28/09, then returned to the upland pine forest west of Hay Road. The snake then frequented the upland from the western end of the Hay Road Pond southeast towards MF 3, often making large movements throughout the area. On 08/11/09, the snake made a large move northwest into the home range of another study snake (Field Number 2006.32). These two snakes were often found in close proximity throughout the field season, though no mating or other significant interactions were observed. It remained in this area for several more re-locations, often sheltering within a hollow oak log. By 09/01/09, the snake had once again crossed Hay Road to the east and back into the general area of its shedding station. The snake was observed to be opaque in this immediate area from 09/16/09 until 10/10/09, when it was relocated in freshly-shed condition and traveling west towards its hibernaculum (NH C). By 10/29/09, the snake was back underground in the abandoned mammal burrow that it used as its hibernaculum (NH C), where it had successfully overwintered in 2007 and 2008. This snake had a home range of 158.4-acres (64.1-hectares) during the 2009 active season.

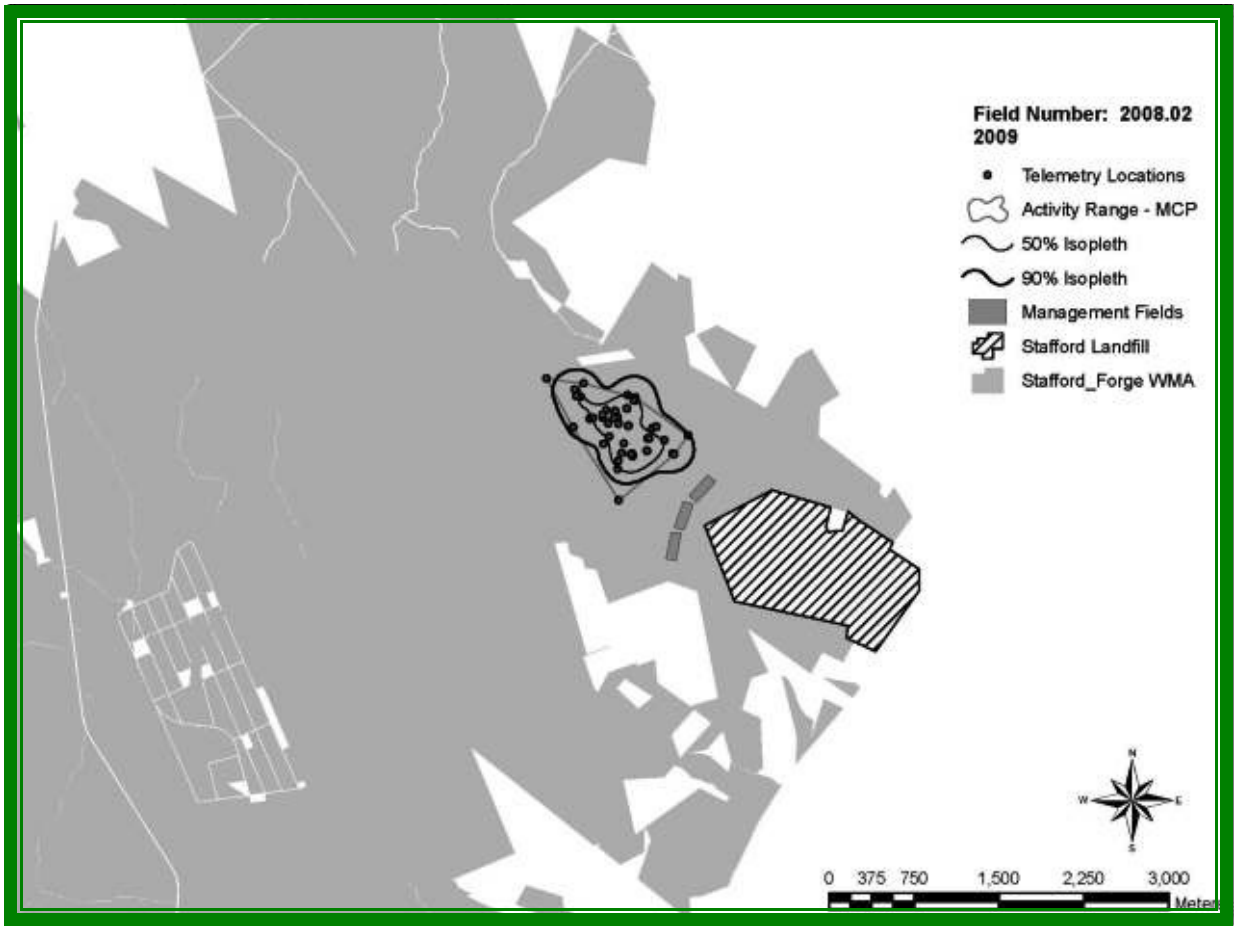



**Figure 29.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2008.02**. The size of the various habitat areas used while being radio-tracked in 2009 was 158.4-acres (64.1-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

***N. Pine Snake 2008.03*** (♀). Current status = Alive and healthy. This snake was originally captured by HA staff attempting to egress from a corralled natural den (NH E), on 04/16/08.

**2008:** It was implanted with a two-year transmitter and released on 05/15/08. This snake was relocated 76 times in 2008. After being released, the snake made a significant move north, crossing Hay Road and utilizing a variety of habitats in and adjacent to the Mill Creek wetland corridor. On a number of occasions, this snake was relocated in the vicinity of a red squirrel feeding station and burrows. This may be indicative of a specific prey preference or a successful foraging strategy. On 09/30/08, this snake returned to den NH E where it successfully overwintered.

**2009:** This snake egressed from NH E on 04/23/09, and was relocated 74 times during the 2009 field season. Once again, it immediately made an extensive move north to the Mill Creek wetland corridor, in an area that this snake utilized extensively during the previous season. This snake was also frequently relocated within the pine/oak forest adjacent to the south. This snake was not observed in any actual courtship or mating behavior by HA staff, although it was relocated on at least two occasions in the immediate vicinity of 2 male pine snakes (Field Numbers 2008.08 and 2009.14, respectively), during the breeding season.

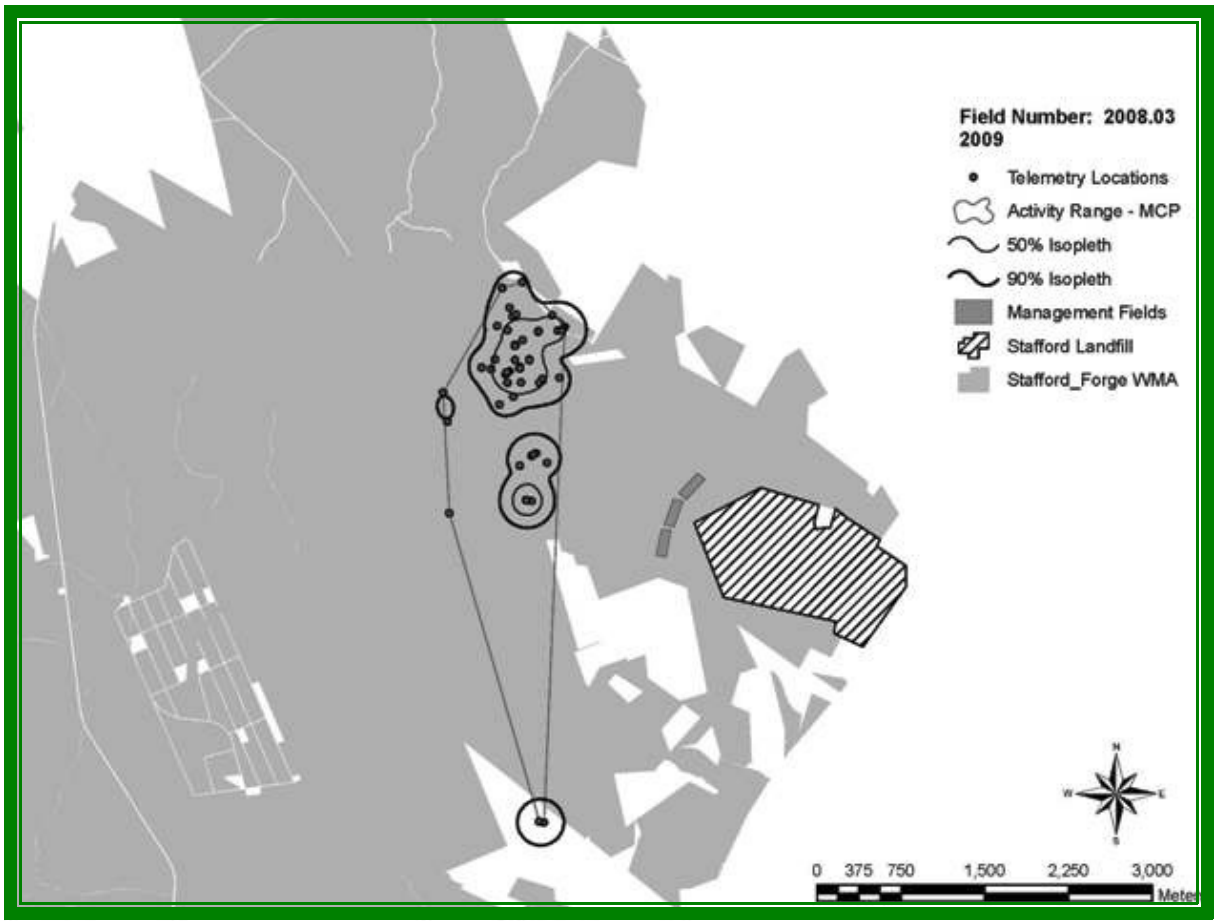



**Figure 30.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2008.03**. The complete size of the habitat area used while being radio-tracked in 2009 was 786.6-acres (318.3-hectares). Source: HA and the Endangered and Nongame Species Program, NJDEP.

Although it was never determined if either of these two males (or possibly another male unknown to the study), successfully mated with pine snake 2008.03, this female was determined to be gravid in early June by HA staff. On 06/28/09 this snake was found within a nest chamber that it had constructed within the area referred to as the "Triangle" (see **Appendix IV**), after making a very large move of approximately 3 kilometers south of any prior relocations. Following nesting and egg deposition, this female returned to the vicinity of the Mill Creek wetland corridor, where it was consistently relocated throughout the remainder of the season. It returned to NH E by 10/14/09, where it successfully hibernated.

***N. Pine Snake No. 2009.13*** (♂). Current status = Alive and healthy. This snake was originally captured by HA staff in trap number 16 of the perimeter drift fence line in early June 2009.

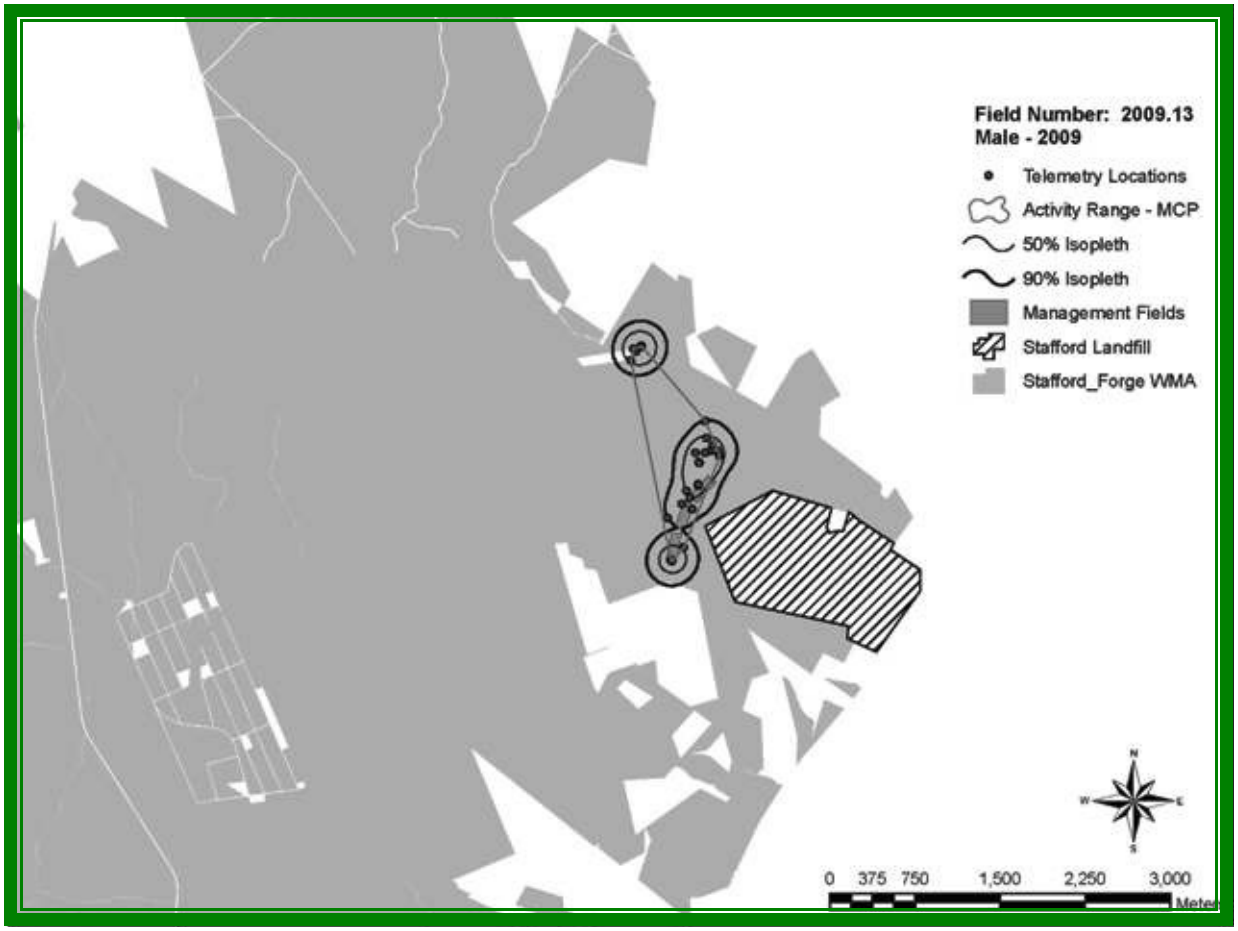



**Figure 31.** Radio-telemetry locations and activity range size (Minimum Convex Polygon and 50% and 90% isopleth from Kernal Analysis) for pine snake number **2009.13**. The size of the forested area used while being radio-tracked in 2009 was 175.1-acres (70.8-hectares). This snake used the managements fields and earth berms extensively during the 2009 active season. Source: HA and the Endangered and Nongame Species Program, NJDEP.

**2009:** It was implanted with a two-year transmitter on 06/04/09 and released on 06/07/09. It was relocated a total of 45 times throughout the 2009 field season; the majority of relocations occurred within the vicinity of the three snake management fields. Often this snake was found foraging near or sheltering within the man-made berms that form the perimeter of the management fields. Towards the end of the 2009 season, this snake moved north across the Mill Creek wetland corridor, where it is currently overwintering within NH FF, a newly identified natural den.

In early October, another study snake (Field Number 2007.10) was initially relocated within this same den, however this snake eventually moved off and selected a new natural den (NH JJ), which is 600 meters to the northwest. Although pine snake 2009.13 was relocated above ground multiple times following its early movement to the general area of NH FF, it was not observed above ground after 10/22/09. Pine snake 2009.13 had a home range of 175.1-acres (70.8-hectares) throughout the 2009 active season.

**Figure 32**. A northwestern view of management field one showing the various native grass growth dominated by switch grass and broom sedge. Photo by Bob Hamilton, HA Staff.

## HABITAT USE AND BEHAVIORAL ANALYSIS

Radio-tracking and consistent monitoring of northern pine snakes at the SPR site revealed some interesting habitat use preferences, movements and behaviors. One of the main research questions to be answered by this investigation is to compare the behavior of the shifted radio-tracked snakes to the non-shifted radio-tracked snakes. **Figures 33** and **34** show two graphs which provide a representation of habitat use and behavioral comparisons of shifted vs. non-shifted snakes in 2009. **Table 2** provides a breakdown of the forested habitat types used by monitored pine snakes (McCormick 1970 and 1979; Boyd 1991). For the purpose of this investigation, habitat types used by northern pine snakes in 2009 were defined as follows:

***Open Field*** - little or no trees, sandy soil often dominated by various native grass species.

***Artificial Hibernaculum*** **-** artificial den constructed by HA and located in the management fields.

***Barren Ground/Disturbed*** **-** habitat with little to no vegetative cover or habitat that has been altered by human disturbance.

***Ecotone Between Upland and Wetland*** **-** transitional edge between upland forest habitat and wetland habitat.

***Forested Wetland*** - hardwood trees and/or cedar dominated wetland corridors.

***Ecotone Between Forest and Barren Ground*** **-** transitional habitat between upland forest and disturbed or barren habitat (e.g., the management fields, SPR property and landfill).

***Pine/Oak Forest*** - pitch pine dominated forest, but containing an oak component.

***Oak/Pine Forest*** - oak dominated forest, but containing a pitch pine component.

***Pine Forest*** **-** pitch pine forest with no other overstory tree species present.

***Note***: The above listed forest types and descriptions were modified from McCormick (1970 and 1979) and Boyd (1991).

### *Use of Fire-Altered Habitats*

The response of pine snakes to the May 2007 forest fire-altered habitat was most obvious by their selection of micro-habitat locations within the Stafford Forge WMA. During the period immediately following the fire, snakes sought cover in pine stump holes, mole tunnels, or at the base of pitch pines under the new growth of the basal branches. Over the last two-years the forest has grown back and pine snakes are using all suitable habitat types available to them. **Figure 34** along with **Table 2** illustrate the selected habitat uses of radio-tracked pine snakes.

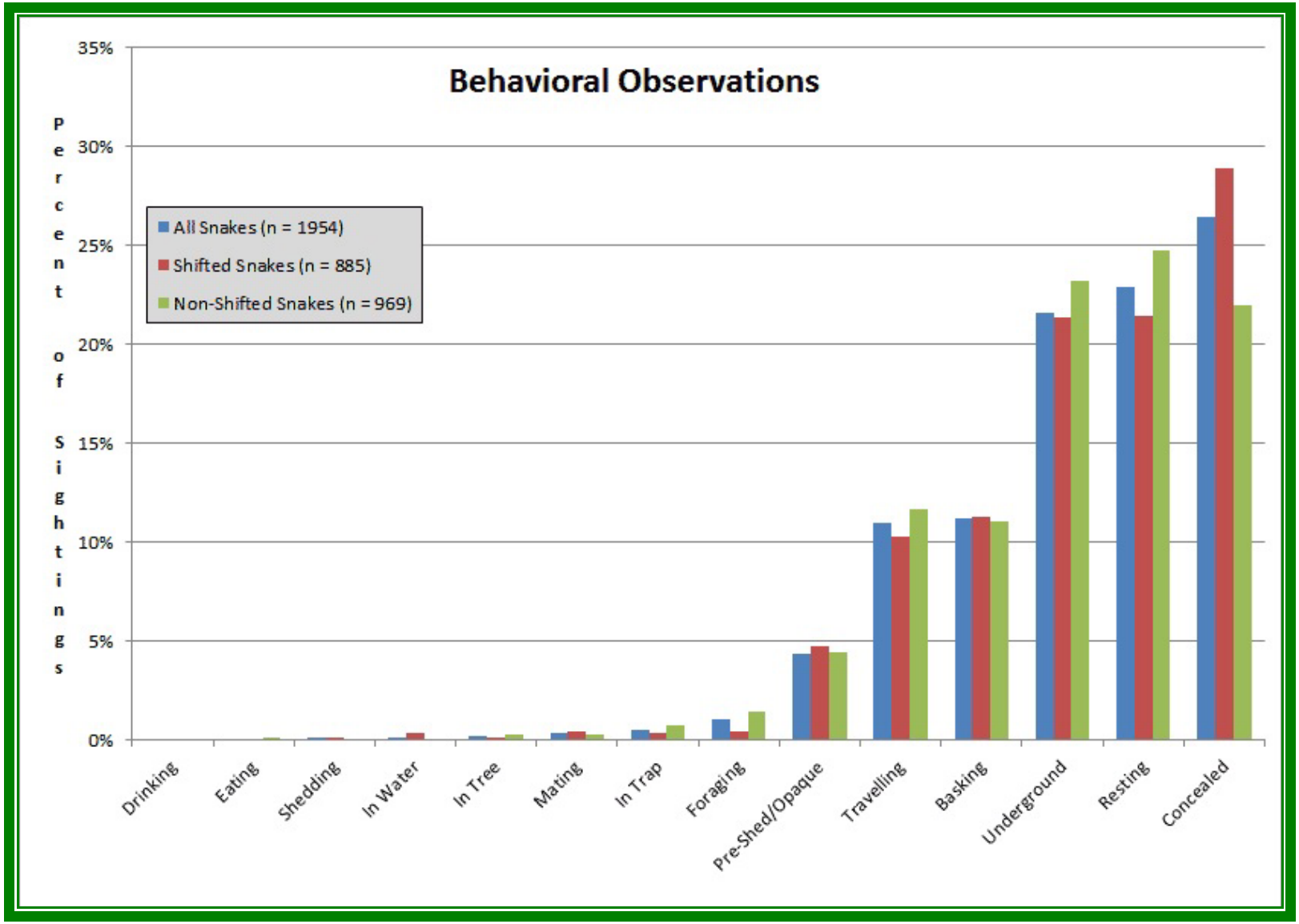



**Figure 33.** Based upon 1,954 radio-tracking observations of 21 monitored snakes, this graph shows the most common activities and behaviors seen by percent. Like most other snake species, pine snakes remain hidden underground most of the time. Source: HA..

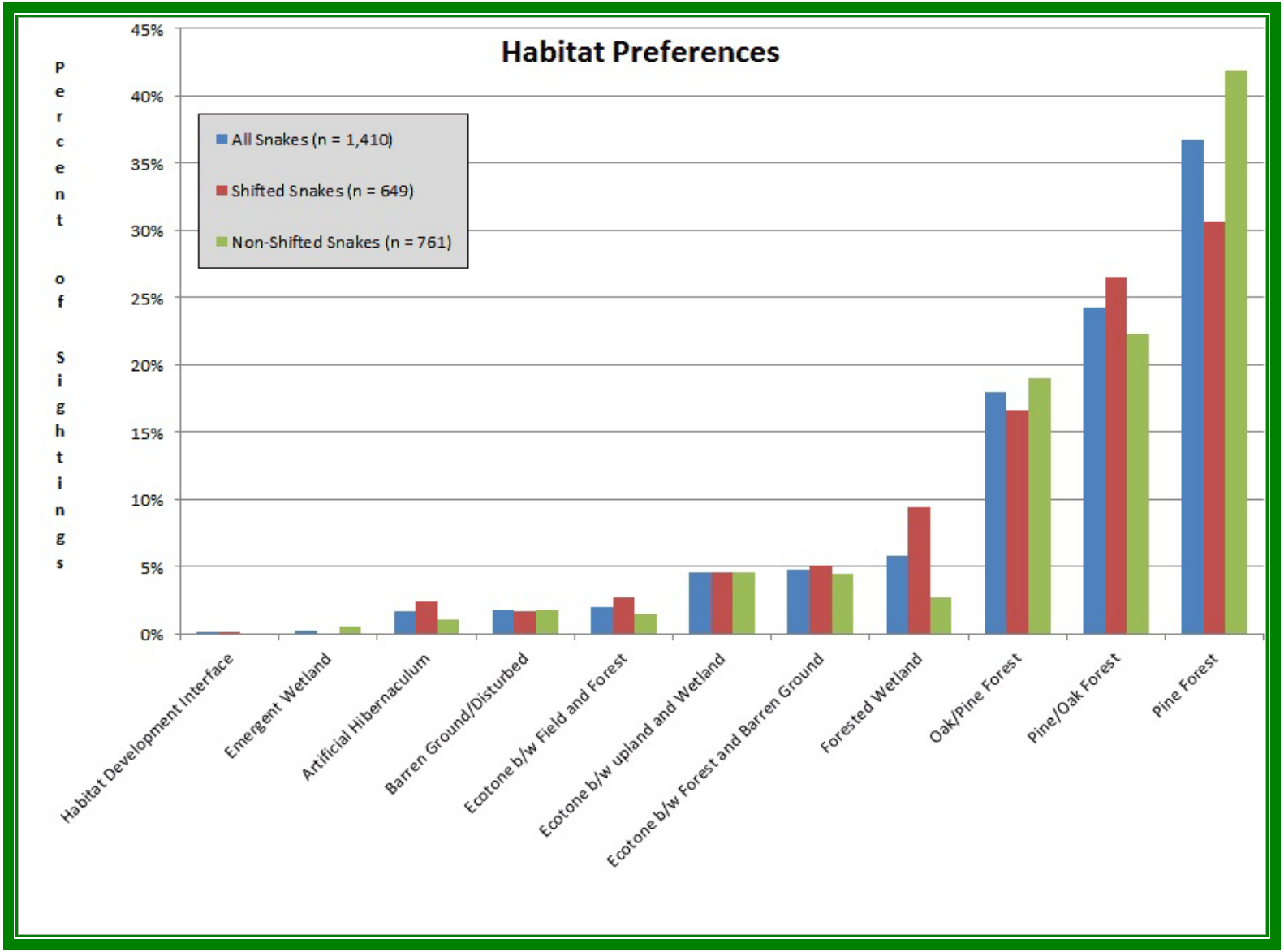



**Figure 34.** Twenty radio-tracked pine snakes selected different micro-habitats within the available forest. Of the 1,410 observations, pine forest was the most frequently selected habitat type, with pine-oak forest being the second most commonly chosen forest type. Source: HA.

**Table 2. Habitat Preferences of Radio-tracked Pine Snakes at Stafford Forge WMA and the Stafford Park Redevelopment Property in 2009.**

| Habitat Types | All Snakes (n = 1,410) | | Shifted Snakes (n = 649) | | Non-Shifted Snakes (n =761) | |
|---|---|---|---|---|---|---|
| | Number of Relocations | Percent of Total | Number of Relocations | Percent of Total | Number of Relocations | Percent of Total |
| Habitat Development Interface | 1 | 0.07% | 1 | 0.15% | 0 | 0.00% |
| Emergent Wetland | 4 | 0.28% | 0 | 0.00% | 4 | 0.53% |
| Artificial Hibernaculum | 24 | 1.70% | 16 | 2.47% | 8 | 1.05% |
| Barren Ground/Disturbed | 25 | 1.77% | 11 | 1.69% | 14 | 1.84% |
| Ecotone Between Field and Forest | 29 | 2.06% | 18 | 2.77% | 11 | 1.45% |
| Ecotone Between Upland and Wetland | 65 | 4.61% | 30 | 4.62% | 35 | 4.60% |
| Ecotone Between Forest and Barren Ground | 67 | 4.75% | 33 | 5.08% | 34 | 4.47% |
| Forested Wetland | 82 | 5.82% | 61 | 9.40% | 21 | 2.76% |
| Oak/Pine Forest | 253 | 17.94% | 108 | 16.64% | 145 | 19.05% |
| Pine/Oak Forest | 342 | 24.26% | 172 | 26.50% | 170 | 22.34% |
| Pine Forest | 518 | 36.74% | 199 | 30.66% | 319 | 41.92% |
| **Total Relocations** | **1410** | --- | **649** | --- | **761** | --- |

By early June 2009, it was obvious that regeneration of understory vegetation components (e.g., blueberry, huckleberry, sheep laurel, scrub oak and mountain laurel), was substantial and it densely covered much of the forest floor. The pine snakes are now able to find suitable ground cover throughout much of the previously burned habitat. With the exception of periodic forays into the Mill Creek floodplain and other wetland corridors to forage for prey, monitored pine snakes did not appear to vacate or avoid the previously burned forest habitat in favor of unburned areas during the active seasons of 2007, 2008 and/or 2009 (HA Staff, personal observations). Rapid vegetation regrowth along the perimeter drift fence had to be periodically cut back to prevent snakes from climbing over the traps and fence (Dargan and Stickel 1949; Enge 1998 and 2001).

## THREE EXPERIMENTAL SNAKE TREATMENTS

***Treatment A Snakes*** (*One Winter, Excluding 2006 Hatchlings*):

There were originally 12 snakes in Treatment A, 9 of which were radio-tracked. The other three snakes were sub-adults and too small to surgically implant. Instead, they were PIT tagged (Elbin and Burger 1994), placed into the one winter treatments in the fall of 2006, and subsequently released into the wild in 2007. One of these snakes has died each year (2006, 2007, 2008, and 2009), from either raptor predation, the forest fire, mammalian predation, or other unknown causes. Six snakes (3 males and 3 females), from Treatment A were still alive at the beginning of the 2009 field season. Two of these snakes (Field Number 2006.11 a male and Field Number 2006.21 a female) were both found deceased during the 2009 field season (please refer to the Individual Snake Synopses section above for more details). Of the four remaining snakes from Treatment A that were still alive at the end of the 2009 season, none overwintered in the artificial dens. One snake returned to a previously used natural den to overwinter in 2009 - 2010 and the others chose new natural dens.

***Treatment B Snakes*** (*Two Winters, Excluding 2006 Hatchlings*):

There were originally 9 snakes within Treatment B. Seven of these snakes (Field Numbers 2006.06, 2006.10, 2006.13, 2006.20, 2006.22, 2006.23 and 2006.27), have died during the course of the three-year study (please refer to **Appendix II** for the Deceased Snake Synopsis). This leaves only two snakes from the original Treatment B group. Of these, one was a juvenile snake that could not be radio-tracked because it was too small. The other specimen, female pine snake number 2006.29, continues to be part of the radio-telemetry aspect of the study. This snake returned to the same natural den (NH T) in which it overwintered in 2008. This den is located in the pine forest west of the management fields.

***Treatment C Snakes*** (*One Winter in HA Lab*):

There were originally 8 snakes in Treatment C. These snakes overwintered in HA's laboratory during the 2006 - 2007 winter, due to various health reasons and were released into AH 1, AH 4, and AH 6 (which were all two winter treatments) in the spring of 2007. One snake (Field Number 2006.30), had its transmitter fail prematurely in 2007 and, therefore has never been relocated. Another snake (Field Number 2006.31) was killed in the forest fire of May 16, 2007. At the beginning of the 2009 field season there were 6 snakes (3 males and 3 females) from the Treatment C group being actively radio-tracked. One pine snake (Field Number 2006.17) was discovered dead on the Garden State Parkway on 05/20/09 (please refer to the Individual Snake Synopses section above for details). Another snake, pine snake 2006.15, never egressed from the large earthen mound in MF 2 where it hibernated during the 2008 - 2009 winter. It is possible that this snake failed to successfully overwinter at this location. Another possibility is that the snake somehow slipped off the external transmitter that is was fitted with at the end of the 2008 field season during the spring egress. This leaves a total of four snakes still alive from Treatment C at the end of the 2009 activity season. Two snakes (Field Numbers 2006.16 and 2006.19) returned to AH 1 to overwinter. One snake (Field Number 2006.08) returned to NH B, a natural hibernaculum located 30 meters northwest of AH 6. The final Treatment C snake (Field Number 2006.28) overwintered in a newly discovered natural den south of the SPR property.

## NON-SHIFTED PINE SNAKES

In order to provide a direct comparison with shifted snakes, a control group of non-shifted resident pine snakes have been fitted with radio-transmitters. The behavior and movement patterns of these non-shifted snakes are monitored and recorded simultaneously and via the same methodology as the shifted pine snakes. A total of 12 non-shifted snakes were radio-tracked in 2009. Most were captured in 2007, but two were captured in 2008, and one was captured in 2009. All of these snakes were captured using various survey techniques, including drift fence trapping, random opportunistic searching, time constrained searching, road cruising and natural den corralling.

All non-shifted snakes have overwintered in natural dens located within their home ranges identified through the radio-tracking efforts over the past three field seasons. In 2009, four of these snakes (Field Numbers 2007.09, 2007.11, 2008.02 and 2008.03) returned to the same overwintering sites used the previous year and five snakes (Field Numbers 2007.05, 2007.07, 2007.10, 2007.14, and 2009.13) selected new locations. Two snakes (Field Numbers 2007.04 and 2007.15) died and one (Field Number 2007.03) is currently in HA's laboratory undergoing rehabilitation due to poor health. Because of their established activity home ranges and fidelity to their traditional winter dens, none of the non-shifted snakes have selected the artificial hibernacula in which to overwinter. On the other hand, some of the shifted pine snakes that were forced to spend one or two winters in the artificial dens have learned that they are suitable overwintering sites and therefore some snakes used them.

## JUVENILE AND HATCHLING PINE SNAKES

### *Hatchling and Juvenile Pine Snakes from 2006 - 2008*

Very few of the hatchling pine snakes released into the artificial dens in the fall of 2006 were recaptured in 2009 (**Appendix III**). Due to the dismantling and removal of the corral walls in 2008, the possibility of recapturing these snakes has been markedly reduced. They have most likely dispersed into the surrounding forested habitat, which makes recapture more difficult because the survival rate of hatchlings is low due to predation (Fukada 1978; Fukada 1960). Also, juvenile pine snakes are secretive and seldom encountered in their natural habitat (Fitch 1999). Therefore, it is impossible to determine how many of the 2006 pine snake hatchlings have succumbed to predation, perished in the May 16, 2007 forest fire, or were lost to due to unknown causes over the past three years. To better account for any 2006 hatchlings that might have overwintered in the artificial hibernacula, HA staff attached traps to all the artificial den entrances in early April of 2009 (please refer to the Management Field Monitoring section). A total of three 2006 hatchling pine snakes were recaptured during the 2009 field season. Two of these snakes (Field Numbers 2006.41 and 2006.46), were captured in the traps attached to the den entrances. Another snake, (Field Number 2006.49) was found basking on top of AH 1 in late April. All three of these snakes were weighed and measured. They had all doubled in length since hatching out in 2006 and were in good health. In 2007, HA captured 10 hatchling pine snakes in AH 4 and AH 6. However, for unknown reasons none of these 2007 hatchlings were recaptured in 2009. It is possible that they dispersed and remained in the forest or were possibly victims of mammal or bird predation (Fukada 1978; Fukada 1960; Fitch 1999).

In 2008 HA captured and PIT tagged eleven new hatchling and juvenile pine snakes (Elbin and Burger 1994). Nine of the snakes were from a nesting/denning location (Natural Hibernaculum "H") south of the SPR property in Stafford Forge WMA. HA staff corralled this hibernaculum at the beginning of the 2009 field season, since it was deemed most likely to contain multiple snakes out of all the natural dens identified through radio-tracking efforts in 2008 (please refer to the Corralling of Natural Hibernacula section). Two of the 2008 hatchlings from the nest were recaptured in the traps during the spring egress. It is not known what happened to the other seven individuals. These were the only two 2008 hatchling pine snakes recaptured by HA staff in 2009.

**2009 *Hatchling and Juvenile Pine Snakes***

HA staff captured and PIT tagged 40 new hatchling and juvenile pine snakes during the 2009 field season. Three of these new snakes were caught in the artificial den traps during the Spring egress. It's possible that these snakes were hatchlings from the two nests identified by HA staff in the management fields in 2008, but this is just speculation. During 2009 HA staff identified several nests within the management fields through radio-tracking. Due to the nesting behavior of the female pine snakes in the management fields (i.e., excavating their burrows in the earthen berms and mounds, rather than in the open sandy soil), it was impossible for HA staff to erect enclosures around the nest burrows to capture newly hatched snakes. HA staff did place cover boards near identified nest areas to provide ground cover for the new hatchling pine snakes. HA also extensively searched the management fields in late summer for hatchling pine snakes without much success, since only one live hatchling was captured. This snake was found concealed under a cover board approximately one meter up a large earthen mound at the far north end of MF 3. Two radio-tracked females (Field Numbers 2006.29 and 2007.15) nested on the very top of this earthen mound. It is therefore highly likely that this hatchling was from one of those nests. Also, a dead hatchling was found under a small log next to the entrance of one of the aforementioned nests. The snake was opaque, suggesting the snake was still in its post-hatch shed at the time of its death, but no cause could be determined. The vast majority of 2009 hatchling pine snakes came from four different clutches located in a triangle shaped section of disturbed pine forest comprising approximately 127-acres south of the SPR property (See **Appendix IV** for frequently referenced landmarks in Stafford Forge WMA). Two natural dens, multiple pine snake nests and hatchling pine snakes have been observed within this area of forest over the entirety of the study. A nest was located within this disturbed habitat via radio-tracked female pine snake 2008.03 in 2009. Upon relocating this snake in her nest, another nest was observed in close proximity. Both nests were corralled by HA staff in order to PIT tag any hatchlings emerging in the fall. A total of 25 pine snake hatchlings were found in the two enclosures. The nest excavated by female pine snake 2008.03, produced 7 hatchlings. The other nest produced 18 hatchlings, indicating that two females laid eggs in their own nest chambers, since the mean clutch size of pine snakes is 9 eggs (Zappalorti et al, 1983; Burger et al, 1987).

As previously mentioned, a nest and hatchlings were found within a meter of NH H in the late summer of 2008. HA staff conducted searches around this hibernaculum during the nesting season in 2009 to see if another nest had been excavated. Although no nest was observed, HA staff did capture six pine snake hatchlings basking around the entrance to NH H in late summer and early fall of 2009. The exact origin of these hatchlings is unknown. The possibility exists that a gravid female excavated a side chamber within NH H in which to deposit her clutch, leaving no evidence of nesting behavior on the ground surface.

## USE OF MANIPULATED AND ENHANCED HABITAT

During the 2009 field season, the management fields were extensively used by pine snakes and other wildlife species. Eleven radio-tracked pine snakes were documented using the perimeter earthen berms for shelter, foraging and as shedding stations throughout the 2009 active field season. Five female pine snakes (Field Numbers 2006.29, 2007.04, 2007.05, 2007.07 and 2007.15), were observed using the management fields for nesting in 2009. Two of these females (Field Numbers 2006.29 and 2007.15), nested on top of the large earthen mound at the far north end of MF 3. Another female (Field Number 2007.04), nested in the earthen berm along the NE edge of MF 3. Female pine snake (Field Number 2007.05) nested in the earthen berm along the western edge of MF 2, within five meters of where she nested in 2008. Female pine snake 2007.07's nesting location was never determined. She was observed in and along the edges of the management fields from 06/26/09 to 06/30/09. During this time period it was determined that she was gravid by her posterior body girth and visibly bulging eggs. On 07/02/09 she was observed moving away from the management fields and appeared thin and no longer gravid. It is not certain where this snake selected to lay her eggs, but HA suspects it was in the berms where the other females nested.

After nesting was completed, 8 cover boards were placed around the nests entrance holes in an attempt to capture and document hatchling snakes emerging from the nests. As previously mentioned, only two hatchling pine snakes, one alive and one dead, were found within the management fields in the late summer.

## ENVIRONMENTAL INSPECTIONS AND MONITORING

Most of the habitat alteration, disturbance and licensed landfill construction on the SPR property was conducted in 2007 and 2008. Since there was little construction activity in the development areas, HA was not requested by Walters to monitor any construction activities within the SPR property during 2009, presumably because most wildlife was removed in 2006, 2007 and 2008. HA staff only conducted intensive snake surveys on the SPR property during the pine snake nesting season (mid-June to mid-July). No pine snake nests were found, however numerous Fowlers toads, black racers, garter snakes and a road killed rough green snake were observed within the SPR property in 2009.

As part of the mitigation and management of rare species, Walter's constructed a southern gray treefrog breeding pond in a portion of Retention Basin D. The basin is located in the northwest corner of the licensed landfill. Only rainwater enters the breeding pond and other retention basins. This site was chosen because adult treefrogs were heard calling in the close vicinity of Basin D in May of 2008. The breeding pond was constructed in the Fall of 2008, so it was available as a breeding site for the treefrogs in the Spring of 2009. This pond was part of the mitigation plan to replace the lost breeding habitat for southern gray treefrogs due to construction of the Stafford Business Park. Monitoring in the Spring of 2009 has shown this pond is extremely successful in attracting calling male southern gray treefrogs. Although we did not see any pairs of treefrogs in the actual mating position (amplexus), during the survey nights, eggs were evidently deposited. On July 31, 2009, tadpole activity was observed within the flooded Retention Basin D (the breeding pond), by HA staff. Several dozen tadpoles of southern gray treefrogs and Fowler's toads were observed surfacing for air. Tadpole activity was concentrated both in the center and edges of the pond.

The presence of adult male southern gray treefrogs calling from the edge of the created pond demonstrates the pioneering ability of the species and important use of this manipulated habitat. No Pine Barrens treefrogs have been seen or heard calling on the altered SPR property in 2009, but this could change as the natural and planted vegetation grows and provides more cover and shade for the amphibians. However, it appears that southern gray treefrogs and Fowlers toads have re-established themselves at several locations on the SPR property and retention basin areas.

**Figure 35.** Juvenile southern gray treefrog (*Hyla chrysoscelis*), in the later stages of metamorphosis. This was one of many observed in this stage of development by HA staff during the 2009 breeding season in Retention Basin D. Photograph by Robert J. Hamilton, Herpetological Associates, Inc.

## MANAGEMENT FIELD MONITORING

While on-site habitat alteration was minimal in 2009, maintenance of the management fields and monitoring of the dens for snake activity continued to be important aspects of HA's research. In an effort to determine the effectiveness of the 6 artificial hibernacula (Artificial Hibernacula 1 – 6), located in the management fields in Stafford Forge WMA, an attempt was made to trap snakes emerging from hibernation in the spring of 2009. Each artificial den has four entrance pipes. HA staff devised a method which allowed the trapping of each individual entrance to the artificial dens. Four-inch corrugated flex-tubing was attached to the openings of the den entrance pipes. Then on the other end we attached the corrugated flex-tubing to one of HA's standard funnel box traps. We used 24 customized snake traps in total, four on each den's PVC entrance pipes. A total of 8 pine snakes are known to have overwintered in the artificial dens during the 2008 - 2009 winter. Six pine snakes (three new juveniles, two 2006 hatchlings, and one radio-tracked adult) were captured in the various den traps during spring egress, and one 2006 hatchling was found basking on top of AH 1 by random searching. The radio-tracked adult, a 2006 hatchling, and a new juvenile were found in traps attached to AH 1. Another radio-tracked adult overwintered in AH 1, but had egressed before the traps were attached. One new juvenile pine snake was found in a trap attached to AH 2, one new juvenile in an AH 3 trap and one 2006 hatchling was found in a trap attached to AH 5. In order to assure capture of late-rising individuals, all hibernaculum traps remained affixed to the entrances and were monitored until 06/02/09.

The small drainage pond that was dug in 2006 to prevent water from flowing into AH 4, continues to act as a vernal pond. Southern gray treefrogs and Fowlers toads have been heard calling at the pond and tadpoles have been seen swimming in it. Leopard and green frogs also use it, along with an occasional box turtle. The only access road and entrance to the three management fields is gated and kept locked for security and to keep vandals or vehicles off the fields.

The bird netting that was placed over the dens in 2007 was damaged by strong wind, snow, ice weight and general inclement weather during the 2008 - 2009 winter season. Since snakes are no longer forced to stay in the dens and predation by hawks is far less likely, the netting was subsequently taken down and discarded. HA regularly searched the artificial den areas for hatchling, juvenile and new adult pine snakes during the 2009 active field season. Besides the pine snakes found in the traps at the beginning of the field season, HA also found one live pine snake hatchling and one dead pine snake hatchling in late summer. HA staff also monitored the management fields to discourage and prevent trespassing or illegal snake collecting. HA did not observe any evidence of trespassing or tampering with the traps or dens in 2009.

### CORRALLING OF NATURAL HIBERNACULA

Since pine snakes will often den communally (Burger et al 1988b), HA corralled some of the natural hibernacula that are used by our study snakes during the 2007 - 2008 winter in an attempt to capture new pine snakes. We used six foot high metal stakes and four foot tall, 1/4 inch metal hardware cloth to construct the temporary circular enclosures. In 2009, HA decided to scale back the number of natural hibernacula corralled. Of all the natural dens we located through radio-tracking efforts in 2008, only one was corralled in the spring of 2009. The hibernaculum that was corralled was NH H. This hibernaculum was corralled due to several hatchling pine snakes and a new adult pine snake found near the den entrance towards the end of the 2008 field season. It was HA's opinion that this den had the highest likelihood of producing multiple pine snakes. Once the traps were attached they were checked every 48 hours during the Spring emergence period (Mid-March through Mid-June).

A total of 10 northern pine snakes were captured in the snake traps that were attached to the natural hibernaculum; this included 5 adults and 5 hatchlings. One of the adults was a radio-tracked male (Field Number 2007.11) and another adult was a previously identified male (Field Number 2008.25) that was found by HA staff, basking next to the den entrance at the end of the 2008 season. As previously mentioned, HA had found a pine snake nest and some hatchlings next to NH H in 2008. Two of these hatchlings (Field Numbers 2008.18 and 2008.21), were caught in the NH H traps during the 2009 spring egress. Additionally, 3 new hatchling pine snakes, 3 new adult pine snakes and two sub-adult northern black racers were also captured in the traps.

Encircling and trapping winter dens is an effective way of learning how many individual snakes may use a particular overwintering site. This type of trapping effort will also demonstrate what other species of snakes share the hibernaculum. Over the past 20-years, HA has learned that several other species of snakes often use pine snake dens to overwinter, including corn snake, hognose snake, coastal plains milk snake, black racer, black rat snake, and on one occasion even a timber rattlesnake (Burger and Zappalorti, unpublished data).

## FORAGING AND PREY AVAILABILITY

**Figure 36**. Study snake 2006.34 in the process of consuming an eastern mole. Photograph by Bernd Skubowius, 2009.

The various habitat types in and around Stafford Forge WMA are rich with birds and small mammal resources which provide an ample food supply for northern pine snakes and other top predators (Burt and Grossenheider 1980; Arnold 1993 and Boyd 2000). HA has operated the perimeter drift fence trapping system (Enge 1997a and 1997b), in the ecotone habitat that separates the SPR property from Stafford Forge WMA's vast pine-oak forest upland between April 15 and October 31 since 2007 to 2009 (with one more year until the fence is terminated on October 31, 2010). The following species of small mammals were seen on the study area or captured in our box funnel traps: short-tailed shrew (*Blarina brevicauda*), masked shrew (*Sorex cinereus*), eastern mole (*Scalopus aquaticus*), white footed-mouse (*Peromyscus leucopus*), red-backed vole (*Clethrionomys gapperi*), woodland vole (*Pitymys pinetorum*), meadow jumping mouse (*Zapus hudsonius*), eastern chipmunk (*Tamias striatus*), red squirrel (*Tamiasciurus hudsonicus*), gray squirrel (*Sciurus carolinensis*) and eastern cottontail (*Sylvilagus floridanus*).

Based upon laboratory and field experiments (Reynolds and Scott 1982), the following birds and small mammals are known to be eaten by pine snakes: eastern towhee (*Pipilo erythrophthalmus*), pine warbler (*Dendroica pinus*), wood thrush (*Hylocichla mustelina*), starling (*Sturnus vulgaris*), mourning dove (*Zenaida macroura*), American robin (*Turdus migratorius*), ovenbird (*Seiurus aurocapillus*), field sparrow (*Spizella pusilla*), house wren (*Troglodytes troglodytes*), masked shrew, eastern mole, star-nosed mole (*Cyanocitta cristata*), white-footed mouse, red-backed vole, woodland vole, eastern chipmunk, eastern cottontail, red squirrel and eastern gray squirrel. However, the most frequent pine snake feeding observations made by HA staff of radio-tracked pine snakes in this study were eastern mole and eastern cottontail. Red-backed voles, meadow voles (*Microtus pennsylvanicus*) and white footed-mice were all readily eaten by pine snakes being held in the laboratory (Zappalorti, unpublished data).

**Figure 37**. Meadow voles, red-backed voles and pine voles are all important prey items for northern pine snakes. These small mammals prefer wet meadows and grassy field habitats. Photo by Zig Leszczynski, HA.

**WINTER AND SUMMER DEN USE**

Two adult study snakes (Field Number 2006.16 and 2006.19) from Treatment "C" (snakes that overwintered in HA's laboratory in 2006), have again returned to AH 1 to spend the winter. These two snakes were released into AH 1 on 04/03/07. They were both forced to overwinter in AH 1, which was a two-winter treatment, during the 2007 - 2008 winter, but then selected and returned to AH 1, by their own choice, to overwinter again in 2008 - 2009. This shows that the artificial dens are not only suitable for pine snakes to hibernate in, but it demonstrates that the snakes learned it was a safe place to spend the winter through pheromone trail-following and returned again on their own free will (Carpenter 1953; Ford 1978, and 1986, Gehlbach et al, 1971).

As previously mentioned, HA also captured two 2006 hatchlings in the traps attached to the artificial dens in the spring of 2009, as well as one basking on top of an artificial den. The details about the three 2006 hatchling pine snakes captured during spring egress are as follows:

1) Pine Snake 2006.41
   Released as a hatchling into AH 1 in September 2006. Captured on 04/28/09 in a trap attached to AH 1.

2) Pine Snake 2006.49
   Released as a hatchling into AH 1 in September 2007. Observed basking on top of AH 1 on 04/25/09.

3) Pine Snake 2006.46
   Released as a hatchling into AH 3 in September 2007. Captured on 05/09/09 in a trap attached to AH 5.

It has been documented that pine snakes can show high fidelity to their den sites, often returning to the same den year after year (Carpenter 1953; Burger et al, 1988, Zappalorti and HA staff, personal observations). The fact that 5 of the 2006 study snakes were confirmed overwintering in the artificial hibernacula during the 2008 - 2009 winter suggests that the dens in the management fields have become an important part of their natural habitat. HA plans to trap the dens during the spring season of 2010 to determine if any other 2006 snakes (besides the two radio-tracked adults), have returned to the artificial dens to overwinter.

In addition to the five 2006 study snakes known to have overwintered in the artificial dens, HA staff captured three new pine snakes in the den traps during the 2009 spring egress. HA believes that two of the snakes were from the 2008 hatchling cohort from one of the females that nested in the management fields that year. The other snake is believed to be a hatchling from the 2007 cohort, based upon its body weight and snout-vent-length (SVL) when captured. The fact that these three snakes were never forced to overwinter in any of the artificial dens, suggests that young snakes from the population are learning to recognize the dens as suitable overwintering locations. No additional snakes of any species were noted in the vicinity of the artificial hibernacula during the spring egress or fall ingress periods of 2009.


**Figure 38.** Den site fidelity by pine snakes is depicted as a percent of the total number of individuals in each group. The three groups are: All Snakes Combined , Shifted Snakes and Non-shifted Snakes (n = 24). Source Herpetological Associates 2009.

In previous studies, northern pine snakes have been observed showing site fidelity to more than one hibernaculum within their home ranges (Burger et al, 1988a and 1988b; Zappalorti, personal observations). Some snakes that were forced to overwinter in the artificial hibernacula during the first 2 winters of the study, returned to their previously learned natural dens when the artificial den corrals were removed. These adult pine snakes already had an established home range within the habitat available to them, and with it a recognition of dens where they had hibernated in the past. The snakes located their known dens via olfactory scent trails and visual cues (Ford 1978, and 1986, Gehlbach et al, 1971).

All of the adult snakes from the one and two winter treatments may have previously overwintered in the various natural hibernacula discovered by radio-tracking. As these natural dens were likely known to the snakes prior to the commencement of this study, it is probable that many of these snakes returned to previously used den sites (Reinert and Zappalorti 1988b, Burger 1990 and 1991). This does not necessarily mean that (in the future) the artificial hibernacula will not be utilized by snakes for overwintering. Other artificial hibernacula constructed by HA have, over time, become a part of the denning network for pine snakes (Frier and Zappalorti, 1983; Zappalorti and Reinert 1994). The six artificial hibernacula constructed by HA in Stafford Forge WMA will remain available as important summer and winter habitat for pine snakes and other snake species.

### *Pine Snake Fidelity to Winter Dens*

For the purpose of this analysis, den site fidelity is described as any free-roaming northern pine snake that returned to the same winter den location two-years in a row (**Figure 38**). We did not include the winter of 2006 and 2007, because the shifted study snakes were forced to hibernate in the six artificial dens or in HA's laboratory. By comparing all the den use observation data collected in 2008 and 2009, it was determined that the percentage of den site fidelity in non-shifted snakes (n = 11), was 72 %. It appears that non-shifted snakes have a greater den fidelity than the shifted snakes (n=13) who show a 46 % fidelity to their winter dens. Given the limited data, this simplified analysis does not take into account fidelity to den sites in non-sequential seasons, nor discrepancies between fidelity to artificial versus natural hibernacula. While it is still too soon to draw solid conclusions based on the information collected to date, subsequent seasons of radio-tracking will allow for a much more in-depth statistical analysis.

## BREEDING AND NESTING OBSERVATIONS

Through intensive monitoring, HA observed courtship, mating and nesting behavior of individual pine snakes within the study population in 2009. Although this behavior is rarely witnessed in the wild, radio-tracking has made it possible to observe the mating habits of pine snakes within the study population. On several occasions in 2009, HA staff observed breeding behavior between pairs of pine snakes.

One breeding observation occurred on 05/09/09 when female pine snake 2007.05 was observed by HA staff mating with male pine snake 2006.34. The same pair was again observed in courtship on 05/18/09. Although this male was observed near female pine snake 2007.05 during the breeding season in 2008, they were never observed in actual courtship or copulation.

Two additional breeding observations occurred on 05/11/09 and 05/22/09 when female pine snake 2006.29 was observed mating with male pine snake 2007.10 (**Figures 11** and **42**). Another breeding observation between pine snakes occurred on 05/20/09 when male pine snake 2007.14 was observed breeding with a previously unidentified adult female. Both courtship and copulation were observed between these two snakes.

Although, these were the only incidences where actual copulation was confirmed among study snakes, HA staff did observe other pine snake courtship behavior. Pine snake 2006.17 (an adult male) and pine snake 2007.15 (an adult female) were located within several meters of each other on 05/18/09. Although no breeding behavior was observed between these two snakes, the female (Field Number 2007.15) was determined to be gravid shortly following the relocation.

Additionally, pine snake 2008.03 (an adult female) was observed being followed by two different male pine snakes on two separate occasions. One of the males was a snake caught during the 2008 field season and the other was a new male (Field Numbers 2008.08 and 2009.14, respectively). Once again, breeding was not observed, but female pine snake 2008.03 was determined to be gravid shortly following the relocation and nested in an area of disturbed pine forest south of the SPR site. Female pine snake 2007.04 was never actually observed mating, but was seen being scent trailed by an new unknown male and subsequently became gravid.

**Figure 39**. A typical pine snake nest burrow entrance in an open sunny field, with a classic sand dump pile entrance. Once the tunnel is long enough, the gravid female seeks refuge in the terminal nest chamber. Photo by David Burkett, HA Staff.

Some intriguing observations were made by HA staff in regards to courtship behavior exhibited between pine snakes during the 2009 field season. Details are provided herewith:

1) Female pine snake 2007.05 was seen breeding with male pine snake 2006.34 again in 2009 after both snakes were observed within close proximity during the 2008 breeding season. This same female was also relocated within close proximity to a young male pine snake that was observed breeding with her the prior season. Although there is no evidence to suggest that pine snakes are monogamous, it is interesting that she was recorded with, or near the same two male snakes during the past two breeding seasons. This is possibly due to overlapping seasonal home ranges (i.e., they are in the same place at the same time each year), or they find each other via olfactory scent trails and visual cues (Ford 1978, and 1986, Gehlbach et al, 1971; Burger 1990 and 1991).

2) It is also interesting to note that some male pine snakes made large moves to breed with certain females, when other females were in closer proximity. This could reflect a necessity to move further to find the nearest available ovulating female, or the snake learned areas where he may have experienced breeding success in the past. Another potential behavior of male pine snakes may be to randomly search until intercepting the scent trail of an ovulating/receptive female. Although it is difficult to accurately assess these possibilities at this time, it is plausible that with further research of pine snake mating behavior will come further understanding of its complexities.

### *Female Nesting Behavior*

Multiple nesting activities were observed in June and early July of 2009. Six of the radio-tracked female pine snakes mated and became gravid. Five of the gravid females nested in the snake management fields, which is part of their intended purpose. Of these five snakes, three were caught in traps along the perimeter drift fence, and one was found on the SPR property during the nesting season. HA staff translocated any pine snakes caught in the traps or on the landfill a few hundred feet into the woods from the trap capture location (please refer to Protocol for Releasing Trapped Pine Snakes or Snakes Found on the SPR site).

The following is a brief synopsis of nesting behavior that occurred within the management fields during the 2009 nesting season:

1) **Female No. 2007.05**

This non-shifted female pine snake was observed breeding with a male pine snake 2006.34 on two separate relocations (05/09/09 and 05/18/09 respectively). Between 06/24/09 and 06/26/09 this female made a large move of approximately 1.5 kilometers northwest to the management fields from an oak/pine forest that it had spent several relocations in while in pre-egg laying shed (it is common for egg-laying snakes to enter a shed period just prior to egg deposition). On 07/02/09 this female was observed by HA staff in the earthen berm along the western edge of MF 2 within a few meters of where it had nested the previous year. On the following relocation the snake had made a large move back to its summer habitat and was no longer gravid. HA staff is confident its eggs were laid in the berm along MF 2, within a few meters of last years nest (Carpenter 1982, Burger and Zappalorti 1986 and 1991).

2) **Female No. 2007.04**

This non-shifted female pine snake was never observed breeding by HA staff, but given her bulk and weight gain she appeared to be gravid during breeding season. On 06/07/09 she made a move of nearly 700-meters S/SW from the Mill Creek wetland corridor into the berm along the east edge of MF 3. Over the course of the next 23 days this female was relocated regularly inside the berm along the eastern edge of MF 3. However, on 06/26/09 this snake was found moving along the drift fence trap line between the management fields and the SPR property and landfill. After failing to breach the perimeter drift fence, this snake returned to the open management field possibly recognizing the field as suitable nesting habitat (Carpenter 1982, Burger and Zappalorti 1986 and 1991). On 06/30/09 she was found concealed in the berm along the NE edge of management field 3 and subsequently nested and deposited her eggs there.

3) **Female No. 2007.07**

This non-shifted female pine snake was also never observed breeding by HA staff, but given her huge bulk and body weight gain it was obvious that she was gravid during the breeding season. On 06/24/09 she was caught in a trap on the perimeter drift fence, at the edge of Hay Road. Before being caught in the trap, she had spent the majority of the month of June in a pine/oak forest approximately 2-kilometers NW of the management fields and the trap line. The snake was walked back into the woods approximately 150-meters perpendicular from where it was caught and released (please refer to the Protocol for Releasing Trapped Pine Snakes Found Within the SPR Property).

On 06/26/09 this snake was relocated concealed beneath vegetative debris next to AH 3. This snake was observed in and around the management fields until 07/02/09, when she was located moving away from the management fields and no longer gravid. It is not certain where this snake nested, but HA believes it was somewhere in the berm along MF 2.

**Figure 40**. An example of a pine snake nest dug into an earth and log berm on the perimeter of management field two. Many nests and test excavations were found in the management fields in 2009. Note the relatively small sand fan and dump pile as compared to a more classic nest shown in **Figure 39**. Photo by David W. Schneider, Herpetological Associates, Inc. 2009.

4) **Female No. 2006.29**

This shifted female pine snake was observed mating with male pine snake 2007.10, on two occasions during the breeding season, once on 05/11/09 and again on 05/22/09. Following the mating observations this snake was regularly located in the upland pine forest west of the management fields. Between 06/24/09 and 06/26/09 this snake made a large move of approximately 1.5-kilometers to the east and managed to breach the perimeter drift fence separating the SPR property from the surrounding forest. She was found in a rock bottomed drainage ditch on the SPR property. This location was approximately 130-meters into the development property and was NW of the beginning of the management field access road. The snake was collected and walked approximately 200 meters (656 feet) into the interior of the forest perpendicular to its capture location and released (please refer to the Protocol for Releasing Trapped Pine Snakes Found Within the SPR Property). This placed the snake in the forest, but very close to the management fields. On 06/28/09 she was relocated 15-meters from AH 6. This snake nested and deposited her eggs on top of a large earthen mound at the northern end of MF 3 sometime between 06/30/09 and 07/04/09.

5) **Female No. 2007.15**

This non-shifted female pine snake was not seen in courtship or mating, but was observed within a few meters of male pine snake 2006.17, during the breeding season. On three separate occasions, 06/03/09, 06/07/09 and 06/26/09, this snake was trapped while attempting to access the SPR property. Each time it was trapped the female snake was relocated in the forest near the management fields (please refer to the Protocol for Releasing Trapped Pine Snakes Found Within the SPR Property). The snake then nested on top of a large earthen mound at the northern end of MF 3, sometime between 06/30/09 and 07/04/09, along with female pine snake 2006.29.

As described above, 2 of these snakes appear to have purposely chosen the management fields to nest. Female pine snake 2007.05 nested in almost the exact same location in the management fields as it did in June of 2008. This suggests fidelity to the nesting area and that this snake recognized the management fields as suitable nesting habitat. Female pine snake 2007.04, was not thought to be gravid in 2008, however it was relocated utilizing the berm along the east and northeast edges of MF 3 during the 2008 field season. Then in 2009, she made a deliberate move to the management fields prior to the June nesting season. This poses some interesting questions:

1) Although the snake was relocated moving along the trap line, it was never found caught in a trap. Was this snake trying to make a concerted effort to access the SPR property to excavate her nest? If so, did she eventually gave up and return to the open sunny habitat she knew was there on the management fields?

2) Since the snake was seen on the berm along the northeast edges of MF 3 during the 2008 field season, did it learn and recognize the management fields as suitable nesting habitat? Did the female snake learn and remember the open field area during the previous season and intentionally selected the site to nest in 2009?

3) Another possibility is, did the gravid female pine snake 2007.04 follow the pheromone scent trails of the other gravid female pine snakes and nest in the same general area as they did on the management fields? The snake scent trailing research of Ford (1978 and 1986), Gehlbach et al, (1971), Reinert and Zappalorti (1988b), and Burger (1990 and 1991), suggest that snakes will follow the pheromone scent trails of conspecifics.

The other three study snakes that nested in the management fields only did so after trying to access their old nesting habitat on the SPR property. As previously mentioned, pine snake 2006.29 was found on the SPR property during the nesting season (while gravid). When it was moved back into Stafford Forge WMA following our protocol, it placed the snake within the forest between the management fields and the perimeter drift fence. Another study female (Field Number 2007.07), was caught in a perimeter drift fence trap, apparently attempting to access its previous nesting habitat. Releasing this snake from the trap also put it very near the management fields, where she eventually nested. It is not known why these two gravid snakes chose the management fields as their nest site after being moved attempting to get onto the SPR property. It is possible these two snakes scent trailed other females into the fields (Ford 1978 and 1986, Gehlbach et al, 1971, Burger 1990 and 1991).

The behavior exhibited by pine snake 2007.15, represents a more complex set of circumstances. This snake was mated and became gravid far south of the management fields, near the Garden State Parkway. During this period, it was found on three separate occasions in traps along the perimeter drift fence. On each successive relocation the snake was found in a trap closer to the management fields. This behavior suggests this snake was consistently attempting to access the old nesting habitat and was moving along the trap line in an effort to breach the perimeter fence. After being caught in the traps three times and needing to lay her eggs, it was decided to relocate her to the edge of management field two for her safety and the safety of her egg clutch.

In hindsight, HA believes that although this was the best decision for the individual pine snake, it may have influenced where the snake would have deposited her eggs. In the future if any gravid females are found trying to access the landfill (which was the historic nesting area), they will be allowed to continue to seek a suitable nesting site on the SPR property.

In addition to the three study snakes found gravid in traps or on the SPR property, one non-study female was taken in a trap while gravid. This same female was found crossing the management field access road while gravid in 2008. The fact that four gravid female snakes were caught either in drift fence traps or on the SPR property is strong evidence suggesting that gravid females have a strong fidelity to their traditional nesting areas and were instinctively trying to access their former nest locations (Burger and Zappalorti 1986 and 1991).

It is interesting to note that the nesting behavior exhibited by radio-tracked females in the management fields is not considered “classic” nesting behavior. More typically, pine snakes excavate their nests in soft sand in open-canopied, sparsely vegetated clearings (Burger and Zappalorti, 1986 and 1991). This type of habitat exists within the management fields, however the radio-tracked females preferred to excavate their nests in the earthen berms and mounds along the edges of and within the management fields.

This may represent a more opportunistic tendency for a safer, more concealed selection of a nest site. It appears that females nesting within the earthen berms and mounds of the management fields did not spend as much time excavating their nests out in the open. Instead, they crawled into the openings in the mounds and dug under the cover of the sand and log mounds where predators (and we human researchers), could not get them. There are rotting pine and oak logs in the mounds which provides shelter and warmth for incubating eggs in addition to natural sunlight. Female pine snake 2008.03, which nested in a more typical fashion in the disturbed pine forest habitat south of the SPR site, spent several hours digging on the surface to make her nest tunnel entrance.

It's possible that these female pine snakes are selecting the existing cavities in the berms and mounds of the management fields in order to conserve valuable energy. Furthermore, they reduce the threat of predation by not exposing themselves to hawks and mammals in the open field. The earth and log berms allow the gravid female snakes easy excavation of the nest tunnel and chamber. This may be yet another nesting variation that Burger and Zappalorti did not observe during their past research with female pine snakes. There may be many variations and differences in the selection of nest sites by gravid female pine snakes which we are just learning about with the help of radio-telemetry as opposed to just visual searching to find the more "classic" nesting areas described by Burger and Zappalorti (1986 and 1991).

**Figure 41**. A recently hatched neonate pine snake in its defensive strike position. Neonates remain in the nest egg chamber for several days, but come to the surface to bask and imprint on the nesting area. Photo by Robert Hamilton, HA Staff.

## DISCUSSION AND PRELIMINARY CONCLUSIONS

### USE OF ENHANCED OR MANIPULATED HABITAT

The Department's Division of Land Management planted the three management fields with native, warm-season grass seed on June 1, 2008. The seed was provided by Walters. It was drill-seeded into the mineral soil with no lime or fertilizer. In 2008, the growth of the grasses and other vegetation was slow, yet steady and continued through the 2009 season (**Figure 32**, page 48). Warm-season grasses often take three or four growing seasons to truly establish themselves. These plants use all their energy by first growing roots for the first two-years, then they grow upward on the surface (Ted Gordon, personal communication). These fields will provide more cover and prey availability for pine snakes as the seed stock and grassy vegetation becomes more established and dense. Open fields provide canopy free habitat for snake thermoregulation, potential nesting areas and also attract seed eating small mammals and birds, which are potential prey items for pine snakes.

During 2009, a total of 11 radio-tracked pine snakes were observed using the management fields for shelter, resting, basking, foraging, shedding and hibernation. Most of these behavioral observations were of snakes using the perimeter earthen berms for concealment. However, compared to previous field seasons, an increase in nesting behavior in and around the management fields was documented in 2009. Five female pine snakes were confirmed nesting within the earth and log mounds that are located along the edges of the management fields. All five were radio-tracked females (four non-shifted snakes and one shifted snake). HA will conduct time-constrained searches for nesting evidence and behavior in the management fields each year for the duration of this investigation. Pine snakes were not the only wildlife observed utilizing the enhanced habitat in and around the management fields. Many different species of reptiles and amphibians including eastern box turtle, northern black racers, eastern hognose snakes, eastern garter snakes, rough green snakes, eastern ribbon snakes, northern fence lizards, southern gray treefrogs, Pine Barrens treefrogs, Fowler's toads, leopard frogs and green frogs were all observed using portions of the three management fields and the man-made vernal pond on the northwest corner of field two. The earthen berms and log piles also provide ideal habitat and cover for prey items such as white-footed mice, meadow voles, red-backed voles and red squirrels.

## RESEARCH QUESTIONS AND FUTURE GOALS

As stated in the introduction section of this report, there are six research questions that the Department and HA are attempting to answer as part of this long-term study. After our third year of this study, we have arrived at some possible answers, while even more new questions seem to arise. In order to scientifically provide answers they must be supported by a significant data set. Below are some preliminary responses to the six questions with only three-years of data.

**Question 1.** Can adult and hatchling northern pine snakes establish themselves and overwinter successfully in constructed artificial hibernacula after being shifted to a different area within their known activity range?

**Answer - Yes**. Even though the shifted pine snakes were forced to spend one or two-winters in the artificial dens (following the management plan's protocol), all the snakes successfully hibernated in them. HA has documented that pine snakes of varying age classes overwintered in one or more of the six artificial hibernacula. The most interesting observation in 2009, was that two adult pine snakes (from the Treatment C snakes) selected on their own, den AH 1 to hibernate during the 2009 - 2010 winter season. Both these snakes overwintered in AH 1 during the 2008 - 2009 winter as well. These two snakes spent the winter of 2006 - 2007 in HA's laboratory and were released into AH 1 (a two winter treatment) in the spring of 2007. Since the artificial den corral walls were removed in the spring of 2008, these snakes were free to select their old natural dens or new denning locations the past two winters, yet they still returned to AH 1 at the end of the active field seasons. It will require additional years of study to fully determine if these snakes have established themselves in the artificial den, but the fact that they have returned two winters in succession suggests that they recognize AH 1 as a suitable overwintering site. As previously mentioned, HA staff caught an additional five juvenile/hatchling pine snakes in the den traps during the spring egress. One additional hatchling was observed basking atop AH 1 in the spring. This is strong evidence that both adult and young pine snakes are able to successfully overwinter in the artificial hibernacula. HA will continue to trap the artificial den entrances during the spring egress over the course of this investigation in order to further determine if adult and young pine snakes continue to utilize the artificial dens to overwinter.

**Question 2.** Do non-shifted northern pine snakes (or other snake species) from the existing Stafford Forge Wildlife Management Area population begin to use the artificial hibernacula constructed at the three management fields on their own?

**Answer - Yes.** This is the second winter that the corral walls have not limited movement to and from the artificial hibernacula. During the 2009 spring egress, HA captured three non-shifted pine snakes in the artificial hibernacula traps. All three of these snakes overwintered in the artificial dens by their own selection and choosing during the 2008 - 2009 winter. HA will continue to trap the artificial dens during the spring egress in subsequent years to further supplement our data on this selection behavior.

**Question 3**. How do the spatial movements and other behaviors (*e.g.*, habitat use, foraging, mating, nesting, and denning) of the shifted pine snakes differ from the non-shifted pine snakes?

**Answer - Inconclusive**. Although differences in home range sizes between shifted and non-shifted pine snakes persisted in 2009, the analysis of behavior and spatial movements across all years of the study is necessary in order to draw meaningful conclusions about home range and behavioral differences. Preliminarily, it appears that during each activity season the non-shifted pine snakes have consistently had larger home ranges than the shifted snakes. This was once again the case in 2009, when the largest home ranges calculated were the Minimum Convex Polygon home ranges of the non-shifted females. Behaviorally, a significant difference in data between the shifted and non-shifted pine snakes is apparent in the "Concealed" behavior category. Radio-tracking revealed that shifted pine snakes were concealed on 28.93% of their total relocations (n = 885), while the non-shifted pine snakes were observed to be concealed on 21.98% of their total relocations (n = 969).

The significance of any difference in percentages of behavioral observations between the two different groups of snakes during the 2007, 2008 and 2009 seasons is not yet fully understood. Future radio-tracking efforts will provide the data necessary to draw conclusions about any behavioral differences observed between the two groups. Any significant differences in habitat use between the two study groups will become more apparent, and be more easily separated out, as the study progresses over the next few years. This will be discussed in detail in the 2010 report and in our final report when the study is completed.

**Question 4**. Do pine snakes from this population (both shifted and non-shifted snakes) attempt to move back onto the redevelopment area of Stafford Township Business Park during the construction period, and if so, does this tendency diminish over time?

**Answer - Yes**. In 2007, two radio-tracked pine snakes entered the SPR property. Captures were also made in the perimeter drift fence of pine snakes attempting to enter the site. In 2008, only one radio-tracked pine snake entered the site at the property line between the SPR property and a power line ROW easement along the eastern border of the property. This was a non-shifted snake whose home range in 2007 and 2008 was immediately adjacent to the SPR property within the Stafford Forge WMA. Additionally, one gravid female pine snake was found crossing a sand road inside the perimeter drift fence on the SPR property in mid-June 2008. The snake was PIT-tagged and released into MF 2 for the snake's own safety due to it's presence in an active construction area. Radio-tracked snakes were documented both in traps and along the trap line, particularly along the southern section.

In 2009, two shifted snakes (Field Numbers 2006.26 and 2006.29) entered the SPR property. One was a gravid female (Field Number 2006.29), which passed the trap line, yet became stuck in a portion of silt fence that surrounded a drainage ditch bordering the landfill. This occurred immediately prior to nesting, and was most likely an attempt by the snake to access the old nesting habitat that existed on the SPR property. The other snake was male pine snake (Field Number 2006.26), which has been found trapped multiple times in prior field seasons attempting to access the SPR property.

Besides the two radio-tracked pine snakes that breached the perimeter drift fence, six additional pine snakes were trapped in the perimeter drift fence in 2009. It is interesting to note that of the six pine snakes trapped, one was trapped twice, and another was trapped five times.

Additionally, a number of observations were made of radio-tracked snakes moving along the trap line. It is unknown at this time whether the tendency by these snakes to continually attempt entrance to the SPR property will diminish over time in either shifted or non-shifted snakes. However, three of the pine snakes (Field Numbers 2006.26, 2007.15 and 2008.13) have been located on the SPR property or caught in traps along the perimeter drift fence during multiple field seasons. This preliminary data suggests that several of the study snakes continue to access the SPR property (despite the exclusion attempts by HA staff and Walters) on a yearly basis.

**Question 5.** Do a higher percentage of northern pine snakes (adult and juvenile) return to and overwinter in the artificial hibernacula when they are kept in an enclosed area around the hibernacula and fed for two winters versus only a single winter?

**Answer - Inconclusive**. This is only the second winter that all radio-tracked snakes were unrestricted in their movements and had the ability to select their own den locations. So far, there is not enough data to completely answer this question. Both adult snakes that overwintered in 2008 and 2009 in AH 1, were from Treatment C. Three hatchlings, 2 Treatment B and 1 Treatment A, were recaptured during the spring egress this year.

Two of the 2006 hatchlings originally released into AH 1 (a two-winter treatment den) were recaptured at AH 1 this past spring. The other 2006 hatchling was originally released into AH 3 (a one-winter treatment) and was recaptured at AH 4 this past spring. This means that 40 percent of the study snakes that have been confirmed overwintering in the artificial dens are Treatment C snakes, 40 percent are Treatment B snakes, and 20 percent are Treatment A snakes. Unfortunately, the death of many of the snakes from Treatment B will influence the results of this two treatment comparison.

**Question 6**. Will shifted and non-shifted gravid female northern pine snakes from this population begin using the three management fields as nesting habitat in future years?

**Answer - Yes**. In 2008, HA observed and documented two separate females (one non-shifted, one new snake) using the management fields for nesting. In 2009, HA observed and documented five separate females using the management fields for nesting. One of these females (Field Number 2007.05), was the same study snake observed nesting in the management fields in 2008. It is possible that other non-radio-tracked female pine snakes could have also nested on one of the three management fields, since numerous potential nests holes and test holes were observed by HA staff in 2009. Nesting behavior will continue to be monitored intensely in 2010.

## COMPARISON OF SHIFTED AND NON-SHIFTED SNAKES

Shifted northern pine snakes (e.g., adults, sub-adults and hatchling) can successfully overwinter in artificial dens that were specifically designed by HA. More important is the fact that two pine snakes from Treatment C have returned to AH 1 for the second winter in a row and selected this overwintering site on their own. They overwintered there during the 2009 - 2010 winter. It remains to be determined whether these snakes and/or other study snakes will return to use the enhanced habitat in subsequent years. HA will continue to closely monitor the six artificial dens for use by pine snakes, as well as other snake species over the next 4 years.

MCP and Kernel home range analysis has determined a marked difference in spatial usage between shifted and non-shifted pine snakes. Early data suggested that the average activity range for the non-shifted snakes was larger than that of the shifted pine snakes. This is contrary to the findings of Reinert and Rupert (1999), where they radio-tracked translocated timber rattlesnakes and found that the translocated snakes had significantly larger home ranges.

However, it should be noted that our study pine snakes were not moved out of their original home ranges, just shifted within their activity areas and forced to stay in artificial dens for one or two winters. The following three years of radio-telemetry will further demonstrate if these two groups of pine snakes have significantly different home range sizes.

**Figure 42**. A male northern pine snake bites and holds a female pine snake on the neck while trying to copulate. This is typical mating behavior during courtship and breeding. Photo by Bob Hamilton, HA Staff.

By using the 2007, 2008 and 2009 field season radio-tracking data, a comparison of the one-winter, two-winter and 'C' treatment snakes has begun. Over the next four-years, HA will continue to determine if these snakes show any difference in den site fidelity with respect to the artificial dens and natural dens. Due to unpredicted and unexpected mortalities caused by a combination of events (i.e., mammal and raptor predators, road kills, forest fire and health problems due to poor surgery by others), the 'B' Treatment (two-winter snakes) is only represented by one radio-tracked snake in 2009. A problem that could not be predicted and was completely unexpected in the approved 2006 study plan (Zappalorti and Golden 2006).

## SUMMARY

In 2009, unrestricted denning and nesting behavior by northern pine snakes was observed within the three experimental management fields. Over the next four-years of the radio-telemetry study and by visual surveys, HA will continue to monitor pine snake use of the enhanced habitat for important denning and nesting behavior. The use of the management fields and associated nesting behavior is likely to continue, 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).

While there are other pine 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), none of these studies compare to this current investigation. The level of effort, the amount of resources and funding that is being provided by Walters, Inc., HA and the NJDEP's Division of Fish and Wildlife is unprecedented. In its third year, this long-term monitoring and radio-tracking study has already revealed some never-before-documented home range movement data, seasonal habitat selection data, foraging and prey types and nest site selection behavior. The results of 2007 and 2008 have already been submitted and the 2009 results are contained in this document and are submitted herewith. There is much more to be learned over the next 4 years and HA looks forward to continuing this important research and investigation.

*Respectfully submitted,*

***Herpetological Associates, Inc.***

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# APPENDICES

# APPENDIX I

| **Appendix I** | | | | |
|---|---|---|---|---|
| **Hibernaculum Designation** | **Snakes that denned in hibernaculum in 2007-08 winter** | **Snakes that denned in hibernaculum in 2008-09 winter** | **Snakes that denned in hibernaculum in 2009-10 winter** | **Description of Hibernaculum** |
| AH 1 | 2006.16, 2006.19, 2006.22, 2006.28 | 2006.16, 2006.19, 2006.41**, 2006.49**, 2009.12** | 2006.16, 2006.19 | Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 1. |
| AH 2 | None Known | 2009.09** | None Known | Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 1. |
| AH 3 | None Known | 2009.11** | None Known | Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 2. |
| AH 4 | 2006.15, 2006.30 | None Known | None Known | Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 2. |
| AH 5 | None Known | 2006.46** | None Known | Artificial hibernaculum created by Walters using HA's design. Located on south side of MF 3. |
| AH 6 | 2006.17, 2006.29 | None Known | None Known | Artificial hibernaculum created by Walters using HA's design. Located on north side of MF 3. |
| NH A | 2006.26, 2006.11 | None Known | None Known | Moderate sized hole in pine forest approximately 90 meters west of MF 3. |
| NH B | 2007.03 | 2007.03, 2006.08, 2006.17 | 2006.08, 2009.16*** | Large mammal burrow in pine forest approximately 70 meters NW of AH 6. |
| NH C | 2007.07, 2008.02* | 2007.07, 2008.02 | 2008.02 | Large mammal burrow in upland pine forest in SFWMA west of management fields. |
| NH D | 2006.32 | None Known | None Known | Stump hole in lowland oak/pine forest approximately 27 meters SW of Hay Road in SFWMA. |
| NH E | 2006.33, 2008.03* | 2008.03 | 2008.03 | Large mammal burrow in upland pine forest in the interior of SFWMA. |
| NH F | 2007.09 | None Known | None Known | Nondescript hole in upland pine forest in interior of SFWMA. |

**Appendix I** (Continued)

| Hibernaculum Designation | Snakes that denned in hibernaculum in 2007-08 winter | Snakes that denned in hibernaculum in 2008-09 winter | Snakes that denned in hibernaculum in 2009-10 winter | Description of Hibernaculum |
|---|---|---|---|---|
| NH G | 2007.14, 2008.04* | None Known | None Known | Small hole leading into earth berm in disturbed pine forest habitat approximately 3.0 km S/SW of the SPR site. |
| NH H | 2007.11 | 2007.11, 2008.18**, 2008.21**, 2008.25**, 2009.02**, 2009.04**, 2009.05**, 2009.06**, 2009.07**, 2009.08**, two (2) sub-adult northern black racers | 2007.11 | Large mammal burrow in disturbed pine forest approximately 100 meters from NH G. Den entrance is approximately 5 meters from where a pine snake nest was discovered this year. |
| NH I | 2006.09 | 2006.09 | None Known | Nondescript hole in upland oak/pine forest approximately 1.1 kilometers N/NW of management fields. |
| NH J | 2007.10 | None Known | None Known | Small nondescript hole in upland oak/pine forest approximately 1.7 km north of management fields within SFWMA. |
| NH K | 2006.21 | None Known | None Known | Small nondescript hole in upland oak/pine forest on privately owned land approximately 2.4 kilometers north of the management fields. |
| NH L | 2007.04 | None Known | None Known | Small mammal burrow at base of a mountain laurel in upland oak/pine forest on privately owned land approximately 15 meters in on west side of route 72. |
| NH M | 2007.15 | None Known | None Known | Stump hole in privately owned upland oak/pine forest south of the SPR site. |
| NH N | 2007.05 | 2007.05, 2006.26 | 2006.26 | Moderate sized hole in upland oak/pine forest south of the SPR site. Not far from NH M. |
| NH O | 2006..34 | None Known | None Known | Small nondescript hole in upland oak/pine forest approximately 1.3 km S/SW of the SPR site. |

**Appendix I** (Continued)

| Hibernaculum Designation | Snakes that denned in hibernaculum in 2007-08 winter | Snakes that denned in hibernaculum in 2008-09 winter | Snakes that denned in hibernaculum in 2009-10 winter | Description of Hibernaculum |
|---|---|---|---|---|
| NH P | 2007.06 | None Known | None Known | This was an unsuccessful attempt by the snake to excavate its own overwintering spot. Snake's carcass was found only a few inches under the surface in the spring of 2008. |
| NH Q | None Known | 2006.11 | None Known | Location is in a section of pine/oak forest near the Garden State Parkway south of the SPR site. No signs of access to underground refugia were noted in the area. |
| NH R | None Known | 2006.21 | None Known | Small hole in pine/oak forest only a few meters in on west side of Route 72. Location is approximately 3.1 km north of MF 3. |
| NH S | None Known | 2006.28 | None Known | Location is in pine/oak forest a considerable distance SW of the SPR site. No obvious entrance holes into denning site were noted. |
| NH T | None Known | 2006.29 | 2006.29, 2009.51*** | Den location is in upland pine forest west of the management fields. |
| NH U | None Known | 2007.04 | None Known | Stump hole on slight upland rise in pine/oak forest approximately 2.25 kilometers north of the management fields and 0.4 kilometers west of Route 72. |
| NH V | None Known | 2006.34 | None Known | Nondescript hole in oak/pine forest south of the SPR site. Location is approximately 7 meters from where this snake overwintered last year. |

**Appendix I** (Continued)

| Hibernaculum Designation | Snakes that denned in hibernaculum in 2007-08 winter | Snakes that denned in hibernaculum in 2008-09 winter | Snakes that denned in hibernaculum in 2009-10 winter | Description of Hibernaculum |
|---|---|---|---|---|
| NH W | None Known | 2006.32 | None Known | Den is located in unburned upland oak/pine forest approximately six meters in on north side of Hay Road. There was no noticeable entrance hole to den location due to large amount of leaf litter on the forest floor. |
| NH X | None Known | 2007.15 | None Known | Mammal burrow approx. 160 meters south of the drift fence along the southern portion of the SBR site near the Costco building. |
| NH Y | None Known | 2007.09 | 2007.09 | Mammal burrow located on private property near the Brighton Road Development Property on west side of Route 72. Location is approximately 4.4 km NW of the management fields. |
| NH Z | None Known | 2007.10 | None Known | Small nondescript hole in same tract of upland oak/pine forest that the snake hibernated in last year. |
| NH AA | None Known | 2007.14 | None Known | Large hunter's pit/mammal burrow in upland pine forest approximately 1.6 km SW of MF 1. |
| NH BB | None Known | None Known | 2007.14 | Large mammal burrow, possibly coyote, in upland pine forest west of Micaja Road. |
| NH CC | None Known | None Known | 2007.05 | Nondescript hole in pine/oak forest south of the SPR site near the Garden State Parkway. |
| NH DD | None Known | None Known | 2006.28 | Nondescript hole in oak/pine forest south of the SPR site. Possible root system of old white oak (*Quercus alba*). |

**Appendix I** (Continued)

| Hibernaculum Designation | Snakes that denned in hibernaculum in 2007-08 winter | Snakes that denned in hibernaculum in 2008-09 winter | Snakes that denned in hibernaculum in 2009-10 winter | Description of Hibernaculum |
|---|---|---|---|---|
| NH EE | None Known | None Known | 2009.13 | Stump hole in oak/pine forest approx. 1.3 km NW of the management fields. |
| NH FF | None Known | None Known | 2006.32 | Nondescript hole in upland pine forest west of Hay Road. |
| NH GG | None Known | None Known | 2007.07 | Cluster of small mammal burrows leading underground in oak/pine forest approx. 1.65 kilometers north of the management fields. |
| NH HH | None Known | None Known | 2006.34 | A nondescript mammal burrow in a pine/oak forest south of the SPR site. |
| NH II | None Known | None Known | 2007.10 | Small stump hole in upland oak/pine forest approx. 2 km N/NW of the management fields. |

* Denotes a snake that was captured in a trap attached to a corralled den in the spring of 2008.

** Denotes a snake that was captured in a trap attached to a corralled den in the spring of 2009.

*** Denotes a snake that was found basking at a known natural den entrance in the fall of 2009.

# APPENDIX II

## Appendix II. Deceased Study Snake Synopses:

### Shifted Snakes

***1) N. Pine Snake No. 2006.06 (♂)***. (Treatment B/2 winter) Deceased in 2008.

This snake was originally captured by Ecolsciences, Inc. in 2004. It was recaptured by EcolSciences, Inc. on 04/19/06 in their eastern den trap array. It was implanted with a transmitter and released into AH 6, which was a two winter treatment, on 09/22/06. This snake was killed and partially eaten by a red-tailed hawk on 03/14/07.

***2) N. Pine Snake No.2006.07 (♂).*** (Died before treatment assignment) Deceased in 2006.

This snake was captured in the eastern den trap array by EcolSciences, Inc. on 04/19/06. This snake died in HA's lab on 09/21/06. HA performed a necropsy and removed the transmitter. The transmitter was located inside the small intestine of the snake and this was determined to be the cause of death.

***3) N. Pine Snake No. 2006.10 (♂).*** (Treatment B/2 winter) Deceased in 2006.

This specimen was originally captured by EcolSciences, Inc. on 05/09/06 near the landfill. This snake was released into Den 6, a two winter treatment, on 09/22/06. 0n 10/30/06 HA staff observed two red-tailed hawks flush from the pine/oak island inside the corral. Upon entering the den corral, the snake's carcass was found partially consumed. It is HA's belief that these two hawks were feeding on the pine snake. Upon perching in nearby trees, the hawks began cleaning their beaks on tree branches (a hygienic behavior used by all bird species immediately after eating). HA also observed these animals to have bulging crops by use of binoculars.

***4) N. Pine Snake No. 2006.12 (♂).*** (Treatment A/1 winter) Deceased in 2006.

This specimen was originally captured by EcolSciences, Inc. on 05/17/06 along the landfill access road. This snake was released into Den 5, a one winter treatment, on 09/22/06. On 10/13/06 this snake was found partially consumed between the hibernaculum and the pine/oak island inside the den. Upon approach, two red-tailed hawks flushed from the AH den area.

***5) N. Pine Snake No. 2006.13 (♂).*** (Treatment B/2 winter) Deceased in 2006.

This snake was originally captured by EcolSciences, Inc. on 05/17/06 in trap 106 along the perimeter drift fence. This snake was released into Den 4, a two winter treatment, on 09/22/06. On 10/31/06 HA staff flushed a red tailed hawk from the area of Den 4. Upon examination of the den, this snake was found partially consumed on top of the hibernaculum.

***6) N. Pine Snake No. 2006.18 (♂).*** (Treatment A/1 winter) Deceased in 2007.

This male snake was captured on the landfill slope by EcolSciences, Inc. on 05/22/06. This snake was released into AH 3, a one winter treatment, on 09/22/06 and hibernated there for the 2006-07 winter. This snake was caught in a corral trap egressing from the den on 05/01/07 and released into the adjacent forest. The snake's first relocation was approximately 0.40 kilometers S/SW of the management fields. All following relocations occurred within a few meters of its first relocation. The snake was found dead following the forest fire on 5/16/07.

***7) N. Pine Snake No. 2006.20 (♂).*** (Treatment B/2 winter) Deceased in 2008.

**2006 - 2008**: This snake was originally captured by EcolSciences, Inc. in trap 3 along the perimeter drift fence on 05/27/06. It was implanted with a transmitter and released into AH 4 on 09/22/06. This snake was caught in the south trap attempting to egress from the den on 05/12/07. It was released into the three-acre corral. After the fire, the snake was found concealed inside a man made earthen mound on the NW side of AH 4 and had suffered burn trauma to its head and neck. On 05/20/07 this snake was recaptured and released back into the one-acre AH 4 enclosure. In the winter of 2007-08 this snake hibernated in AH 4. This animal never egressed from AH 4. It died during hibernation possibly from burn injuries sustained from the May 2007 forest fire.

***8) N. Pine Snake No. 2006.22 (♂)***. (Treatment B/2 winter) Deceased in 2008.

**2006 - 2007**: This snake was originally captured by EcolSciences, Inc. in trap 95 along the perimeter drift fence on 05/27/06. This snake was released into AH 1, a two winter treatment, on 09/22/06 where it spent the 2006-07 winter. On 04/24/07 this snake was found in the west trap of AH 1 attempting to egress into the three-acre outer corral. On 05/17/07, the day after the forest fire, this animal was found concealed in the NW side of a man made earth berm just outside of the inner corral. The snake was collected and relocated into the one-acre AH 2 enclosure until repairs could be made on AH 1. On 06/15/07 this snake was again released into the one-acre enclosure of AH 1 were it was radio-tracked throughout the season. This snake hibernated in AH 1 for the 2007-2008 winter.

**2008:** In April, 2008 this snake was observed to be breathing irregularly. The animal was taken to a veterinarian where it died. The exact cause of death is unknown, but the necropsy revealed a white chalky substance surrounding the heart, possibly indicative of gout.

***9) N. Pine Snake No. 2006.23 (♀).*** (Treatment B/2 winter) Deceased in 2006.

This female snake was originally captured by EcolSciences, Inc. on 5/30/06 in trap 74 along the perimeter drift fence. The snake was released into AH 4 on 09/22/06. On 10/09/06 this snake was radio-tracked outside of the corral fence. The snake's partially consumed carcass was found in a pine tree at breast height. While collecting the carcass, a red-tailed hawk began to scream toward

the direction of the collectors from a treetop 5 meters away.

***10) N. Pine Snake No. 2006.27 (♀).*** (Treatment B/2 winter) Deceased in 2006.

This female snake was originally captured by EcolSciences, Inc. near the landfill on 06/22/06. This snake was gravid and laid 11 eggs in HA's lab. It was released into AH 1, a two winter treatment, on 09/22/06. On 11/17/06 HA staff observed a red-tailed hawk trapped between the ground and the netting surrounding AH 1. Once the hawk was removed from the den enclosure, HA staff discovered the partially consumed carcass of this snake on the SE side of the hibernaculum.

***11) N. Pine Snake No. 2006.31 (♀).*** (Treatment C/Lab) Deceased in 2007.

This female snake was originally captured on 07/01/06 in trap 113 along the perimeter drift fence by EcolSciences, Inc. The snake was gravid and laid a clutch of 10 eggs in the HA lab where it also overwintered in 2006-2007. It was released into AH 4, a two winter treatment, on 04/03/07. On 05/01/07 this snake was found in the east corral trap of AH 4 and released into the three-acre outer corral. For approximately one month after the forest fire on 05/16/07, this snake was consistently relocated within an earthen berm immediately southwest of AH 4. The decision was made to dig up the snake to determine whether or not it was deceased. On 06/14/07 the charred remains of this animal and the transmitter were dug out of the berm. The forest fire was determined to be the cause of its death.

***12) N. Pine Snake No. 2006.33 (♀).*** (Treatment A/1 winter) Deceased in 2008.

**2006 - 2007:** This snake was originally captured in trap 5 along the perimeter drift fence by EcolSciences, Inc. on 08/11/06. This animal was implanted with a transmitter and released into AH 5, a one winter treatment, on 09/22/06, where it hibernated in the 2006-07 winter. This snake was tracked inside the den until it was caught attempting to egress on 05/11/07. Shortly after leaving the den this snake moved 1.6 kilometers west towards Grays/Micaja Road, a well used dirt road in the interior of Stafford Forge Wildlife Management Area. For the remainder of the field season this snake was relocated in the heavily burned upland pine forest west of the management fields. This snake hibernated in a large mammal burrow (NH E) in 2007-08 in a heavily burned portion of the upland pine forest approximately 1.6 kilometers west of the management fields in Stafford Forge WMA.

**2008:** This snake was observed on the surface near the entrance hole of NH E in March 2008 when HA staff were preparing to corral the denning site. The ambient air temperature was at or near 0 degrees Celsius at the time. HA decided that this animal was behaving in a manner that would result in its death, so it was collected to be observed by a veterinarian. The animal died in the HA field trailer on 03/24/08. The carcass has been frozen and retained for further analysis.

**Non-Shifted Snakes**

***1) N. Pine Snake No. 2007.02 (♂).*** Deceased in 2007.

This male snake was originally captured by HA staff on 05/02/07. The snake was caught at the base of a stump pile in MF 2. It was implanted with a transmitter and released on 05/04/07. After its release this snake spent the first two relocations in the upland pine forest west of the management fields and then moved north towards Hay Road. This snake was killed in the forest fire on 5/16/07. The thoroughly burned remains of this snake were found under a burnt pitch pine log on the forest floor.

***2) N. Pine Snake No. 2007.06 (♀).*** Deceased in 2008.

**2007:** This snake was originally captured by HA staff while radio-tracking. This snake was found traveling in burned upland pine forest 15 meters from the location of Pine Snake 2006.21 on 06/03/07. Due to the small size of this snake, it was decided that a smaller, one year transmitter would be needed for implantation. The snake was placed in AH 1 while awaiting the delivery of a smaller transmitter. This snake was not found on the surface in AH 1 until late in the season, despite repeated search efforts. HA determined that it was too late in the season to implant a transmitter. In order to determine where this snake would hibernate, an external transmitter was fitted on the animal. The snake was released on 10/10/07. It never traveled far from where it was released and was only relocated in 3 different locations over the following month. All relocations occurred in the burned upland pine forest west of the management fields inside Stafford Forge Wildlife Management Area. On 10/15/07 the tail end of this snake was observed just inside a freshly excavated hole 2 meters from a dirt bike/ATV trail. The snake hibernated in this location (NH P) for the 2007-08 winter.

**2008:** In 2008, this snake had not emerged from its overwintering location by mid-May. On 05/21/08 HA staff observed a portion of the snake's carcass on the forest floor above its overwintering location. Evidence of digging by an unidentified mammal was noted at the site. HA staff proceeded to excavate the area around the exposed remains. The remainder of the snake was found in an advanced stage of decomposition, with the bulk of the carcass and the still active transmitter found only four inches below the surface (just under the top soil layer). No holes were found providing this animal deeper access underground. It is believed that this animal failed to select (or create) a suitably deep hibernaculum, and subsequently froze to death.

***3) N. Pine Snake No. 2007.08 (♂).*** Deceased in 2007.

This large male snake was originally captured by HA staff in a heavily burnt pine forest on 6/04/07 during a random search effort. When captured, the snake had visible burns and scars on portions of its body. It was implanted with a transmitter on 07/19/07 and released the following day. This snake remained in the general area of its capture location for the first week after being released. On

08/01/07 this snake was relocated within 15 meters of a residential property in the village of Warren Grove, Ocean County, New Jersey. From 08/03/07 until 09/04/07 this snake was consistently relocated in either open field or disturbed habitat, including the front lawn of a private residence. All of the property was situated along the east side of Route 539 in the village of Warren Grove. On 09/04/07 this snake was found dead on Route 539 in Warren Grove by an HA staff member.

***4) N. Pine Snake No. 2007.12 (♀).*** Deceased in 2007.

This female snake was relocated 9 times during the 2007 field season. It was found concealed inside an abandoned motorcycle gas tank on 06/20/07 by HA staff during random search efforts. The capture location was in transitional habitat of oak/pine forest to hardwood swamp approximately 90 meters from the HA/Walters Homes trailer complex on Stafford Blvd. (previously Recovery Road).

The snake was implanted with a transmitter on 07/25/07. From 07/30/07 to 08/11/07 this snake was relocated beneath a concrete slab in a disturbed open field directly behind the trailer complex. On 08/13/07 the snake was relocated in a metal pipe running under ground in the pine/oak forest behind the trailers. On 08/15/07 this snake was found dead in an open field behind the trailer complex. The cause of death appeared to be human-induced blunt force trauma to the head and neck region of the snake.

***5) N. Pine Snake 2007.13 (♀).*** Deceased in 2007.

This female snake was relocated 39 times during the 2007 field season. It was captured on 07/13/07 crossing a dirt trail south of the construction site. This snake had an underdeveloped right eye. It was implanted with a transmitter on 07/25/07 and released. Throughout the season this snake never traveled far from its original capture location (please refer to the ***Home Range Analysis*** for more details). It was often relocated in an upland pine and pine/oak forest near the large wetland corridor that runs through the wildlife management area S/SW of the site. Several relocations occurred along the edges of the wetland corridor. This snake was found dead on 10/16/07 approximately 400 meters SE of its previous relocation. Two pieces of vertebrae as well as the transmitter were recovered. The cause of death is unknown, but predation is suspected.

# APPENDIX III

**Appendix III** Hatchling Snakes Recaptured Since Initial Release Into Artificial Hibernacula in September 2006.

| HA Field Number | Recaptured in 2007 | Recaptured in 2008 | Recaptured in 2009 |
|---|---|---|---|
| 2006.36 | Yes (In AH 6 trap during spring egress) | No | No |
| 2006.37 | No | No | No |
| 2006.38 | No | No | No |
| 2006.39 | No | No | No |
| 2006.40 | Yes (In AH 1 trap during spring egress) | No | No |
| 2006.41 | Yes (In AH 1 trap during spring egress) | No | Yes (In AH 1 trap during spring egress) |
| 2006.42 | Yes (In AH 5 trap during spring egress) | No | No |
| 2006.43 | No | No | No |
| 2006.44 | Yes (In AH 5 trap during spring egress) | No | No |
| 2006.45 | No | No | No |
| 2006.46 | No | No | Yes (In AH 3 trap during spring egress) |
| 2006.47 | Yes (In AH 1 trap during spring egress) | No | No |
| 2006.48 | Yes (Under cover board near AH 2) | No | No |

**Appendix III** (Continued)

| HA Field Number | Recaptured in 2007 | Recaptured in 2008 | Recaptured in 2009 |
|---|---|---|---|
| 2006.49 | No | Yes<br><br>(Crawling along perimeter drift fence near trap 55) | Yes<br><br>(On top of AH 1 on 04/25/09) |
| 2006.50 | No | No | No |
| 2006.51 | No | No | No |
| 2006.52 | Yes<br><br>(In AH 2 trap during spring egress) | No | No |
| 2006.53 | Yes<br><br>(In AH 3 trap during spring egress) | No | No |
| 2006.54 | No | No | No |
| 2006.55 | No | No | No |
| 2006.56 | No | No | No |
| 2006.57 | No | No | No |
| 2006.58 | Yes<br><br>(Found dead in the AH 1 outer corral after the May 2007 forest fire) | N/A | N/A |
| 2006.59 | No | No | No |
| 2006.60 | No | No | No |
| 2006.61 | No | No | No |
| 2006.62 | No | No | No |
| 2006.63 | Yes<br><br>(In AH 2 trap during spring egress) | No | No |

**Appendix III** (Continued)

| HA Field Number | Recaptured in 2007 | Recaptured in 2008 | Recaptured in 2009 |
|---|---|---|---|
| 2006.64 | Yes<br>(In AH 3 trap during spring egress) | No | No |
| 2006.65 | Yes<br>(Found dead near AH 3. Cause unknown.) | N/A | N/A |
| 2006.66 | No | No | No |
| 2006.67 | No | No | No |
| 2006.68 | No | No | No |
| 2006.69 | No | No | No |
| 2006.70 | Yes<br>(In the inner corral of AH 6) | No | No |
| 2006.71 | No | No | No |
| 2006.72 | Yes<br>(In AH 1 trap during spring egress) | No | No |
| 2006.73 | Yes<br>(In AH 2 trap during spring egress) | No | No |
| 2006.74 | Yes<br>(In AH 2 trap during spring egress) | No | No |
| 2006.75 | No | No | No |
| 2006.76 | No | No | No |
| 2006.77 | Yes<br>(In AH 2 trap during spring egress) | No | No |

**Appendix III** (Continued)

| HA Field Number | Recaptured in 2007 | Recaptured in 2008 | Recaptured in 2009 |
|---|---|---|---|
| 2006.78 | Yes (In AH 1 trap during spring egress) | No | No |
| 2006.79 | Yes (In AH 5 trap during spring egress) | No | No |
| 2006.80 | No | No | No |
| 2006.81 | No | No | No |
| 2006.82 | Yes (In AH 2 inner corral) | No | No |
| 2006.83 | Yes (In AH 5 trap during spring egress) | No | No |
| 2006.84 | No | No | No |
| 2006.85 | No | No | No |
| 2006.86 | Yes (In AH 5 trap during spring egress) | No | No |
| 2006.87 | Yes (In AH 2 trap during spring egress) | No | No |
| 2006.88 | No | No | No |
| 2006.89 | Yes (In AH 5 trap during spring egress) | No | No |
| 2006.90 | No | No | No |

**Appendix III** (Continued)

| HA Field Number | Recaptured in 2007 | Recaptured in 2008 | Recaptured in 2009 |
|---|---|---|---|
| 2006.91 | Yes (In AH 5 trap during spring egress) | No | No |
| 2006.92 | No | No | No |
| 2006.93 | No | No | No |
| 2006.94 | No | No | No |
| 2006.95 | Yes (In AH 3 trap during spring egress) | No | No |
| 2006.96 | Yes (In AH 4 inner corral) | No | No |
| 2006.97 | No | No | No |
| 2006.98 | Yes (In AH 6 trap during spring egress) | No | No |
| 2006.99 | No | No | No |
| 2006.100 | No | No | No |
| 2006.101 | No | No | No |
| 2006.102 | No | No | No |
| 2006.103 | No | No | No |
| 2006.104 | Yes (Observed near AH 3) | No | No |
| 2006.105 | Yes (Observed near AH 5) | No | No |

**Appendix III** (Continued)

| HA Field Number | Recaptured in 2007 | Recaptured in 2008 | Recaptured in 2009 |
|---|---|---|---|
| 2006.106 | Yes<br>(Observed near AH 1) | No | No |

# APPENDIX IV

## APPENDIX IV: LANDMARK DESCRIPTIONS FOR MAP LEGEND

**1. The Management Fields:** Three (3) consecutive, partially cleared sections of forest located within the SFWMA. These areas, comprising three (3) acres each, have been enhanced by the creation of artificial hibernacula and the planting of warm-season grasses, in addition to other methods of encouraging utilization by pine snakes and other species.

**2. SPR Property:** Location of Stafford Park Redevelopment site.

**3. The Triangle:** A large (approximately 127 acre) section of old disturbed forest located in the southern portion of SFWMA. This area is characterized by its distinctive triangular shape when viewed from the air, and by a series of low, man-made transverse ridges created years ago for reasons undetermined. This open canopied, sandy area has become an important denning and nesting site for northern pine snakes.

**4. Hay Road Pond:** A small body of water less than two (2) acres in size, located approximately one (1) kilometer NW of the SPR property, and immediately SW of Hay Road.

**5. Turtle Pond:** A small body of water approximately one (1) kilometer east of the Beach Pond, referenced by the frequent observation of aquatic turtles within its environs.

**6. Beach Pond:** A small body of water located west of the SPR site, referenced by the open sandy shore along its eastern edge.

**7. Mill Creek Wetland Corridor:** An extensive wetland corridor lying largely to the NW of the SPR property. The environs of this wetland and the varied habitats within the associated Mill Creek system are extensively utilized by area pine snakes and other herpetofauna.

**8. Cedar Run Wetland Corridor:** A relatively small (in comparison to the Mill Creek wetland), narrow wetland corridor extending SE of the Beach Pond. This particular wetland is often utilized by study snakes frequenting the southern portion of SFWMA.

**9. The "Power Cut":** A series of overgrown roads and narrow clearings, accessed from Route 72 and extending to the immediate east of the Mill Creek wetland corridor. The purpose behind the original construction of these narrow roads/trails is unknown, but they traverse and provide access to habitat important to several study animals.

**10. The Glass Pile:** An old disturbed, open canopied site characterized by non-native vegetation and a series of large grass-covered mounds of earth, old bottles, and other debris.

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# *2009 Annual Northern Pine Snake Monitoring and Radio-tracking Report, at the Stafford Business Park, Stafford Township, Ocean County, New Jersey*

***Submitted October 13, 2010***


## *Herpetological Associates, Inc.*

***Environmental Consultants - Plant and Wildlife Specialists***
***575 Toms River Road Jackson, New Jersey 08527***

***and***

## *Division of Fish and Wildlife*

***Endangered and Nongame Species Program***
***New Jersey Department of Environmental Protection***
***Trenton, New Jersey 08625***